Challenges and Opportunities for Food and Nutrition Security in the Americas

The View of the Academies of Sciences

IANAS Regional Report

November 2017

Challenges and Opportunities for Food and Nutrition Security in the Americas

The View of the Academies of Sciences

Free access to this book and the Summary of this publication at:
www.ianas.org

The Inter-American Network of Academies of Sciences (IANAS) is a regional network of Academies of Sciences created to support cooperation to strengthen science and technology as tools for advancing research and development, prosperity and equity in the Americas. IANAS is regional member of the Inter Academy Partnership (IAP)

IANAS Co-Chairs: Juan Asenjo and Jeremy McNeil
Project Coordinator: Michael Clegg
Editorial Committee: Michael Clegg (Chair, USA), Eduardo Bianchi (Argentina), Jeremy McNeil (Canada), Luis Herrera Estrella (Mexico), Katherine Vammen (Nicaragua).
Chapter Coordinators: Eduardo Bianchi (Argentina); Einstein Tejada Vélez (Bolivia); Evaldo Vilelo (Brazil); John Klironomos (Canada); Mark Wuddivira (Caribbean); Elizabeth Hodson (Colombia); Víctor Jiménez (Costa Rica); María Teresa Cornide (Cuba); Carlos Muñoz Schick (Chile); Helmut Betancourt and José Tallaj (Dominican Republic); Jenny Ruales (Ecuador); Noel Solomons (Guatemala); Carolina Alduvín (Honduras); Sol Ortiz (Mexico); Jorge Huete (Nicaragua); Bruno Zachrisson (Panama); Gustavo González (Peru); Michael Allen (USA); María Cristina Cabrera (Uruguay); María Soledad Tapia (Venezuela)
Book Coordination and IANAS Executive Director: Adriana de la Cruz Molina

Spanish copy editor and Spanish proofreading: Ma. Areli Montes Suárez (Mexico) and authors of the chapters
Translation and English copy editor: Suzanne Stephens (UK)
English copy editor and English proofreading: Margaret Ellen Reynolds Adler (US)
Special support for the Brazilian chapter: Jeremy McNeil (Canada) and Geraldo Bueno Martha Junior (Brazil)
Editorial Design and support during the printing process for the English and Spanish publications: Víctor Daniel Moreno Alanís
Cover Design: Víctor Daniel Moreno Alanís (Mexico)
Web Design: Víctor Daniel Moreno Alanís (Mexico) and Viridiana González (Mexico)
Administrative Support from Germany: Jana Hinz and Anja Geißler, The Deutsche Akademie der Naturforscher Leopoldina
Administrative Support from Mexico: Alejandra Muñoz Buenrostro (2017), Verónica Barroso (2016), Luis Arturo Dassaev (2016 Mexico Workshop Organization), IANAS

Printed by The Inter-American Network of Academies of Sciences (IANAS-IAP) Calle Cipreses s/n, Km 23.5 de la Carretera Federal Mxico-Cuernavaca, 14400 Tlalpan, Distrito Federal, Mexico. The Federal Ministry of Education and Research (German: Bundesministerium für Bildung und Forschung BMBF) Heinemannstraße 253175 Bonn and the German National Academy of Sciences-Leopoldina. And the Inter Academy Partnership (IAP).

ISBN: 978-607-8379-29-3
Printed in México
Free public access of this book in English and Spanish at www.ianas.org

Challenges and Opportunities for Food and Nutrition Security in the Americas

The View of the Academies of Sciences

Federal Ministry of Education and Research
The Inter-American Network of Academies of Sciences
Leopoldina National Akademie der Wissenschaften
The InterAcademy Partnership

Acknowledgments

IANAS is very grateful to the Academies of Sciences of the Americas and to the scientists and experts listed below who generously gave their valuable knowledge and time for the development of this publication.

Argentina

Eduardo Dante Bianchi, María Cristina Añón, Eduardo Pagano, Martín Piñeiro, Carolina Szpak, Eduardo Trigo, Sergio Vaudagn, Fiorella Bianchi

Bolivia

Einstein Tejada Vélez, Marcelo Eduardo Arze García, Mónica Moraes R., Franklin Bustillos Gálvez, Daniela Raquel Larrazábal Vélez Ocampo, Andrés Trepp del Carpio, Lilibeth Leigue Arnéz, Gonzalo Ávila Lara, Jorge Blajos Kraljevic, Carlos Arturo Mariscal Padilla, Óscar Jesús Cabrera Coca, Jaime Manuel Ernesto Gutiérrez Guerra, Zulema Lehm Ardaya

Brazil

Evaldo Ferreira Vilela, Elibio L. Rech Filho, Geraldo Bueno Martha Junior, Eliseu Roberto de Andrade Alves, Maurício Antōnio Lopes, Élcio Perpétuo Guimarães, Paulo Renato Cabral, Cleber Oliveira Soares, Grácia Maria Soares Rosinha, Antônio Marcio Buainain, Marilia Regini Nutti, Geraldo Magela Callegaro

Canada

John Klironomos, Satinder Kaur Brar, Evan Fraser, Krishnamoorthy Hegde, Negin Kazemian, Ashley McInnes, Jeremy Nichol McNeil, Mitra Naghdi, Vinayak Pachapur, Mehrdad Taheran, Frances Henry

Caribbean

Mark N. Wuddivira, Vidya de Gannes, Gerrit Meerdink, Nequesha Dalrymple, Shantelle Henry

Colombia

Elizabeth Hodson de Jaramillo, Jairo Castaño, Germán Poveda, Gabriel Roldán, Paul Chavarriaga

Costa Rica

Víctor M. Jiménez, Catalina Acuña-Gutiérrez, Marilín Agüero Vargas, Alfredo Alvarado, María L. Ávila-Agüero, Marialis Blanco, Marcela Dumani, Patricia Esquivel, Andrés Gatica-Arias, Eric Guevara, Andrés Hernández-Pridybailo, Raquel Hernández Cordero, Andrea Holst, Karol Madriz, Julio F. Mata-Segreda, Olman José Quirós-Madrigal, Ricardo Radulovich, Álvaro Salas Chaves, Paúl Solórzano Cascante

Cuba

María Teresa Cornide Hernández, Walfredo Arnaldo Torres de la Noval, Ramón de la Concepción Pichs Madruga, René Pablo Capote López, Amelia Capote Rodríguez, Arnaldo Álvarez Brito, Mario Pablo Estrada García, Sergio Jorge Pastrana, Olegario Muñiz Ugarte, Julio Abraham Baisre Álvarez, Faustino Cobarrubia Gómez, María Felicia Díaz Sánchez, Lianne Fernández Granda, Marisol González Pérez, Abel Hernández Velázquez, Julián Herrera Puebla, Mayuly Martínez Valenzuela, Hilarión Rodobaldo Ortiz Hernández, Luis Raúl Paz Castro, Eduardo Planos Gutiérrez, Jonathan Quirós Santos, Iván Relova Delgado, Armando Rodríguez Suárez, Odalys Uffo Reinosa, Antonio Vantour Causse, Daysi Vilamajó Alberdi, Gisela Alonso Domínguez, Ondina Jacinta León Díaz, María del Carmen Pérez Hernández, Adolfo Rodríguez Nodals, José Luis Rodríguez García, Daniela de las Mercedes Arellano Acosta, Olimpia Carrillo Farnés, René Florido Bacallao, Anicia García Álvarez, Alexander Miranda Caballero, Armando Nova González, Aída Ramírez Fijón, Julio Larramendi

Chile
Carlos Muñoz Schick, Cristian Mattar, Roberto Neira, Marcos Mora, Jacqueline Espinoza, Óscar Seguel, Osvaldo Salazar, Rodrigo Fuster, L. Antonio Lizana, Cristian Cofré, Anna Pinheiro, Lorena Rodríguez

Dominican Republic
Helmut Bethancourt , Jorge A. Tallaj A., Lourdes Tapia Benoit, Pedro Pablo Peña , Angel Roberto Sánchez, Elpidio Avilés Quizada, Rafael Pérez Duvergé, Anabel Kunhardt , Miguel J. Henríquez, Lidio Martínez

Ecuador
Nikolay Aguirre, Charles W. Barnes, María Eugenia Ordóñez, Jenny Ruales

Guatemala
Noel W. Solomons, Edwin Josue Castellanos, Florencio Rolando Cifuentes Velásquez, Silvana Maselli Conde , Mónica Ninette Orozco Figueroa, Pamela Marie Pennington, Jack Clayton Schuster, Gamaliel Giovanni Zambrano Ruano

Honduras
Carolina Alduvín, Napoleón Molina, Dinie Espinal, Carlos Almendares Ordóñez, Maritza Midence Moncada

Mexico
Sol Guerrero Ortiz, Agustín López Munguía, Natalhie Campos Reales, Elizabeth Castillo Villanueva, Luis Herrera Estrella, Sol Ortiz García

Nicaragua
Jorge A. Huete-Pérez, Manuel Ortega Hegg, Mario R. López, Mauricio Córdoba, Salvador Montenegro, Katherine Vammen, María J. Cortez, Ivania A. Cornejo

Panama
Bruno Zachrisson, Ismael Camargo, Carlos Him, Enrique Murillo, Rodrigo Cambra, Dimas Arcia

Peru
Gustavo F. Gonzales, Ana Colarossi, Nicole Bernex, Verónica Rubín de Celis, Lidia Sofía Caballero-Gutiérrez, Fernando James Álvarez

United States
Michael F. Allen, Peter L. Morrell, Charles W. Rice, Henry J. Vaux, Clifford N. Dahm, Rebecca R. Hernández

Uruguay
María Cristina Cabrera, Laura Astigarraga, Omar Borsani, Gianfranca Camussi, Pablo Caputi, Miguel Carriquiry, Pablo Chilibroste, Milka Ferrer, Guillermo Galván, Fernando García Préchac, Lucía Grille, Carmen Marino Donagelo, Daniel Panario, Ali Saadoun, Pablo Soca, Valentín Picasso, Daniel Vázquez, Fernanda Zaccari

Venezuela
María S. Tapia, Marelia Puche, Alejandro Pieters, Juan Fernando Marrero, Santiago Clavijo, Alejandro Antonio Gutiérrez Socorro, Carlos Machado-Allison, Susana Raffalli, Marianella Herrera, Maritza Landaeta de Jiménez, José Félix Oletta, Juan Comerma, Óscar Silva, Marta Barrios, Aída Ortiz, Eladys Córcega, Enio Soto, Livia Pinto, Daniel Vargas, Víctor García, Juan Carlos Rey, Juan Carlos Aciego, Naghely Mendoza, Gerardo Fernández, Francisco Bisbal, Susana Raffalli

Organizations supporting this publication at various stages of development

International Organizations

Germany

The Federal Ministry of Education and Research

The Deutsche Akademie der Naturforscher Leopoldina
Jörg Hacker, President and Volker Ter Muelen, Former President

European Academies' Science Advisory Council (EASAC) Biosciences Program
Robin Fears, Director

The InterAcademy Partnership

Inter Academy Partnership, IAP-Science
Peter McGrath, Coordinator

Member Academies of IANAS

North America

The Royal Society of Canada: The Academies of Arts, Humanities and Sciences of Canada
Maryse Lassonde, President

The National Academies of Sciences
Marcia McNutt, President

Mexican Academy of Sciences
José Luis Morán López, President

Central America and the Caribbean

Cuban Academy of Science
Ismael Clark Arxer, President

Academy of Sciences of the Dominican Republic
Luis Sheker, President

Academy of Medical, Physical and Natural Sciences of Guatemala
María del Carmen Samayoa, President

National Academy of Sciences of Costa Rica
Pedro León Azofeifa, President

Nicaraguan Academy of Sciences
Manuel Ortega Hegg, President

Panamanian Association for the Advancement of Science
Martín Candanedo, President

National Academy of Sciences of Honduras
Mario Lanza Santamaría, President

South America

Academy of Physical, Mathematical and Natural Sciences of Venezuela
Gioconda San-Blas, President

Colombian Academy of Exact, Physical and Natural Sciences
Enrique Forero, President

Brazilian Academy of Sciences
Luis Davidovich, President

National Academy of Sciences of Peru
Abraham Vaisberg Wolach, President

National Academy of Sciences of Bolivia
Gonzalo Taboada, President

Chilean Academy of Science
María Teresa Ruiz, President

National Academy of Exact, Physical and Natural Sciences of Argentina
Roberto J.J. Williams, President

National Academy of Sciences, Argentina
Juan Tirao, President

The National Academy of Sciences of Uruguay
Rafael Radi, President

Academy of Sciences of Ecuador
Paola Leone, President

Regional Members

Caribbean Academy of Sciences
Winston Mellowes, President

First Workshop / México 2016

Mexican Academy of Science
Jaime Urrutia Fucugauchi, Former President, and Renata Villalba, Executive Coordinator

Planning Meeting / Peru 2017

National Academy of Sciences of Peru
Abraham Vaisberg Wolach, President and Gustavo González, Vice-President

Support / USA 2016-2017

US-National Academy of Sciences
John Hildebrand, Foreign Secretary and John Boright, Executive Director, International Affairs

Table of contents

Foreword

The InterAcademy Partnership (IAP) global network of the world's science academies brings together established regional networks of academies, forming a new collaboration to ensure that the voice of science is heard in addressing societal priorities.

Combatting malnutrition in its various forms – undernutrition, micronutrient deficiencies as well as overweight and obesity – is a problem faced by all countries. The transformation of agricultural production toward sustainability is a global issue, connected with the global challenges of poverty reduction, employment and urbanization. International academies of science have a substantial history of interest in these areas, for example as indicated by the InterAcademy Council publication in 2004 "Realizing the promise and potential of African agriculture". Science has the potential to find sustainable solutions to challenges facing the global and national food systems relating to health, nutrition, agriculture, climate change, ecology and human behaviour. Science can also play a role in partnering to address important policy priorities such as competition with land use for other purposes, for example energy production, urbanization and industrialization with environmental connections for resource use and biodiversity. The Sustainable Development Goals adopted by the UN in 2015 provide a critically important policy framework for understanding and meeting the challenges but require fresh engagement by science to resolve the complexities of evidence-based policies and programmes.

There is an urgent need to build critical mass in research and innovation and to mobilise that resource in advising policy makers and other stakeholders. Academies of science worldwide are committed to engage widely to strengthen the evidence base for enhanced food and nutrition security at global regional and national levels. In our collective academy work, we aim to facilitate learning between regions and show how academies of science can contribute to sharing and implementing good practice in clarifying controversial issues, developing and communicating the evidence base, and informing the choice of policy options. The current IAP initiative is innovative in bringing together regional perspectives, drawing on the best science. In this project, we utilize academies' convening, evidence-gathering, analytical and advisory functions to explore the manifold ways to increase food and nutrition security and to identify promising research agendas for the science communities and investment opportunities for science policy. A core part of this work is to ascertain how research within and across multiple disciplines can contribute to resolving the issues at the science-policy interface, such as evaluating and strengthening agriculture-nutrition-health linkages. Food systems are in transition and in our project design we have employed an integrative food systems approach to encompass, variously, all of the steps involved, from growing through to processing, transporting, trading, purchasing and consuming, disposing or recycling of food waste.

Four parallel regional academy network working groups were constituted: in Africa (NASAC), the Americas (IANAS), Asia (AASSA) and Europe (EASAC). Each has an ambitious mandate to analyze current circumstances and future projections, share evidence, clarify controversial points and identify knowledge gaps. Advice is proffered on options for policy and practice at the national-regional levels to make best use of the resources available. Each Working Group consisted of experts from across the region nominated by IAP member academies and selected in order to provide an appropriate balance of experience and scientific expertise. The project is novel in terms of its regionally-based format and its commitment to catalyze continuing interaction between and within the regions, to share learning and support implementation of good practice.

These four regional groups worked in parallel and proceeded from a common starting point represented by the agreed IAP template of principal themes. Among the main topics to be examined were the science opportunities associated with:

- Ensuring sustainable food production (land and sea), sustainable diets and sustainable communities, including issues for agricultural transformation in face of increasing competition for land use;
- Promoting healthy food systems and increasing the focus on nutrition, with multiple implications for diet quality, vulnerable groups, and informed choice;
- Identifying the means to promote resilience, including resilience in ecosystems and in international markets;
- Responding to, and preparing for, climate change and other environmental and social change.

Each regional group had the responsibility to decide the relative proportion of effort to be expended on different themes and on the various elements within the integrative food systems approach, according to local needs and experience.

All four networks are now publishing their regional outputs as part of their mechanism for engaging with policy makers and stakeholders at the regional and national levels. In addition, these individual outputs will be used as a collective resource to inform preparation of a fifth, worldwide analysis report by IAP. This fifth report will advise on inter-regional matters, local-global connectivities, and those issues at the science-policy interface that should be considered by inter-governmental institutions and other bodies with international roles and responsibilities. We hope that the IAP project will be distinctive and add value to the large body of work already undertaken by many other groups. This distinctiveness will be pursued by capitalizing on what has already been achieved in the regional work and by proceeding to explore the basis for differences in regional evaluation and conclusions. We will continue to gather insight from integration of the wide spectrum of scientific disciplines and country/regional contexts.

This project was formulated so as to stimulate the four regional networks in diverse analyses and syntheses according to their own experience, traditions and established policy priorities, while, at the same time, conforming to shared academy standards for clear linkage to the evidence available. The project as a whole and in its regional parts was also underpinned by necessary quality assessment and control, particularly through peer review procedures.

We anticipated that the regions might identify different solutions to common problems – we regard the generation of this heterogeneity as a strength of the novel design of the project. We have not been disappointed in this expectation of diversity. While the regional outputs vary in approach, content and format, all four provide highly valuable assessments. They are customized according to the particular regional circumstances but with appreciation of the international contexts and are all capable of being mapped onto the initial IAP template. This latter IAP collective phase of mapping, coordination and re-analysis is now starting. According to our interim assessment, the project is making good progress towards achieving its twin objectives of (i) catalysing national-regional discussions and action and (ii) informing global analysis and decision-making.

We welcome feedback on all of our regional outputs and on how best to engage with others in broadening discussion and testing our recommendations. We also invite feedback to explore which priorities should now be emphasised at the global level, what points have been omitted but should not have been, and how new directions could be pursued.

We take this opportunity to thank the many scientific experts, including young scientists, who have contributed their time, effort and enthusiasm in our regional working groups that have done so much to help this ambitious project fulfil its promise to be innovative and distinctive. We thank our peer reviewers for their insight and support, and all our academies and their regional networks and our core secretariat for their sustained commitment to this IAP work. We also express our gratitude for the generous project funding provided by BMBF.

Krishan Lal and Volker ter Meulen

Co-chairs, IAP for Science

Introduction

According to the United Nations the world's human population is projected to reach about 9.8 billion by 2050, increasing by almost 30% over the next 32 years from its current 2017 level of 7.6 billion. In addition, demand for food is expected to increase more rapidly, by roughly 50%, owing to the combination of increased population and improved standards of living. If we take these numbers at face value, the global agricultural system will need to increase food production by at least 50% over a little more than one human generation. Moreover, the food supply will need to be more nutritious to reduce the health system and human costs associated with malnutrition and the current obesity epidemic, thereby necessitating new crop mixes, more efficient production systems and major changes in agri-food industries. All of this will need to be achieved with minimal increases in arable land and without accelerating environmental degradation.

To assess the likelihood of meeting global food and nutrition needs by 2050, the German Federal Ministry of Education and Research commissioned the Inter Academy Partnership (IAP) to undertake an ambitious global project evaluating the role of science, technology and innovation (STI) in addressing the challenges of food and nutrition security. The IAP chose to implement the project by directing its four regional networks of science academies to conduct separate evaluations to result in regional reports, intended for subsequent integration into a global report. This book represents the evaluation of food and nutrition security (FNS) in the American hemisphere, conducted by the science academies of the Americas, through the Inter American Network of Academies of Science (IANAS).

Accordingly, the current book represents an ambitious collaboration among all of the science academies in the Americas, involving more than 200 FNS experts. To initiate the FNS project, IANAS convened more than 80 experts from 21 countries and the Caribbean region at the Mexican Academy of Sciences from September 18-20, 2016, to discuss the future of food and nutrition security in the Americas. The group decided to produce country assessments from which a regional summary would be synthesized. This scheme had proved quite successful for IANAS publications on water and it seemed to offer the most useful strategy, because FNS policy is determined at the national level and this approach could provide directly relevant inputs to national policy makers.

The current book is comprised of 22 chapters assessing the FNS status of every major country in the Americas including the Caribbean region. It also includes intervening boxes that consider important overarching issues, such as the role of gender in FNS, technological opportunities, the potential of the Americas to help feed a more populous world and policy challenges. PDFs of the book are available in both Spanish and English at the IANAS web site (IANAS.org).

Major findings are that STI played a large role in meeting 20th century FNS challenges and STI will be an essential element in meeting 21st century FNS needs. The Americas are fortunate in having a wealth of natural resources and in having strong STI institutions. Major challenges involve implementing sustainable practices and minimizing environmental degradation. Water is a significant limiting resource that will require STI inputs into improved management and conservation strategies. Deforestation and the degradation of soils continues to present a challenge. There is a need for investments in scientific infrastructure to assure maximum progress. Much can and should be done to improve transportation and other infrastructure to minimize food wastage. There is a strong need for greater regional collaboration and coordination with respect to STI and a continued need for the STI training of talented young people to replace a generation that is now leaving the scene. Scientific progress is only part of the solution to the multi-faceted FNS problem. Sound evidence based policy will be essential to effectively address future needs and opportunities. Taken in total the report shows that, if properly managed, the Americas are well positioned to meet the FNS challenges of the future and to serve as a resource for other less fortunate areas of the world.

IANAS has been very fortunate in having a superb team of translators, copy editors and design experts, led by Adriana de la Cruz (IANAS Executive Director), who worked from the Mexican Academy of Sciences to produce this volume. We owe a special thanks to Adriana and her team for their diligence and outstanding work. We also wish to acknowledge our debt to the Mexican Academy of Sciences and IAP for their continued generous support.

Juan A. Asenjo
IANAS Co-Chair

Jeremy McNeil
IANAS Co-Chair

Michael Clegg
Project Coordinator

Executive Summary and Major Findings

The Americas are heterogeneous with respect to climates, topographies, agricultural practices, health and nutrition challenges, research and educational development, and governmental institutions. Despite these heterogeneities, there are a number of generalizations that emerge from the IANAS assessment of food and nutrition security in the Americas. One is that Science, Technology and Innovation (STI) have played, and will continue to play a key role in agricultural development, in the provision of nutritious foods and the guarantee of food security. A second key finding is that the Americas, like other regions of the world, face major challenges in environmental degradation, including the degradation of essential water and land resources. Addressing these challenges will require continued STI investment, together with adequate training for a new generation of qualified professionals as well as the implementation of more effective evidence-based policies at the governmental and inter-governmental levels. Finally, broader international cooperation is essential to achieving food and nutrition security for all countries and peoples.

The major findings of the assessment of food and nutrition security (FNS) in the Americas are presented in a brief, succinct bullet point format. The detailed arguments that support these findings and their resulting conclusions can be found in the chapter assessments below.

Owing to an exceptional abundance of natural resources, the Americas are a privileged region. The region's wealth in agrobiodiversity, arable land and availability of water, all constitute major advantages for the future.

- The Latin American region is a biodiversity superpower that includes five of the ten most biodiverse countries in the world.
- Latin America is the largest net food exporter in the world, yet 18 countries in Latin America and the Caribbean are net food importers.
- North America is the second largest net exporter.
- Aquaculture has emerged as a major industry in countries such as Canada, Chile, Mexico, Peru, Argentina, and Ecuador.
- More than 85% of all Biotech and GM crops are currently planted in the Americas, which have provided substantial environmental benefits through reduced herbicide use, low or non-tillage practices, increased productivity per unit land area and reduced Greenhouse Gas (GHG) emissions.
- The region of the Americas has major potential for growth in food production.

There is substantial diversity among national agricultural research systems, infrastructure, investments in human capital, in financing capabilities and in the roles of public and private sectors in the provision of STI. Some critical issues include the following:

- While STI capacity is substantial among large countries in the Americas, it is less well developed in many smaller countries, making regional cooperation especially important. In almost all countries, universities are crucial in training human capital for food systems and are key sources of research and innovation.
- There has been a long-standing practice of supporting international exchange in graduate education for agriculture and related subjects, but participation by the United States has declined, while increasing opportunities in Brazil and various European countries have, in part, compensated. In general, these exchange practices are not formalized into international governmental agreements and access to infrastructure and financial support varies greatly among countries.
- Broadly speaking, collaboration between universities and research centers is not robust, so it is important to create more stable and dynamic links. The CGIAR centers such as CIAT (International Center for Tropical Agriculture, Colombia), CIMMYT (International Maize and Wheat Improvement Center in Mexico), and IICA (Inter-American Institute for Cooperation on Agriculture, Costa Rica) stand out as an exception by connecting agricultural research throughout Latin America and the world.
- Public investment is essential for agricultural research in all the countries of the region. However, in many countries in the Americas, investment is far below the average of the most developed countries and even below those recommended by organizations such as the United Nations.
- Many countries do not have adequate databases for characterizing the status of their agricultural system and there is insufficient statistical information on the sector.
- The nations of the Americas are not very integrated with respect to agricultural trade and economic policies. A valuable first step is the regional network of public food supply and marketing systems for Latin America and the Caribbean (LAC) to promote inclusive and efficient production and marketing created in 2015 by Brazil, Bolivia, Chile, Costa Rica, Ecuador and Saint Vincent and the Grenadines, but more needs to be done.
- There are very few private companies in the field of agriculture or agricultural biotechnology with their own research programs in most of the countries in the region. The United States, where approximately 60% of the agricultural research investment comes from the private sector, is an exception. Canada follows with roughly 12% of private sector investment.
- Effective collaboration networks between research centers and private companies are crucial, so that efforts in science and technology are focused on solving problems related to the needs of the productive sector.
- In many countries, the link between scientific research and the food and nutrition security needs of vulnerable populations is weak.
- Reducing food waste and loss is a joint task in which all actors - producers, distributors, retailers, consumers, research institutions and governments - must intervene decisively.

- The identification and correction of the substantial weaknesses in the agri-food systems of many countries in the Americas constitute an urgent agenda that can be most efficiently pursued within an interregional cooperative framework.

The efficient use of water resources is essential for future growth in food production, public health and quality of life in the Americas.

- Poor water quality and inefficient water management are among the greatest environmental challenges for the Americas. The Americas are rich in water resources, but STI based improvements for water management, especially with respect to optimizing irrigation efficiency, are essential to meeting the food producing potential of the region.
- Periodic droughts exacerbate water management problems; years of high rainfall lead to over use, followed by economically painful contractions in lean years.
- Water quality is increasingly degraded by unwanted contaminants, including pathogens, fertilizers, pesticides, decomposed plant material, suspended sediment, and other contaminants such as fuels and solvents. Runoff into streams and lakes causes turbidity that is harmful to fish and adds materials that, over time, reduces the volume of lakes and reservoirs. Eutrophication of surface waters due to agricultural inputs such as phosphorous and nitrogen is a continuing problem.
- The focus is shifting from land productivity to water productivity which requires changes in cropping patterns, innovative irrigation approaches, crop improvement strategies, novel policies and greater investment in research and capacity development.
- Institutions and protocols need to be developed and implemented for groundwater management. Groundwater resources are important as buffers to drought and supplements to surface supplies. There are many instances throughout the Americas where groundwater resources will be prematurely depleted if left unmanaged.

Water, Food and Energy are interdependent resources that need more integrated management.

- It is important to identify the energy forms that use large amounts of water and to gradually replace them with ones with the potential to reduce water use.
- Innovations in solar and wind energy production have almost no impact on water.
- The water requirements used to irrigate crops grown for biofuels can be much larger than for the extraction of fossil fuels. Biofuel based subsidies that incentivize farmers to pump aquifers at unsustainable rates have led to the depletion of groundwater reserves and such practices must be discouraged.

The region of Latin America continues to suffer massive deforestation and associated environmental degradation. The largest net losses (3.6 million hectares/yr) were recorded between 2005 and 2010 and occurred in South America.

- In all countries, the conversion of forests to farmland increases erosive processes and has an extremely negative impact on water bodies and riparian zones, due to higher rates of sedimentation, eutrophication and reduction of the regulation capacity of the hydrological regime, leading to higher risks for flooding intensity. Deforestation is also a major cause of greenhouse gas accumulation and therefore a driver of climate change.

- Most areas of the Americas are facing great challenges related to the destruction and fragmentation of habitat. This is caused by the expanding agricultural frontier, urbanization, tourism and other land and commercial developments, together with changing consumption habits.
- Deforestation in many areas of the Americas has a high impact on quality of life especially for poor and rural populations.
- Deforestation has multiple economic and social drivers including: (1) population growth, (2) land use changes (spread of the agricultural frontier), (3) unsustainable economic expansion, (4) poverty, and (5) corruption.

Climate change research is essential, not only because agriculture is a major source of GHGs, but also to develop strategies for climate adaptation and mitigation in every country.

- The abundance, incidence and severity of pest and disease attacks is one of the major predictable threats of climate change.
- In situ and ex situ preservation of local genetic resources is an important insurance policy against climate change.
- The Caribbean is particularly vulnerable to environmental degradation and at the greatest risk of climate related disasters. The Caribbean is also the most vulnerable region for FNS, because it is heavily dependent on imports and suffers from a weak, undiversified economy. More attention must be focused on the special needs of the Caribbean region.
- A focus on average climate statistics obscures the fact that it is the extreme events that cause most damage. It will be important to manage for extreme events and to recognize that what were once believed to be 100 year events are now more likely to be decadal or even more frequent. Strategies to minimize risk will become essential tools.

A key future challenge is to produce more healthy food without increasing agricultural area, while simultaneously reducing greenhouse gas emissions and reducing wastage.

- Based on the ranking of 25 countries in the 2016 Food Sustainability Index (including measures of food waste, sustainable agriculture and nutritional challenges), the countries in the Americas that were ranked occupy mid to low levels: Colombia 10, United States 11, Argentina 14, Mexico 15, and Brazil 20. This suggests that there are substantial opportunities for further improvement in the Americas.
- An important step forward will be the adoption of the circular economy model of reducing, reusing and recycling in production. This model should promote sustainability and encourage the process of value addition for products such as processed foods, probiotics, prebiotics, nutraceuticals, bioenergies and biomaterials, thereby strengthening and diversifying local economies.

- Modern technologies, such as biotech crops and precision agriculture, are critical to producing more healthy food without increasing agricultural acreage, while at the same time reducing greenhouse gas emissions and wastage.
- However, the adoption of modern technologies is slowed by constraints on infrastructure that are common to all countries in the Americas. These constraints include the development of adequate irrigation systems, adequate water and food storage capacity, sufficient transport and road systems, and adequate investment in STI producing institutions.
- Big data and modern Information Technology (IT) offer substantial opportunities to advance sustainable management practices. These approaches can be especially valuable in anticipating and mitigating climate related impacts, enhancing water use efficiency and improving agricultural efficiency.

Malnutrition, food insecurity and obesity coexist to a greater or lesser degree, as well as chronic diseases related to obesity.

- In several countries in the Americas, a reduction in poverty and malnutrition over the last 10 years has been associated with an increase in obesity. Thus, poverty reduction is a necessary, but not a sufficient condition for adequate, healthy diets.
- Non-communicable Diseases (NCDs) represent the main cause of morbidity and mortality in the United States, Argentina, Uruguay and Chile and impose heavy costs on health care systems.
- More behavioral research is needed to determine how food choices are made and how they can be modified, together with a more rapid assimilation of science based best practices into the food production system.
- It is crucial to recognize, and incorporate into policy, the key role gender plays in food production, food preparation, food selection and nutrition.
- There is a strong need for more effective systems for water purification and distribution. Safe drinking water remains an important issue in the Americas and has a clear link with the incidence of foodborne disease.

Progress in the Americas over the last quarter century has been impressive and STI have played a major role in improvements linked to the Millennium Development Goals (MDGs). STI will continue to play a key role in achieving the Sustainable Development Goals (SDGs) by 2030, but progress will depend, in part on greater regional and global cooperation in STI, and partly on the development of more uniform policy frameworks.

- STI is essential, not only to achieving food and nutrition security, but also to eradicating poverty, protecting the environment and accelerating the diversification and transformation of economic conditions.
- Agriculture is increasingly seen as a dynamic sector, driven by STI, for the transformation of national economies in the future. However, it will be important to generate an enlarged framework for STI cooperation and coordination in the Americas with respect to FNS.

- Past investments in agricultural research have yielded high returns (estimated at 20 to 40-fold globally), but rates of gain are now declining as the potential of older technologies (e.g., green revolution) are fully exploited. A whole suite of new technological innovations shows great promise for future plant and animal improvement. These new innovations include more efficient use of water and nutrients, increased yields, more effective approaches to pests and diseases, the integration of robotics with big data and advanced algorithms for more efficient management, and the adoption of best practices in agriculture. It will be important to accelerate the rate at which promise is turned into practice.

STI alone cannot achieve all the advances in FNS required for the future. STI advances, combined with effective evidence-based policy, must be implemented more widely in the Americas.

- It is hard to overemphasize the importance of governance and public policy in achieving both food and nutrition security and in supporting the development of more sustainable agricultural policies. One only needs to consider the present situation in Venezuela where an otherwise well-endowed country is suffering from food shortages, owing to poor public policies.
- There is a trade-off between high investment-high efficiency agricultural systems and small holder agriculture in many countries in the Americas. This social trade-off is a major public policy issue.
- Trade in agricultural products has historically been distorted by subsidies and barriers to market access. These distortions will need to be reduced in the future.
- Most countries in the Americas are in need of better functioning policies and more effective enforcement to promote the sustainability of forest, marine, inland and ground waters, and all other terrestrial ecosystems and their biodiversity.
- Poverty eradication and food and nutrition security are closely linked goals that must be pursued together.
- The secondary effects of agricultural policies should be taken into account, such as migration of the rural population to urban centers, and impacts on land use and conservation.
- In many countries, regulations relating to such things as pesticide use, over use of antibiotics, organic agriculture and the reduction of food waste, are inadequate.
- Evidence based regulation should be improved to more effectively combat food borne diseases.
- There is an important role for international aid donors and NGOs in advancing STI based FNS in many countries in the Americas.
- The potential for involving the Organization of American States more actively in facilitating STI based approaches to FNS must be explored.
- Organizations such as IANAS can also accelerate progress by reaching out to national policy makers and advocating for evidence based FNS policies. IANAS has a significant presence in most countries in the Americas through the national science academies.

The gradual shift in STI investment from public to private sectors must be monitored and understood, so that gaps in public support can be prioritized.

- The low research participation of the private sector in most counties is deemed a major deficit.
- There is a need for better methods for communicating STI advances and investment opportunities to national policy makers and the public.

The challenge for the Americas will be to retain the ability to feed and adequately nourish itself while also making a substantial contribution to the food supplies available to the rest of the world.

Michael Clegg
Project Coordinator

The challenge for the Americas will be to retain the ability to feed and adequately nourish itself while also making a substantial contribution to the food supplies available to the rest of the world

Special Feature

The Role of the Western Hemisphere in Feeding a More Populous World

Henry J. Vaux (USA), Professor & Associate Vice President Emeritus, University of California.

Current patterns of food and nutrition security in the Western Hemisphere look reasonably favorable in comparison with other regions of the world. While there are locales and sub-regions that face food and nutrition inadequacies, the broad hemispheric picture is one of food surplus and there is significant potential for future food sufficiency.

Consider production and export figures for several major agricultural commodities from the Americas.

- Three of the top 7 wheat exporting countries globally are in the Americas.
- Seven of the top 20 wheat exporting countries globally are in the Americas.
- Only 2 of the top 10 and 3 of the top 20 wheat importing countries globally are in the Americas
- For corn, the top three exporters are from the Americas.
- Soybean meal exports are dominated by Argentina, Brazil, the U.S. & Paraguay.
- Fishmeal exports globally are led by Peru and Chile.

These data suggest the significant role that the Western Hemisphere currently plays in helping to feed the rest of the world. In addition, the Hemisphere appears well positioned in a production sense to address its food and nutrition issues as well as some of those elsewhere in the world in the future. Midline projections from the Population Reference Bureau indicate that global population will grow by 36% between 2013 and 2050. This translates into an annual growth rate of 1.2%. There will be 2.6 billion more mouths to feed by 2050 than there were in 2013. For the Western Hemisphere, population is projected to grow by 28% over the same period. With the exception of Central America, national growth rates will be lower than the projected global growth rate. Economic growth rates, while less certain, are projected to be positive both for the hemisphere and globally. Economic growth will drive growth in the demand for food and fiber and, as incomes grow, the pattern of demands for food will also change.

Zehnder (2002) identifies the countries and regions where population growth will be concentrated. He shows that most of these countries are unlikely to have sufficient resources (water and, to some extent, land) to expand food production for a growing population. Vorosmarty, et al., (2010) identify global threats to water security. Their analysis shows that the number of countries with insufficient water for agriculture will likely grow through 2050. These analyses draw attention to the fact that insufficient land, water and home grown food in individual countries could be addressed through enhanced international trade in agricultural products. In the absence of a globally catastrophic war or widespread isolation of nation-states from each other, the agricultural economy of the world is likely to become further globalized. In such a world the problems of inadequate resources and productive capacity in individual countries can become global problems that countries with sufficient water and food will be expected to help solve.

Under presently foreseeable circumstances, the Americas will remain one of perhaps three areas or regions that will be in a position to grow significant quantities of food for export to countries that have insufficient capacity to grow all of their own food. The other areas are Europe and former USSR republics such as Ukraine. In order for the Americas to reach their full potential to help provide food for exports means that appropriate policies will be needed in both food short and food rich countries if the global problem is to be attacked globally. The challenge for the Americas will be to retain the ability to feed and adequately nourish itself as well as making an important contribution to the food supplies available to the rest of the world.

It is important to recognize that specific policies must be adapted to the circumstances of individual countries and regions. Nevertheless there are several broad policy realms that will need widespread attention throughout the Americas as well as the world.

- Effective policies are needed to facilitate international trade and facilitate the flows of produce, implements and know how through that trade. In spite of the importance of enhanced trade humanitarian aid will continue to be important, especially in short term situations.
- Policies that facilitate the development of technical improvements, including the further development of biotechnology and its fruits, will be helpful.
- Policies that support development and facilitation of effective and efficient management of agriculture itself as well as the resources upon which it depended will also be needed.
- Policies the promote the efficient management and protection of water resources, including ground water, will be essential if healthy agricultural systems are to be maintained.
- Policy support for discovery and implementation of ways to improve nutrition and educate consumers will also be essential.
- Policies that support improved agricultural productivity in both developed and developing countries will also be needed.

References

Vorosmarty, C.J., P.B. McIntytre, M.O. Gessner, D. Dudgeon, A. Prosevich, P. Green, S. Glidden, S.A. Sullivan, C. Reidy Leimann and P.M. Davies. 2010. Global Threats to Human Water Security and River Biodiversity. Nature 467 555-561. September.

Zehnder, A.J.B. 2002. Wasserrssourcen und Bevolkerungsentwicklung. Nov Acta Leopoldina NF 85(323): 399-418.

Photograph of Henry J. Vaux

Food and Nutrition Security in Argentina

Vineyards in Maipu, province of Mendoza, Argentina © Shutterstock

Argentina

[1] Eduardo Bianchi
[2] María Cristina Añón
[3] Eduardo Pagano
[4] Martín Piñeiro
[5] Carolina Szpak
[6] Eduardo Trigo
[7] Sergio Vaudagna

Summary

Argentina is a country with a vast area and range of climates, coupled with a wealth of natural resources, including products created by agricultural activity. It is a major food producer and worldwide exporter. This chapter describes the main features that make Argentina a key food producer. It reviews its current demographic status and future trends and describes the state of its population's food and nutrition security. It also details the institutional environment in which research is conducted in this field, outlining its strengths and weaknesses.

It evaluates the current degree of degradation of the water and soil, energy matrix and forests, as well as the potential impacts of climate change. Technology and innovation related to the agricultural sector and food production are also analyzed, with an emphasis on the country's biotechnology status. The possibility of increasing the efficiency of the food system, as well as aspects related to human health, particularly regarding the nutrition of the country's population are also explored. Although public policy issues run throughout the chapter, a special section is devoted to highlighting the most relevant and urgent policies required to enable the agricultural sector to play a key role in a process of overall, sustainable and inclusive economic development.

Argentina is a great producer and exporter of food. Yet with over eight million Argentinians living in poverty and **one and a half million lack food and nutrition security**

I. National characteristics

a. Territorial extension, relief, environmental heterogeneity and arable land

Argentina lies to the south of the American continent, occupying an area of 3,761,274 square kilometers, three quarters of which are on the American continent and the remainder in Antarctica. Thus, Argentina extends longitudinally from North of the Tropic of Capricorn to the South Pole. Since Argentina is a country with a vast area, it contains a variety of forms of relief. Although it consists mainly of plains, covering more than half the total area, there are also mountains and plateaus. The plains are located mainly in the East of the territory, while the mountainous areas occupy the western sector and the largest plateau, the Patagonian Plateau, is located in the South of the country.

This large area contains a succession of climates encompassing tropical ones in the North and the West; subtropical ones in the North and East; temperate ones in the Center; temperate cold ones in the southern mainland and cold in the island area and the Antarctic. This diversity of climates favors the presence of an enormous variety of natural resources. Thus, products from tropical climates, such as cotton, rice, sugar cane, tobacco, mate and citrus, and from Mediterranean climates, such as vines, olives and apples, are all grown in Argentina, due to the layout of the mountains, the circulation of the winds and the water network. However, the country is mainly known for its Pampas plain or Pampa, an immense fertile plateau of 700,000 km² located in the Center-East of the territory. The fact that the country is nearly totally covered by a thick sedimentary mantle with gentle slopes and humid climates, together with the availability of groundwater at a low depth, has led to the development of soils suitable for agriculture and livestock, making this enormous area a preponderant factor in Argentina's economic development.

b. Demographic characteristics and future trends

Despite its enormous area, Argentina is relatively sparsely populated, with 43.6 million inhabitants in 2016, and a population density of 15 inhabitants per square kilometer, considering only its area in the American mainland. One of the characteristics of the Argentine demographic structure is the sharp difference in population density among its regions. Owing to historical and economic factors, almost half the country's population is concentrated in the City of Buenos Aires and the surrounding urban area (Greater Buenos Aires).

Argentina's life statistics are similar to those of developed nations, with a declining birth rate and a contraction of population growth. Over the past five years, the Argentinian population has registered an average annual growth rate of 1%, meaning that the population growth rate is expected to slow down in coming years, achieving a total of 57 million inhabitants throughout this century. The population change will be mainly due to population growth, since the projected migratory contribution is very low.

The most notable change in the population over the next few decades will be its marked aging, with a progressive expansion of the adult and elderly population, accompanied by the reduction of the youth and child population. Consequently, the median age will increase from 30 to 46. The third age (65-79 years) will double its relative share over the course of the century, while the fourth age (over 80 years) will be the segment with the largest relative growth, in the context of a significant increase in life expectancy throughout the present century. This phenomenon will pose a serious challenge to the financing of health and social security systems, since the economically active population will decline in relative terms.

c. Poverty and food security

In Argentina, poverty has been a matter for concern for a number of decades. The 1990s saw sharp increases in the unemployment rate, and therefore in the vulnerability of broad sectors of society. The crisis in late 2001 caused a significant fall in real wages, a significant increase in unemployment levels and higher poverty levels. Consequently, over the past 15 years, poverty has been an issue on the economic and political agenda, and has proved difficult to reduce, despite the presence of inclusive policies and solid social welfare programs. Thus, a hard core of the population remains marginalized, even in times of economic prosperity.

Data obtained by the Argentinian Catholic University in 2015, which explores poverty from a multidimensional perspective, including income, safe food, health protection, access to basic

[1] **Eduardo Bianchi,** Chapter Coordinator. Researcher and professor, Escuela Argentina de Negocios (EAN), eduardodbianchi@gmail.com **[2] María Cristina Añón,** Doctor of Science in Biochemistry; Full Professor, Faculty of Exact Sciences, National University of La Plata; Senior Researcher, CONICET; Center for Research and Development in Food Cryotechnology (CONICET, CIC, UNLP), mcacidca@gmail.com **[3] Eduardo Pagano,** University of Buenos Aires, National Council of Scientific and Technical Research; Institute of Research in Agricultural and Environmental Biosciences, INBA, Faculty of Agronomy, epagano@agro.uba.ar **[4] Martín Piñeiro,** Member of the Argentine Council of International Relations (CARI) and the Group of Southern Producing Countries (GPS), martin.pineiro2@gmail.com **[5] Carolina Szpak,** Researcher and professor, Escuela Argentina de Negocios (EAN). carolina.szpak@ean.edu.ar **[6] Eduardo Trigo,** Grupo CEO S.A., ejtrigo@gmail.com **[7] Sergio Vaudagna,** Professor, Food Technology Institute, Agroindustry Research Center, National Institute of Agricultural Technology (INTA), vaudagna.sergio@inta.gob.ar

services, decent housing, access to education and employment and social security, estimate that during that year, nearly 20 million people had at least one shortcoming in the areas mentioned (47.7% of the population), 11.4 million had at least two (26.4% of the population) and approximately 6.7 million had at least three of these shortages (15.1%). On the other hand, according to data from government agencies for the second quarter of 2016, people living in poverty - measured in terms of incomes – accounted for 32.2% of the population and 23.1% of households. At the same time, about 6.3% of the population were indigent, equivalent to 4.8% of households. In absolute terms, there were 8.8 million people living in poverty and 1.7 million in extreme poverty.

According to these studies, a household is considered poor if the incomes of its members are unable to meet a set of food and non-food needs considered essential. For its part, a household is considered indigent if its income is insufficient to cover a food basket capable of meeting a minimum threshold of energy and protein needs. In this respect, then, in the first four months of 2016, there were 1.7 million people in Argentina lacking food security.

In geographical terms, the most severely affected households are those located in the metropolitan area of Buenos Aires and the large metropolitan areas in the interior of the country. In terms of stratification by education, the most vulnerable households are those with heads of household who have not completed middle school, are engaged in informal employment and have children.

d. Agroindustrial production

The agroindustrial sector has been and continues to be a key component of the Argentinian economy. Currently, primary and processing activities contribute approximately 20% of the Gross Domestic Product (GDP) and 45% of the Gross Added Value (GAV) in goods. In turn, they account for 8% of total direct employment and 36% if one includes indirect employment linked to agroindustrial value chains.

Thus, Argentina is a major producer of cereals, such as wheat, maize, sorghum, rice, barley; oilseeds such as soybeans and sunflowers; industrial crops such as cotton, sugar, mate, tobacco and tea; and fruits and vegetables. The country also plays a key role in livestock production, mainly beef and dairy products. In several of these products, Argentina is a major global producer and consequently also a top exporter. The two main products are undoubtedly soybean and beef.

Soybean production is extremely competitive in Argentina, having adapted well to the various ecological systems of the Pampa and the NE and NW regions. Since the introduction of transgenic soybeans in 1996, in conjunction with direct sowing, there has been an exponential increase in the area planted with this crop, leading the country to become one of the main producers and exporters of soybeans and its derivatives. Thus, in Argentina, the area planted with soybean compared to other crops, mainly cereals, is much larger: approximately 70%.

Map 1. Geographical position of Argentina

Beef production is also very important, ranking second after soybeans. Primary production is extremely atomized, with a large share of small- and medium-sized enterprises, with a cattle stock of approximately 55 million head. Most of production is undertaken in systems based on extensive pastures, whether natural or cultivated, where livestock are fed.

The basis of this expansion has been the incorporation of new lands into production, mainly into agriculture, as well as the increase of productivity. In both cases this has been the result of the adoption of new technologies and organizational and management innovations. In fact, the Argentinian countryside has undergone profound modifications in recent decades. At the moment it is experiencing a technological, organizational and productive paradigm change, within the framework of the biological revolution. Process innovations in the direct sowing of crops and grasslands, associated with increased use of genetically modified varieties, have driven the exponential growth of agricultural production.

Together with the adoption of these technological packages, the emergence of new companies that supply specific inputs and services has led to a network model among producers, contractors, workers and suppliers, very different from the traditional organizational model of the Argentinian countryside.

e. Trends in urbanization

The process of urbanization in Argentina has developed rapidly since the early 20th century, with a trend since the middle of that century toward the reduction of the rural population in absolute terms. The current rate of urbanization is 90%, making the country one of the world's most urbanized nations.

Its urban system is extremely disparate in terms of population densities, concentrated mainly in large cities, particularly Buenos Aires and the Metropolitan Region of Buenos Aires, while vast regions of the country are unpopulated. Whereas the Autonomous City of Buenos Aires has 14,450 inhabitants per square kilometer, in much of the country, population density is fewer than 15 inhabitants. There are also a series of intermediate cities and small population centers, in the latter case with fragile regional interconnections and significant differences in the capacity to provide goods and services to their inhabitants and rural surroundings.

f. Impacts of migration

Mass immigration to Argentina was a key factor in the country's transformation in the 19th century. Between 1830 and 1950, the country received 11% of the total number of Europeans who left their continent. In the following decades, migration from Europe ceased, while immigration from the neighboring countries (Chile, Bolivia, Paraguay, and Uruguay) and Peru increased. Thus, since the second half of the 20th century, immigration from these countries has constituted the most dynamic migration to the country. Although the current importance of immigrants in the Argentine population is minimal, most of the foreign population originates from these countries. According to the latest census, published in 2010, the foreign resident population in Argentina stood at approximately 1,800,000, equivalent to 4.5% of the total population. Of this foreign population, 75% came from neighboring countries and Peru.

Although the settlement pattern of these immigrants differs according to their nationality and the historical moment of the migratory current, the flow of migrants from the adjacent countries and Peru meets part of the demand for semi-skilled and low-skilled work in the country's urban labor markets, mainly in the Metropolitan Area of Buenos Aires. However, most of these workers are employed in productive sectors where unregistered employment or informal work predominates, one of the main problems that afflicts the Argentinian labor market in general. Thus, the majority of wage-earning immigrants, like Argentinian workers working in the same sectors, lack both social security coverage and the rights and benefits of a formal employment relationship.

g. Main exports, imports and markets

Argentina is a major exporter of agroindustrial products. In 2016, they stood at about US $40 billion, accounting for almost 67% of the country's total exports, including raw primary products ($16 billion USD) and agricultural manufactured goods ($23 billion USD). Three-quarters of agroindustrial exports correspond to soybean, maize, wheat, beef, sunflower, dairy and barley production chains. Foreign sales of the soybean complex (beans, flour, oils and biodiesel) account for nearly half the agroindustrial exports and 30% of the country's total.

A high level of concentration of exports can also be observed in more specific products. Thus, most agroindustrial exports consist of soybeans, soybean meal, soybean oil, maize, wheat, beef, milk powder and barley, fruit, vegetable and fruit preparations, and crustaceans and prawns (**Table 1**).

Export markets for agroindustrial products also show a high degree of concentration, the MERCOSUR countries (Brazil, Paraguay, Uruguay and Venezuela), the European Union and China being the main destinations. Argentina mainly sells MERCOSUR countries: wheat, soybean oil, corn, soybean meal and pellets, whole milk and beer barley. Exports to the EU are heavily concentrated on soybean meal and pellets, and beef. Meanwhile, the main products shipped to China are soybeans, frozen beef and barley.

In recent years, Argentina's biodiesel exports have increased, making it one of the world's leading exporters, with European Union countries and the United States being the most important destinations.

Argentina's food imports are insignificant by comparison, totaling US $2 billion in 2016. The main products purchased abroad are bananas, coffee, tuna and cacao.

II. Institutional framework

a. National Agricultural and Agro-Food Research System

In Argentina, the National Agricultural and Agri-Food Research System comprises national and public institutions, among which are the National Institute of Agricultural Technology (INTA), the National Institute of Industrial Technology (INTI), National Council of Scientific and Technical Research (CONICET) centers and national universities. Agricultural research is also undertaken by private institutions, such as the Argentine Association of Regional Consortia

Table 1. Agroindustrial exports from Argentina, 2016

Main products	Million USD	% of total
Soy complex	18.400	47
Beans	*10.000*	*26*
meal	*4.000*	*10*
Oils	*3.200*	*8*
Biodiesel	*1.200*	*3*
Maize	4.100	11
Wheat	1.800	5
Meat	1.500	4
Vegetable and fruit preparations	1.200	3
Shrimp and prawn	1.000	3
Fresh fruit	900	2
Barley	600	2
Dairy	600	2
Sub-total	30.100	77
Total agroindustrial products	**39.000**	**100**

Source: Compiled by the authors based on INDEC.

of Agricultural Experimentation (AACREA) and public-private partnerships.

The National Institute of Agricultural Technology (INTA) is a decentralized state agency with operational and financial autarchy, answerable to the country's Ministerio de Agroindustria. Created in 1956, its Board of Directors comprises representatives of the public and private sectors, ensuring the active participation of the productive and academic sectors in setting and prioritizing the institute's overall policies and strategies. INTA is composed of 15 Regional Centers, 52 Experimental Agricultural Stations, 359 Outreach Units and six Research Centers with 22 Research Institutes, providing broad national coverage. The National Programs and National Networks are the programmatic instruments organized by discipline or value chain. Regarding food safety and quality, INTA has a transversal program for the various value chains that address these issues. The National Agribusiness and Value Added Program consists of three major projects that include the following areas: development and optimization of agroindustrial processes for added value; optimization of integral quality and other strategies for adding value to food, and technological processes to add value at source in a sustainable way.

INTA is the parent organization of The Institute of Food Technology (ITA), whose research and development activities are divided into four areas: Food Protection; Biochemistry and Nutrition; Food Processing, and Physical and Sensory Analysis. INTA is linked to various public and private institutions, both national and international, with which it participates in knowledge networks.

Another key institution in the science and technology sector in Argentina is the National Institute of Industrial Technology (INTI), whose main objective is the generation and transfer of technological innovation to industry, ensuring that the quality of the processes, goods and services produced in the country adhere to global norms and trends. INTI has four centers specializing in food: Agrifoods, Meats, Cereals and Oilseeds, and Dairy. These centers seek to contribute to the technological development of the food industry, especially food of plant origin, by providing technical support and the transfer of technology to the productive sector, by promoting technological innovation, optimizing the quality and safety of food products, as well as the efficiency of production processes, while protecting the environment.

It is also important to highlight the creation of the CONICET Food Safety Network. The general objective of this network is to develop and analyze scientific and technological information on the current status of Food Safety to serve as the basis for the adoption of public policies. To this end, the Food Safety Network encourages and promotes the interaction of CONICET with national and international health institutions that manage risk from a Food Safety perspective. At the same time, it provides technical assistance to assess and substantiate priority issues for the country's food safety.

b. Universities and Research Institutes

Argentina currently has 54 public and 49 private universities, with a significant concentration of national university establishments in the Buenos Aires Metropolitan Area. At the undergraduate level, a significant number of public and private universities offer degree programs in the areas of food and nutrition, such as a BSc in Food Science and Technology, a BSc in Food Technology, a BSc in Food Sciences, Food Engineering and a BSc in Nutrition. There is obviously a difference in the profile of the degree programs offered in these areas between the public and private spheres. In the first case, there is a marked preference for courses related to science, technology and food engineering, particularly in Academic Units of Exact Sciences, Agricultural Sciences, Veterinary Sciences and Engineering, whereas in the second case, nutrition programs prevail, particularly in Academic Units related to Health Sciences.

At the postgraduate level, public universities offer Master Degree Programs in Food Science and Technology, Food Technology and Hygiene, Food Technology, Food Safety and Quality and Agribusiness and Food. Only three public universities offer doctorates specifically in Food and Nutrition; in the others, they are subject-based (doctorates in chemistry, biochemistry, engineering, or medicine, etc.), even though students have been trained in the field of food, food safety or nutrition.

At the undergraduate level, the infrastructure of the Argentinian university system, both public and private, is extremely varied; investment is required, particularly for buildings and latest-generation equipment for students.

The national university system has several research groups in the area of science, technology and food engineering, which includes study groups in the areas of food and nutrition security. The degree of development of the latter varies, as does their infrastructure. Many of these groups are located exclusively in the university area, while others, particularly the most consolidated ones, depend on a university and on CONICET or other provincial entities such as the Commission for Scientific Research of the Province of Buenos Aires. Most of the consolidated groups that undertake their activities in the area of food are multidisciplinary, comprising Biochemists, Engineers, Chemists, Agronomists and Biotechnologists. These groups undertake experimental activities, at the laboratory and pilot-plant level, as well as theoretical modeling studies. The lines of research-of-interest are modified according to the latest developments in the national and international fields, and incorporate new technologies and equipment. Many of these centers have research projects related to nutrition and food security, addressed from a variety of perspectives.

A recent study commissioned by the Ministry of Science, Technology and Productive Innovation shows that in the 2009-2014 period, the publications with the greatest impact at the international level correspond to the area of food science, which includes at least partly the topics-of-interest. This area combines a low share of the country's total publications with a very high impact.

Both public and private universities and research groups/centers/institutes train human resources with the skills currently required. It should be noted that despite the importance of the food sector for the country, the number of students who choose degrees related to food, safety and nutrition is small in comparison with traditional programs. The same trend is observed in the number of researchers involved in these areas. Over the next few years, the programmatic development and contents of the various degree programs designed to train professionals in these areas should be overhauled, in order to provide future graduates with new tools for a much more technological world, which will probably require a smaller number of jobs.

A glaring weakness in Argentina is the low participation of the private sector in the financing of scientific and technological activities, as well as in the demand for new developments/studies of interest to the industrial sector. This fact is relevant in the food sector, including the areas of safety and nutrition.

c. Outlook for the future

Argentina is a country with several opportunities in the agri-food sector, particularly if it continues applying new technological developments and increases the added value of its products. This requires a modern, efficient system of human resource training, at both the undergraduate and graduate levels. Both public and private investment is required to improve university infrastructure and equipment. Degree programs should be overhauled to adapt them to the technological changes the world will face in the coming decades, thus equipping graduates with the tools required for their subsequent insertion into the labor market. These new program developments should take into account the need for interaction with other disciplines and interdisciplinary training. It will also be necessary to maintain and strengthen the financing of the Science and Technology sector and substantially increase the contribution of the private sector, both financially and in terms of the demand for new knowledge and development, as well as possibilities for interaction.

III. The Characteristics of Resources and Ecosystems

a. Water and the challenges for the next 50 years

Although Argentina is rich in water resources, they are unevenly distributed throughout its territory. A single area comprising 84% of the country's water resources occupies a quarter of the total area, and accounts for 70% of the total population and 80% of the country's agricultural production. The other three quarters of the country are arid and semi-arid zones, where 30% of the total population lives and agricultural production requires irrigation.

It is estimated that the country has an average annual water supply of approximately 20,000 m³ per inhabitant and an average annual rainfall of 600 mm. Average drinking water per inhabitant is 400 liters per day, although losses in the network and clandestine connections reduce this figure to 250 liters per day per inhabitant.

In terms of the economic and social use of water, 80% of the population have a household connection to a potable water network, while 47% have a household connection to a sanitary sewer network. Coverage reaches 90% when improved sanitation systems are considered. Only 12% of collected waste water is treated before being returned to the areas for receiving water. It is important to note the link between basic sanitation services and health, since approximately 15% of the population lack access to basic sanitation services. Thus, despite being a country with abundant water resources, certain sectors of the population are unable to meet their basic needs for this resource. In the metropolitan areas of the largest cities, there is a lack of supply networks coupled with the pollution of surface and underground resources, whereas in the case of rural populations in arid and semi-arid areas, water supply capacity is compromised.

As to the use of water for agricultural activity, Argentina has an average of water withdrawals for this purpose of less than 5%, well below a situation of water stress. However, agricultural water use faces problems in certain areas, such as excessive water salinity, poor soil drainage, technologically outdated irrigation systems and low water-use efficiency.

As a counterpart to the country's wealth in this resource, Argentina's total water supply is increasingly conditioned by the pollution of rivers, lakes and aquifers by diffuse and concentrated sources. For example, the discharge of liquid effluents without decontamination treatment affects the basins of the Matanza-Riachuelo and Reconquista Rivers in the Metropolitan Area of the City of Buenos Aires, as well as other large cities in the interior of the country, reflecting a significant degree of contamination.

At the same time, climate change poses new and increasing challenges. One of these is the increase of annual average precipitations throughout the country and the frequency of extreme precipitation. Another challenge is the increase in temperatures in the mountainous zone of Patagonia and Cuyo, due to the retreat of glaciers, the increase in river flows and the greater frequency of floods.

b. Soil

Argentina's agricultural area totals approximately 150 million hectares. About 50 million hectares are cultivated areas, distributed mainly among annual crops (soybean, wheat, sorghum) accounting for nearly 30 million hectares, and cultivated pastures used for livestock production, occupying 12 million hectares, the remainder being allocated for other industrial crops (cotton, sugar, mate, tobacco and tea) and fruit and vegetable production.

Since 1990, Argentina has had a Soil Atlas, which classifies soils according to their capacity for use. The total estimated area of the best soils for crop production, classified in classes I, II and III, is approximately 46 million hectares. Given that the new technologies make it possible to cultivate some of the soils classified in class IV (with some restrictions), it is estimated that 8 million ha of this type of soil could be added, bringing the total available area to 54 million ha.

Historically, agriculture was developed on the best soils. However, technological progress enabled it to expand to land with a lower yield in the pampean zone as well as the NE and NW of the country. Although it involved an economic-productive improvement for the region, this expansion entailed other aspects in addition to social ones, related to soil erosion. Thus, pampean agricultural expansion occurred at the expense of pastures and the remnants of natural pastures, while expansion toward the NE took place at the expense of native forests. For example, the Gran Chaco ecoregion has been particularly affected by deforestation rates higher than the continental and world averages (0.82% per year in Argentina, 0.51% in South America and 0.2% worldwide), as transgenic soybean has been introduced.

This has led to the conversion of natural lands into farmland, which has increased the erosive process. Erosion has a negative impact on watercourses, riparian environments and sumps, which results in higher rates of sedimentation and clogging, eutrophication, and the reduction of the regulation capacity of the hydrological regime, therefore, greater flood intensity. Moreover, the land incorporated into the agricultural production process has also been contaminated by pesticide residues and other agrochemicals.

Argentina's challenges include the establishment of a national soil health monitoring system, increased investment in activities that promote sustainable management, the creation of programs to reduce its degradation and the recovery of degraded soils. In this respect, new technologies are particularly important for reducing the toxicity and environmental impact of agricultural activity.

c. Energy resources

The Argentinian Energy Matrix, which indicates the availability and incidence of each energy source in the total supply, shows that most of the energy consumed by the country is of non-renewable origin (about 90%), primarily natural gas and oil, while 8% corresponds to renewable energy. It should be noted that this composition is important regarding environmental aspects, given the link between fossil fuels and global warming.

Conversely, the country has energy opportunities that require development, for which technologies are available. The first opportunity lies in the degree of insolation of much of Argentinian territory, which would allow the use of solar energy. At the same time, the coastal area, particularly the Patagonian region, has winds that can be used to obtain wind power. The third option lies in the scope of national agricultural activity, where crop biomass has an enormous potential for obtaining biofuels such as biodiesel and bioethanol, as well as biogas.

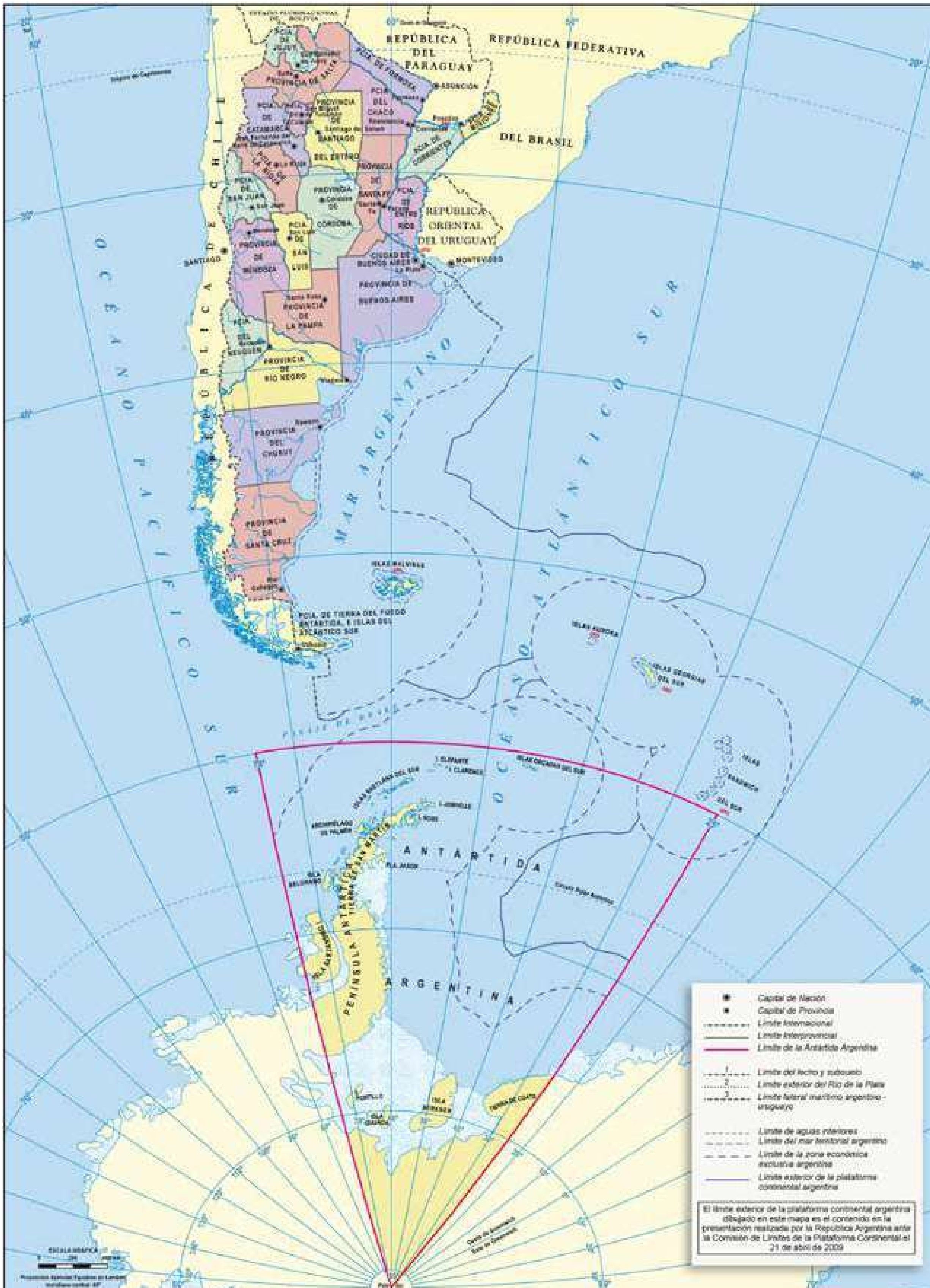
The importance the country places on renewable energies through norms and programs that encourage their use, such as the National Development Regime for the Use of Renewable Energy Sources and, recently, the RenovAr Program, which launched a call for proposals for the incorporation of renewable energy sources into the electricity system suggests that in the future, renewable energies will increase their presence in the country's energy matrix.

d. Forestry

The size of its territory and its diversity of climates mean that Argentina possesses significant forest wealth. This in turn favors climate regulation, biodiversity, water basin protection, soil conservation, water supply and ecosystem maintenance. The country boasts 1.2 million ha of forest plantations and 50 million ha of native forests. Implanted forests are dominated by rapidly growing species such as pine and eucalyptus. Native forests, however, contain trees such as red quebracho, carob and white quebracho.

The country has comparative advantages as regards forest production. It is estimated that the average yield rate is 25 cubic meters per year. In the country's most productive areas and with proper management, greater yields are obtained: 33 cubic meters per year in conifers, doubling the average of the main countries, and 43 cubic meters per year in eucalyptus.

Among the challenges facing forestry in terms of environmental sustainability, is the increase in the number of hectares of established forests and working on lines of research to achieve the genetic improvement of species. It is also essential to overcome the tendency to reduce the area of native forest to make room for other activities, particularly when deforestation is not properly handled or protected. For all these reasons, the sanitary status achieved must be maintained. It is also crucial to make progress with respect to the final use of the products and by-products created along the value chain, especially with regard to mechanical processing residues from wood and forest waste from the extraction of forests, which can be used as forest biomass for energy generation.



REPÚBLICA DEL PARAGUAY
REPÚBLICA FEDERATIVA DEL BRASIL
REPÚBLICA ORIENTAL DEL URUGUAY
REPÚBLICA DE CHILE
OCÉANO PACÍFICO SUR
OCÉANO ATLÁNTICO SUR
MAR ARGENTINO
PROVINCIA DE BUENOS AIRES
PROVINCIA DE LA PAMPA
PROVINCIA DE RÍO NEGRO
PROVINCIA DEL CHUBUT
PROVINCIA DE SANTA CRUZ
PROVINCIA DE MENDOZA
PROVINCIA DE CÓRDOBA
ANTÁRTIDA ARGENTINA
PENÍNSULA ANTÁRTICA

Argentina's features make it one of the world regions with greatest natural advantages due to the rapid growth of its plantations and its productive potential, with the possibility of increasing forested hectares and creating a significant economic and environmental impact.

e. Agriculture, environment and climate change

Recent years have seen setbacks in environmental issues. Air and water pollution, waste and deforestation have become serious problems, together with increased use of agrochemicals.

Structural change from traditional grazing to intensive farming entailed significant environmental externalities. The introduction of direct seeding implied new possibilities in areas that were closed to crops due to water constraints by turning them into productive land. However, the expansion of the agricultural frontier has also been largely due to deforestation, mainly by allocating new areas to soybean cultivation. Thus, between 1990 and 2015, nearly 20% of the forest area was cleared, particularly in the North of the country. Deforestation rates in this region reached alarming rates. Between 2001 and 2014, Argentina lost about 50,000 km² of wooded areas, equivalent to the size of Denmark or Belgium.

Forests play a critical role in carbon sequestration, biodiversity conservation, soil fertility, watershed protection and flood prevention. Deforestation in the upper basins of the main rivers is related to riparian floods, responsible for half the damage caused by the country's natural disasters.

Climate change has also made its effects felt in the country. Since 1960, average annual rainfall has increased by 3.5% per decade, while the share of intense rainfall events has risen by 1.7% per decade, increasing the incidence of floods. In most of the country, the temperature has risen by almost half a degree Celsius since 1960, whereas in the southern region it has increased by 1°C.

Projections suggest that the country as a whole will experience a rise in average temperatures, together with an increase in rainfall. Climate change is likely to substantially alter agricultural productivity. Thus, some crops such as maize will see a decline in yields, while others, such as soybeans, could benefit from expected climate changes, which could translate into an increase in productivity of approximately 35%, due to the increased availability of water in the month of February. In this context, and in line with past events, land degradation and land conversion are environmental threats that are a matter for concern.

The impact of farming on the environment and public health should therefore be adequately properly assessed, taking into account the fact that environmental degradation disproportionately affects lower-income populations.

IV. Technology and Innovation

a. The Role of biotechnology

Innovation is fundamental in Argentina, whose industry is based largely on small- and medium-sized enterprises and innovative entrepreneurs. Agricultural entrepreneurs have the same idiosyncrasy, characterized by their level of technical training and speed in acquiring new technologies. Among these, biotechnology has played a significant role in recent years.

The advent of biotechnology applied to agricultural activity in the late 1980s fell on fertile ground. At that early stage, two issues seemed promising: on the one hand, the genetic transformation of plants and, on the other hand, the production of plants by tissue culture. The innovation was produced by a company that appropriated the tools for transgenesis and those required for the regeneration of plants from somatic cells, either to support transgenesis or to obtain commercial clones. As for animal biotechnology, the initial interest was linked to breeding, mainly through semen-conservation and embryo-transplantation techniques.

i. Agricultural biotechnology

Although materials obtained from tissue cultures for the provision of fruit and vegetable companies were available from the early 1990s, the key moment in the history of Argentinian biotechnology was marked by the emergence into the market of the first transgenic event: the glyphosate herbicide-resistant soybean, which began to be planted in 1996 and which, in four years, covered almost the entire area under cultivation with this crop. This was followed by maize resistant to lepidopteran and coleopteran insects due to the incorporation of the *Bacillus thuringiensis* toxin gene. These two species, together with cotton, represent all the genetically modified organisms in production in Argentina, significantly exceeding 90% of use in all cases. Although there are numerous variants and combinations, they are all related to herbicides and insect resistance. A virus-resistant potato and a drought-resistant soybean have recently been approved for marketing. These two cases are interesting for two reasons: the events do not involve resistance to herbicides or insects and both were developed in Argentina.

ii. Agricultural biotechnology

There are many aspects in which animal biotechnology can contribute to production. However, in the same way or to an even greater extent than what happens with plant biotechnology, society's misgivings make it difficult to produce materials obtained from these tools. Cloning and transgenesis are the two topics that have elicited the greatest interest.

iii. Pests and diseases

Due to the intensive use of materials with identical characteristics of insect resistance (the Bt gene) and herbicides (glyphosate), resistance appeared in animal pests and weeds. The use of shelters and crop rotation, both of which were advisable, have not been widely accepted by producers, which puts these technologies at risk. The technical response to alleviate these deficiencies is based on the generation of transgenics resistant to other herbicides (2,4-D, for example) and gene stacking. While these alternatives achieve a short-term response, they do not answer – and may even increase – the doubts of certain sectors of society.

b. Prospects for new agricultural products

Three "waves of agricultural biotechnology" have traditionally been mentioned. The promises biotechnology made to society included a first wave of genetically modified materials aimed at increasing yields with the aforementioned insect and herbicide resistance events. During the second wave, the genes incorporated would create an improvement in the nutritional quality of the materials destined for human consumption, whereas with the third wave, transgenesis would turn plants into manufacturers of products destined for agroindustry ("*agrofarming*") and the pharmaceutical industry ("*agropharming*"). Although there are some specific cases, such as soybeans with better quality oil or the famous golden rice, interest in biotechnological development has stopped at the first wave, where the immediate beneficiary is the agricultural producer. Part of society's critical view of transgenics is based on the fact that the consumer, in his risk-benefit assessment, fails to perceive the advantages of transgenics and has many doubts.

At present, there are three areas where biotechnology could provide opportunities for Argentina.

i. Transgenics

Innovation will have to explore genes that are more widely accepted by consumers, in other words, those included in the second and third waves. A crop that produces grains with greater iron availability or human insulin might elicit a more positive reaction from society.

ii. New breeding techniques

As an alternative to transgenesis, methodologies have recently emerged which, despite involving the manipulation of DNA, do not incorporate foreign genes, thus do not produce genetically modified organisms, as currently defined. Among these, gene editing using CRISPR/Cas9 technology seems to be the one with the greatest potential. The lower relative cost and the reduction of commercial regulation obstacles increase the appeal of exploring these techniques.

iii. Improvement based on sequencing and molecular markers

Sequencing techniques have been become available to a large number of research groups in various countries. Nowadays, sequencing the entire genome of a species offers no difficulty for trained groups or medium-sized enterprises. Improvement based on molecular markers has therefore become a very powerful alternative. The exploration of traits in germplasm banks and the tracking of these in the offspring make it possible to achieve materials with similar characteristics to those obtained through transgenesis or gene editing. This is crucial when it comes to quantitative traits, based on many genes, such as yield, drought resistance or meat quality.

c. Opportunities and obstacles to new management technologies

Opportunities are based on the fact that Argentinian science is developed and globally competitive. The country has significant intellectual capital, with the ability to cope with the most complex technologies. However, two key points must be addressed. The first is to achieve appropriate interaction between research centers and companies, so that creative efforts focus on solving problems related to production. The second is the development and modernization of equipment and the implementation of financing sources designed to incorporate technology.

As far as agricultural biotechnology is concerned, the threats are closely linked to those faced by the national seed industry. Lack of technological growth on the one hand, coupled with the failure to recognize the value of germplasm, on the other, could lead to the absorption of these companies by multinationals, which has happened in recent years, causing a significant reduction in the number of national breeders. Most of these companies are small- and medium-sized, undertake traditional genetic improvement and are not highly technified. Unless these companies are helped to make the technological leap, they run the risk of disappearing.

Currently, in order to compete, large companies need to jump from marker-assisted improvement using "Single Nucleotide Polymorphism" (SNP) to broad, genomic selection. In order to survive, many companies will need to begin venturing into marker-assisted selection, even the most basic ones. National seed companies that market transgenic materials incorporate the events of multinational companies. There are no developments of national events available on the market. The alternative for growth and competitiveness is based on the New Improvement Techniques (NBT) and molecular improvement. In order to sustain these initiatives, it will be necessary to provide the country with data sequencing and analysis platforms in a representative amount. Installed capacity is currently substantially lower than that of other countries on the continent.

A similar situation has been observed in livestock biotechnology. Improving major breeds requires substantial support for sequencing techniques, particularly data analysis.

d. Marine resource development

Argentina has contact with ocean waters in the East, since it has an extensive maritime area with natural features that allow the existence of a diversity of fishing resources. The most important species, in terms of the volume of their catches, are hake, squid and shrimp. A considerable part is destined for export, representing an income of approximately $1,500 million USD a year. Per capita consumption is estimated at between seven and eight kilos per year, well below beef consumption.

In recent years, “Pampa Azul” has been launched, a strategic scientific research initiative in the Argentine Sea that includes exploration and conservation activities, technological innovation for productive sectors linked to the sea and scientific dissemination aimed at the public in general.

V. Increasing the efficiency of food systems

a. Technology applied to agricultural production

Technological and organizational changes in the value chains of major cereals and oilseeds, as well as the better international conditions recorded in the past two decades, resulted in significant increases in the productivity of these crops. Yields have steadily risen on the basis of technological packages involving high-yield seeds, agrochemicals, direct seeding, precision machinery for sowing and harvesting and better crop and product management throughout the value chain. Thus, the productivity of annual crops grew at much higher rates than livestock production, resulting in higher relative margins per hectare and contributing to the expansion of the area planted with grains and oilseeds.

Argentina is one of the leading countries in the use of these technological packages, with almost 23 million hectares dedicated to genetically modified soya, maize and cotton. Since the introduction of these technologies in the country began in 1996 with the adoption of glyphosate-tolerant soybeans, another 20 events have been approved: 15 for maize; three for cotton, and two for soybean. Thus, the area planted with these genetically modified crops amounts to 100% of the total in the case of soybeans, 86% of the total in the case of maize and 99% of the total in the case of cotton. The dynamics of the adoption of these technologies by Argentina is nearly unprecedented in the rest of the world. The similarity of agro-ecological conditions facilitated the transfer of new technologies.

b. Technological changes in agriculture

However, these technological packages are not used to the same extent by those engaged in agriculture. Since there are significant differences or gaps among the productivity levels of the various producers, it would therefore be possible to obtain significant productivity gains if these differences were eliminated. Moreover, there are technologies currently present in advanced countries that could be adopted for use in the country.

In the first case, it has been estimated that narrowing the current technological gaps would significantly increase productivity. **Table 2** shows the productivity gains by product type derived from narrowing the gap between High (HTL) and Low Technology Levels (LTL), on the one hand, and between HTL and Medium Technology Levels (MTL) on the other. Thus, for example, narrowing high and low technological gaps could result in 155% productivity increases in beef, 109% increases in sunflower and 100% in wheat, while closing the gap between high and medium technologies would, for example, result in productivity increases of 62% for beef, 36% for sunflower and 34% for sorghum.

At the same time, there are a number of technologies with advanced development that are expected to reach conditions for commercialization over the next decade, which could affect the evolution of the production and productivity of agriculture in Argentina. **Table 3** displays examples of these technologies.

Technological improvements, whether through narrowing the gaps among producers or incorporating new packages, are crucially dependent on the government policies that affect these decisions. These include the incentive to invest in these technologies, the existence of programs that facilitate technological diffusion and transfer and appropriate regulatory frameworks for these activities.

Other aspects that may influence the evolution of the perspectives of new technologies for agriculture are the regulatory framework related to biosafety and intellectual property issues. Biosafety regulations are very important when using genetically modified crops. Intellectual property issues are essentially related to the seed market. Although Argentina has an intellectual property protection system in place, the prevailing situation in the seed market is the presence of an illegal market that significantly reduces the capacity to protect innovations and to recover research and development investments.

VI. Health Considerations

a. Foodborne diseases

The human body is constantly exposed to toxic substances of different origins and subject to metabolic imbalances that affect its health, which can trigger acute or chronic diseases. One of the most significant health problems

Table 2. Productivity increases due to narrowing of technological gaps in % yield per hectare per year

Products	LTL-HTL Gap	MTL-HTL Gap
Barley	54%	21%
Beef	155%	62%
Cotton	50%	20%
Maize	70%	30%
Peanuts	80%	33%
Rice	60%	19%
Sorghum	66%	34%
Soybean	67%	21%
Sugar cane	44%	25%
Sunflower	109	36%
Wheat	100%	29%

Source: Trigo (2016)

Table 3: Examples of new biotecnologies

Products	Technologies
Maize	• Improved herbicide tolerance • Insect resistant and greater yield • Stress-tolerant (1st generation of drought tolerance)
Soybean	• Improved herbicide tolerance • Insect resistance • Greater yields • Greater oleic oil • Omega-3 enriched • Low in saturated fat
Rice	• Herbicide tolerance • Golden rice 1 (Beta-carotene enriched) • Golden rice 2 (Beta-carotene enriched)
Wheat	• Herbicide tolerance • Drought tolerance

Source: Trigo(2016).

worldwide is foodborne diseases, known in Spanish as ETA, which are caused by the consumption of food or water contaminated with microorganisms or parasites or by toxic substances produced by them. At present more than 250 ETA are known whose cause may be infectious or toxic. The most vulnerable groups to these diseases in Argentina are children under 5, the elderly and expectant mothers.

Argentina has a normative framework for the control and prevention of diseases and health problems associated with food, as well as a group of organizations responsible for this issue. The Argentine Food Code (CAA), in force throughout the national territory, is the technical regulation that establishes the hygienic-sanitary, bromatological- and commercial-identification provisions that must be complied with by establishments, natural or legal persons and products within its sphere. It therefore describes the conditions in which foods must reach the consumer so that they are safe. It consists of 22 chapters which include provisions referring to the general conditions of factories and food shops, food preservation and treatment, use of utensils, containers, containers and wrappers, specifications regarding different types of food and beverages, auxiliaries and additives, and food labeling and advertising standards.

The National Administration of Medicines, Food and Medical Technology (ANMAT) is a decentralized agency, under the Ministry of Health of the Nation, which contributes to the protection of human health, ensuring the effectiveness, safety and quality of medicines, food and medical devices. In the particular case of food, this is done through the National Food Institute (INAL), where INAL-ANMAT has a food surveillance system and can participate as extra-sector actors in the laboratory surveillance system run by the System National Health Surveillance of the Ministry of Health of the Nation. CONICET has recently implemented a Food Safety Network, whose overarching objective is to develop and analyze information related to food safety.

The safety of the food production chain varies considerably throughout Argentina: Large enterprises coexist with international quality management and certification systems, and small- and medium-sized enterprises that have begun to work with good manufacturing practices and hazard analysis and critical control points; and with artisanal and regional producers, fairs and markets with restricted access to these systems. It is therefore necessary to strengthen this branch of activity, within the framework of a federal system of effective, coordinated surveillance.

b. Overweight and obesity

Argentina, like the rest of Latin America and the world, faces another serious public health problem related to overweight and obesity. The latest world map on the prevalence of overweight, recently released by the World Health Organization (WHO), says that North America and Europe are the continents with the greatest problems of obesity. In South America, Argentina is among the countries with the highest proportion of overweight individuals, 63.9%, while the obese population accounts for 23.6% of the total. These figures are worrisome, given that within a decade obesity in Argentina increased by over 60% (the value corresponding to 2005 was 14.6%).

As in the rest of the world, the causes of overweight and obesity are changes in habits of the population, particularly those related to a marked increase in physical inactivity and a change in diet reflected in a growing intake of processed foods, fast foods and above all, sugary drinks, crackers and cookies. Moreover, Argentinians consume insufficient amounts of fruits and vegetables (about half the recommended amounts). One of the most vulnerable populations is children and adolescents: one in three adolescents between 13 and 15 years old is overweight or obese. According to WHO, Argentina has a high percentage of obesity in children under 5, with a prevalence rate of 7.3%. Obesity is a prevalent disease at all levels of income, making it a public health problem.

Undoubtedly, beyond what has been done to date, Argentina faces the challenge of reducing foodborne diseases and drastically modifying the population's eating habits to reduce the serious problem of overweight and obesity it faces. It is essential to obtain reliable statistics that will include all the country's social classes and regions and find new ways to educate the population about the influence of food on health and change, not only their eating habits, but also their lifestyle.

Since obesity is part of the metabolic syndrome and constitutes a risk factor, it is an indication of an individual's susceptibility to various noncommunicable diseases, particularly cardiovascular diseases, type 2 diabetes *mellitus*, sleep apnea, osteoarthritis, certain forms of cancer and dermatological and gastrointestinal diseases. According to official data, noncommunicable diseases account for just over 70% of deaths, particularly cardiovascular diseases (40.2%), followed by cancer. These diseases are also the main cause of potentially lost years of life and require the use of significant health resources.

In recent years, the population has become increasingly aware of the incidence of good nutrition in reducing chronic diseases. The production sector has accompanied this awareness through the introduction into the market of various functional foods, particularly in the dairy and bakery chain. However, legislation has not accompanied this process, since so far there has been no specific regulation regarding functional foods and possible function and health claims. In the scientific-technological sector, many working groups are engaged in the search for new foods and/or bioactive components and the study of the physiological bases that demonstrate their beneficial action for consumer health.

c. Incentives to change patterns of consumption and personalized nutrition

In order to encourage changes in consumption patterns, the state is promoting actions designed to directly affect companies in the food value chain as well as consumers. The Ministries of Health and Agroindustry of the Nation made an agreement with the Coordinator of Food Product Industries (COPAL) in order to promote a healthy, balanced diet. In particular, it will work to reduce critical nutrients in food production, such as fats, sugars and sodium. It will also encourage smaller portions in certain foods that are harmful in excess, especially for children. An important aspect to be addressed is the reduction per capita of beef consumption, an important component of the consumption pattern of Argentinians, which currently stands at 70 kilograms per inhabitant.

With regard to consumers, the aim is to work on education as a key success factor, therefore incorporating these issues into schools, as well as into the information provided to society in general, through food labels and responsible advertising practices. Specifically, in schools, the authorities have begun to promote the introduction of food and nutrition education into school curricula, in addition to regulating the incorporation of a supply of healthy food into shops and school cafeterias.

With a longer-term, more complex vision, it is important to point out the progress being made in other nations, which Argentina must achieve. Beyond the physiological effects of the components of the diet, the genetic base of each individual is fundamental. In more developed countries, significant progress has been made in linking genes to diseases and the effect of food components on the expression or silencing of these genes. The ultimate goal of these studies is to achieve personalized nutrition based on each individual's genetic load. Argentina is still a long way from being able to achieve this type of nutrition. A major challenge is for these developments to be available to the entire population rather than to just a select few.

VII. Policy considerations

a. Policies for a more efficient and environmentally sustainable agriculture

The Argentinian agricultural sector is traditionally competitive, particularly in certain products such as soybean, wheat and maize and their derivatives, as well as beef. Global demand for agricultural products is expanding for a number of reasons. These include increased food demand, mainly through the incorporation of part of the world's population into higher income segments, the use of plant sources for energy production and also their use through biotechnology, for example, in the production of industrial inputs and the food industry. This scenario generates good prospects for the country's productive activity while at the same time posing the challenge of joint work between the public and private sectors.

The country has replicated the global market structure, which has become more complex and concentrated in large players. This latter feature could encourage the achievement of a substantial technological leap, but it requires Argentina's insertion into agroindustrial value chains to prevent it from being relegated to the mere provision of raw materials or first-stage processing products, as is largely the case at present. A fundamental characteristic of this challenge is that it be achieved in a balanced way, in other words, through an equitable, environmentally sustainable income distribution process firmly rooted in the local economy, in order to create a spillover effect into other productive sectors.

To this end, traditional policies must be implemented that seek to improve profitability, family farms must be incorporated with a greater degree of market access, while transparency in price formation must be improved. A set of policies are also required to work on responsible, environmental sustainability for this activity, while scaling up value aggregation within the global value chain of biological origin.

The objectives of these policies focus on:

a. Encouraging sustainable development in order to promote the increase of agroindustrial supply to enable it to be directed to both the domestic and overseas markets. This increase must go hand in hand with an improvement in the standard of living of small producers. This requires the development of mechanisms to ensure the achievement of competitive, transparent prices, freedom to market, the facilitation and extension of access to credit, the increase in the supply of insurance against production losses, the effective dissemination of Associativism tools and their advantages and the adoption of good practices with the incorporation of the corresponding technology.
b. Improving competitiveness through the incorporation of technology and knowledge, tax promotion and the improvement of logistics and infrastructure.
c. Advancing international insertion through global value chains while advancing beyond its current stage of being a supplier of raw material and first-stage processing products. To this end, good agricultural practices are important, such as the consolidation of the formalization of certain tasks or productive links, as well as a suitable regulatory framework for international standards. All of this must be accompanied by a trade policy that improves Argentina's market access conditions.

i. Financing

In order to achieve these objectives, various types of policies must be developed. Expanding access to the financial system is crucial to the sustainability of agricultural production and the growth and modernization of the latter. This requires maintaining and improving existing lines of credit for investment and working capital, facilitating credit conditions, and implementing new lines, together with technological and environmental aspects, as well as joint activity by the producer rather than just the financing of a product. In order to promote access to credit, it is essential to change current regulations, and above all to encourage access by small producers and rural contractors. This should be complemented by the development of new financial instruments, such as making it easier for agribusiness companies to go public and reciprocal guarantee tools.

ii. Competitiveness

In terms of advancing the search for competitiveness, this involves not only maintaining a competitive exchange rate and limiting tax distortions on the final product, but also working on various aspects of the value chain, including infrastructure and logistics (transitability of roads, rail transport system, navigability and port system, energy works, works to contain floods, etc.), sanitary and phytosanitary aspects, more and better access to market information, reference markets for non-traditional products and minimizing concentrated groups' abuse of their dominant position, among other aspects. Some of these points are particularly significant for small producers and their sustainability and growth over time.

iii. Environmental legislation

In terms of environmental legislation, a law must be passed on Minimal Budgets for Environmental Land Management, drawing up a strategy for the use, handling and resolution of conflicts related to the soil and associated natural resources. It is also necessary to advance a Water Use Law in order to regulate the use of this resource in an environmentally friendly manner and reduce the underlying conflicts between provincial and municipal jurisdictions. A similar situation should occur with land use. In the latter case, it is necessary to draw up Phytosanitary Management and Application regulations that will provide a framework of safer applications, taking care of the environment. In forestry, it is necessary to work on the implementation of Native Forests Law No. 26,331 in various parts of the country, in order to facilitate its implementation, as well as to promote forest development, particularly in erosion-sensitive areas. Regulating the advance of the agricultural frontier and its planning is a priority task for environmental preservation.

iv. Research, innovation and development

Work is also required on the research, innovation and development component. The country must develop specific legislation in order to provide credit incentives and encourage risk capital investment for the development of new technologies. From an operational point of view, public research, innovation and development institutions should be able to provide modern legal instruments that provide agility, flexibility and autonomy in resource management to work in conjunction with other associations related to the value chain (public-private consortia and special-purpose entities), implement subsidies and tax incentives for the establishment and operation of technology parks and incentives for patent registrations. In order to speed up the incorporation of issues being dealt with in other parts of the world, which would facilitate environmentally responsible production with added value, it is essential to work to promote the internationalization of these institutions as a way of incorporating new knowledge and speeding up technology transfer.

One of the topics that require particular attention is strengthening advanced research (biotechnology, nanotechnology, earth sciences) in sustainable production systems, competitive biomass products and production models that combine high productivity with efficient resource use, while maintaining resistance to pests, diseases and climate change.

v. Energy Matrix

One of the technological aspects that can be developed is the agro-energy component. This gradual conversion of the energy matrix to renewable energy sources requires a policy that will prioritize clean energy production, as well as promoting the production of hydrated ethanol; linking the state's role to the announcement of public tenders for electricity, taking into account the environmental, electrical and economic attributes of the use of bioelectricity. Industry sources propose instituting a differential auctioning program by source and/or region as a key factor in enabling power generation from biomass.

vi. Food and human health

Another issue that must be worked on is agrifood protection. To this end, it is necessary to strengthen the economic and human resources of control agencies, to prepare and update them according to international standards and at the same time, to enable them to access small producers' markets. Effective access to up-to-date information, control procedures and the implementation of good practices are a key aspect of the process.

In order to progress steadily in all these points, it is essential to have human resources trained in both theoretical and management aspects. To this end, both the state and the private sector should allocate funds to the development and dissemination of technical and university degree programs, as well as to specializations in environmental issues and their application in various types of production.

From the point of view of the consumer, there are two aspects that must be achieved on a massive scale to raise awareness about environmental and health issues in terms of the responsibility associated with purchase decisions. The first of these is education, which requires incorporating information and debate from an early age. The daily application of responsible consumption at a young age should be massive and available to all socioeconomic levels. At the same time, the state can act by providing financial incentives for consumers who choose to consume responsibly. Civil associations are another alternative, which play an increasing important role in consumer awareness. The development of indicators by degree of corporate responsibility in environmental aspects and in terms of healthy products is an example of some initiatives by this type of association that end up influencing a larger sector of the population.

Last, it is necessary to promote the collection of statistical data of appropriate quality to be used as the basis for risk assessments, and to enable the state to promote a systematic survey of information on the country's nutritional and health status, and how they influence eating habits, through comprehensive consumer surveys of the population. It is also vital to promote the development of new foods with improved nutritional profiles and instill healthy lifestyles in the population for the various age groups and people who need special diets, to promote public policies that encourage the incorporation of new processing technologies, emerging technologies and incorporate new technologies (processing, nanotechnology, functional foods, etc.).

b. International trade, food security and global governance

World food production and consumption projections indicate that geographical divergence between production and consumption will increase. International trade will therefore become increasingly important as a mechanism for balancing needs and availability. In this respect, then, there is and will be a growing link between food security in many countries, particularly net food importers, and the trade policies of other countries, which are usually net food exporters.

In the context of the sharp rise in food prices, a proliferation of policies aimed at improving or preventing worsening food security was recorded in many countries in

2007-2008. Several of these policies were defensive and some had negative impacts on international trade, further damaging food security, particularly in net food importing countries.

Examples of these policies include domestic production support, export taxes and quantitative restrictions - including bans - on exports. Argentina was one of the countries that adopted some of these policies in order to decouple domestic prices from the rise in international food prices. Many of these measures were implemented within the framework of World Trade Organization (WTO) agreements as well as outside them.

This strong link between international trade and food security, and the experience of what happened during the 2007-2008 food crisis, point to the need to build institutional instruments that allow a certain degree of capacity for the global governance of food and nutritional security, thereby restoring confidence in international trade as an adequate food source. An agreement between net exporting and importing countries, with supply commitments and market access, could be one route toward a multilateral food security agreement.

VIII. Abstract

The agricultural sector is of vital importance to Argentina, not only because of its impact on the creation of domestic wealth, but also due to its key role as a net food exporting country. Despite its importance as a food producer, there are currently around 9 million people living in poverty, 1.7 million of whom lack food and nutrition security.

The country is a major producer of cereals, oilseeds, industrial crops, fruit and vegetables, beef and dairy products, as well as a significant global exporter of some of these products. The agricultural sector is currently undergoing a technological, organizational and productive paradigm shift, with the emergence of new economic actors, giving rise to a very different organizational model from the traditional one.

Although the country has a large national agricultural and agri-food research system, public and private investments are required to improve its infrastructure and equipment, and to reverse the low participation of the private sector in the financing of scientific and technological activities related to these issues.

Argentina has an abundance of water, coupled with good soil quality. However, pollution and climate change are affecting the availability of these resources. For its part, the energy matrix makes intensive use of non-renewable energy, although the country has many objective possibilities of developing alternative energy sources.

Technological and organizational changes in the value chains of major cereals and oilseeds have led to significant increases in the productivity of these crops. However, these technological packages are not used to the same extent by the actors in agricultural activity,

meaning that significant productivity gains could be achieved if these differences were reduced. Moreover, the country could adopt technologies that are present in more advanced countries, which would also boost productivity.

Thus, Argentina has every possibility of achieving a sustainable increase in food production, based on its high level of competitiveness and its wealth of natural and human resources. These possibilities must be consolidated through long-term state policies that promote investment and increased funding for innovation, research and development. A consensual strategy must be implemented for agricultural activity and food production that strikes a balance among economic, social and environmental sustainability.

These possibilities of the country imply that Argentina is in very good condition to collaborate with the global food and nutrition security goal

References

Anlló, G., R. Bisang y M. Campi (2013). *Claves para repensar el agro argentino.* Buenos Aires, EUDEBA.

Banco Mundial (2016). "Análisis Ambiental del País: Argentina", *Serie Informes Técnicos* N° 9, May 2016.

Bianchi, E., M. Piñeiro, M. Trucco and L. Uzquiza (2010). "Food Security Policies in Latin America", *Series on Trade and Food Security,* Policy Report 4, International Institute for Sustainable Development.

Geografía de la Argentina. CREDILIBRO, Ediciones Credimar, 1998.

González, Leandro M. (2015), "Proyecciones de la población argentina a lo largo del siglo XXI", *Notas de Población* N° 101, July-December 2015, Año XLII, pp. 37-58. Santiago, CEPAL, Nacional Unidas.

GPS (2015). *Objetivos y políticas para la agroindustria argentina 2015-2020.* Grupo de Países Productores del Sur, January 2015.

INDEC (2013). *Estimaciones y proyecciones de población 2010-2040: total del país.* Instituto Nacional de Estadísticas y Censos.

Interamerican Network of Academies of Sciencies (IANAS) & Foro Consultivo Científico y Tecnológico, AC (2012). *Diagnóstico del Agua en las Américas.* México, March 2012.

Ministerio de Ciencia, Tecnología e Innovación Productiva (2016). *Biotecnología argentina al año 2030: Llave estratégica para un modelo de desarrollo tecno-productivo.* Digital book, November 2016.

Ministerio de Planificación Federal (2011). *Plan Estratégico Territorial Avance II: Argentina Urbana. Lineamientos Estratégicos para una Política Nacional de Urbanización.* Ministerio de Planificación Federal, Inversión Pública y Servicios.

OIM (2012). "El Impacto de las Migraciones en Argentina", *Cuadernos Migratorios* N° 2, April 2012, Organización Internacional para las Migraciones, Oficina Regional para América del Sur.

Pascale Medina, C., M. Zubillaga and M. Taboada (Eds.). *Los suelos, la producción agropecuaria y el cambio climático: avances en la Argentina.* Ministerio de Agricultura Ganadería y Pesca.

Pellegrini, Pablo A. (2013). *Transgénicos: ciencia, agricultura y controversias en la Argentina.* Editorial Universidad Nacional de Quilmes, 1st edition.

Piñeiro, M., M. Myers and L. Uzquiza (2016). "Securing Global Food Supply: What Role for Latin American's Net Agricultural Exporters", The Dialogue and Group of Producing Countries from the Southern Cone (GPS).

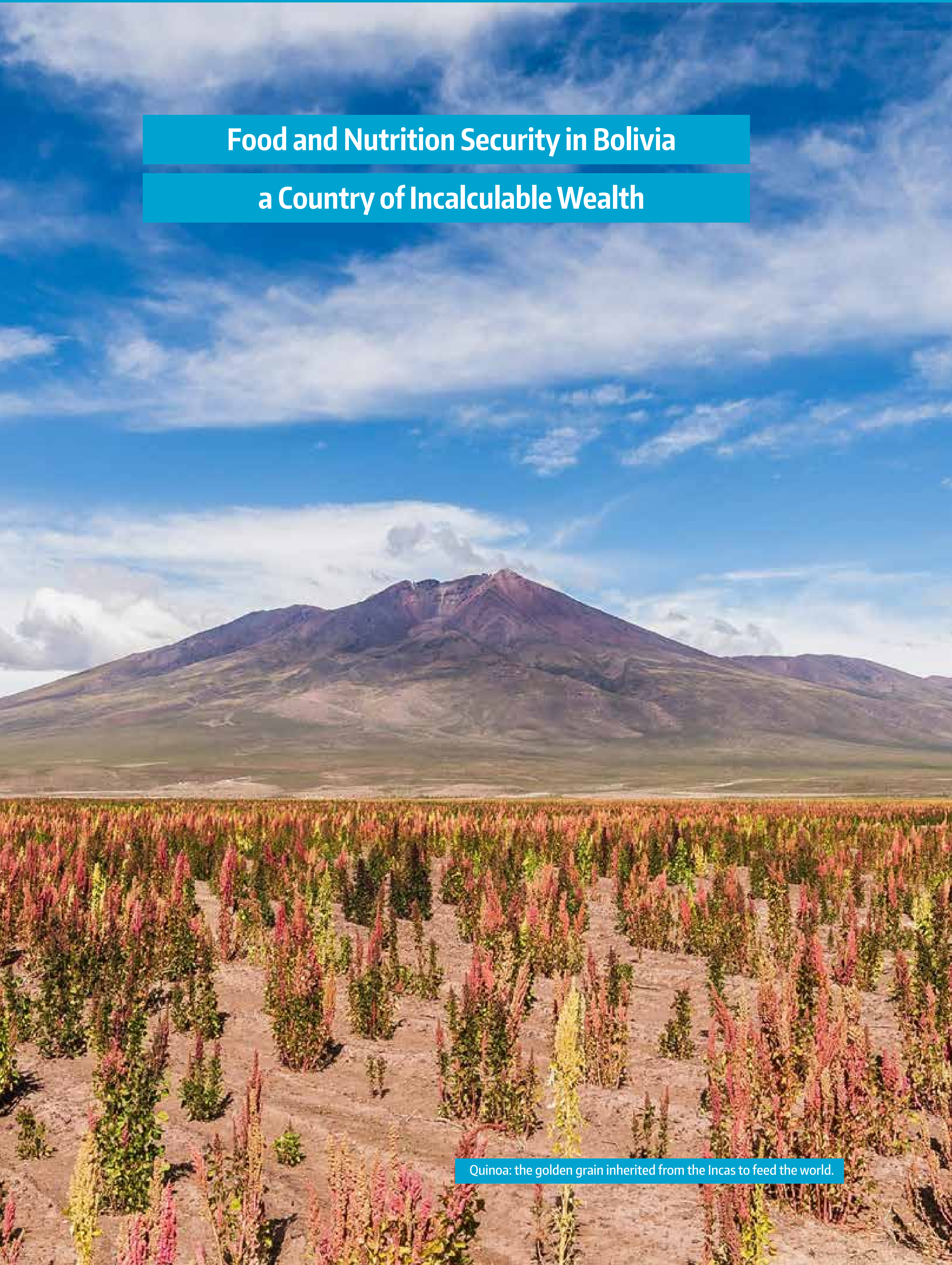
Propato, T. and S. Verón (2015). La matriz energética argentina y su impacto ambiental, *Revista Ciencia Hoy*, N° 144, July 2015.

Trigo, E. (2016). "Potential productivity increases in the Argentine agri-food production", Grupo de Países Productores del Sur (GPS), October 2016.

UCA (2016). "Tiempo de Balance: Deudas Sociales Pendientes al Final del Bicentenario", Observatorio de la Deuda Social Argentina (OSDA), Universidad Católica Argentina.

Food and Nutrition Security in Bolivia

a Country of Incalculable Wealth



Quinoa: the golden grain inherited from the Incas to feed the world.

Bolivia

[1] Einstein Tejada Vélez
[2] Marcelo Eduardo Arze García
[3] Mónica Moraes R.
[4] Franklin Bustillos Gálvez
[5] Daniela Raquel Larrazábal Vélez Ocampo
[6] Andrés Trepp del Carpio
[7] Lilibeth Leigue Arnéz
[8] Gonzalo Ávila Lara
[9] Jorge Blajos Kraljevic
[10] Carlos Arturo Mariscal Padilla
[11] Oscar Jesús Cabrera Coca
[12] Jaime Manuel Gutiérrez Guerra

Bolivia is blessed with enormous biological and biogeographic diversity, but **must invest in science, technology and innovation to mitigate climate change and to meet future food challenges**

Summary

Bolivia is a country with a wide range of incalculable wealth, reflected in the abundance and diversity of its natural resources, culture and traditions. The sharp contrasts in its territory and people show that this is a part of the world with an enormous amount of diversity. Bolivia is inhabited by populations which, despite this legacy, have undergone extremely difficult circumstances. As a result, they have developed skills and experiences to thrive and adapt to the adversity of extreme situations. This is especially evident in the rural setting, where for centuries small farmers have learned to subsist, produce and support their families despite the difficult conditions. However, this immense scenario which harbors extremely diverse and nutritious productive systems, and is capable of feeding not only its population but the whole of the Americas in a sustainable, environmentally-friendly way, is not being managed in a planned, technologically appropriate manner. The growth of ecological awareness is a crucial element for achieving the survival of species and productive ecosystems in Bolivia, where, because of the biological complexity, hundreds of species interact in small spaces. Priority actions for achieving agricultural sustainability cannot separate productive aspects from considerations that promote respect for the other ecosystem resources involved in its fields and species. Some potential scenarios for better agricultural production for the following decades are based on scientific research to create capacities to achieve the optimal use of new energy forms. The development of new land management models and rational resource use would make it possible to focus on climate change adaptation and mitigation strategies, boost production and ensure that less of what is already produced is lost.

Introduction

In an ideal situation, a population reaches its optimal state of food and nutrition security when it is supported by food sovereignty. This is understood as the right of peoples to control and decide their own agri-food and productive system, thus accessing healthy, nutritious, culturally adequate food, produced in a sustainable, ecological way. Conversely, data on the current state of food security in Bolivia show that the country is at risk, due to the levels of national food insecurity, exacerbated by inadequate nutrition that currently affects a quarter of the population.

Bolivia's inhabitants are a long way from controlling the agri-food system that characterizes national production, since not only does the political slogan "indigenous native or peasant family farming" lack agroecological orientation, but also the numerous laws enacted fail protect its food stability, or the environment where they live and produce food. Artisanal fishing and harvesting systems in several parts of the country continue to be based on inequitable processes that reduce their autonomy. The performance of food imports shows that in recent years, Bolivia has become increasingly dependent on a growing volume and variety of imported products.

Accordingly, the prices of various foodstuffs consumed by Bolivian households are increasingly reliant on the behavior of international markets. Thus, the human right to the permanent provision of healthy, nutritious, sufficient and culturally appropriate food is not guaranteed. The extreme parcelization of the ownership of the productive areas and the degradation of the land in the western part of the country, where most of the rural farmers are concentrated, together with the increasing migration to cities, are other variables that exacerbate the crisis of peasant production, which could gradually reduce its importance as a food producer. At the regional level, the country's tropical lowland regions have land suitable for agriculture that could play a more important role in the country's agricultural production, particularly regarding beef and dairy cattle and poultry production.

This document comprising various experts' views is not intended to provide a definitive opinion on the validity and scope of the concepts, but rather to constitute a space for analysis and discussion with the participation of governments and civil society. It could soon become the most significant issue for defining the prolongation and survival of the human species and other living beings. Bolivia certainly has potential and all it requires are attitudes, knowledge and practices which respect ancestral knowledge of the environment and are supported by the rigor of science and scientific research.

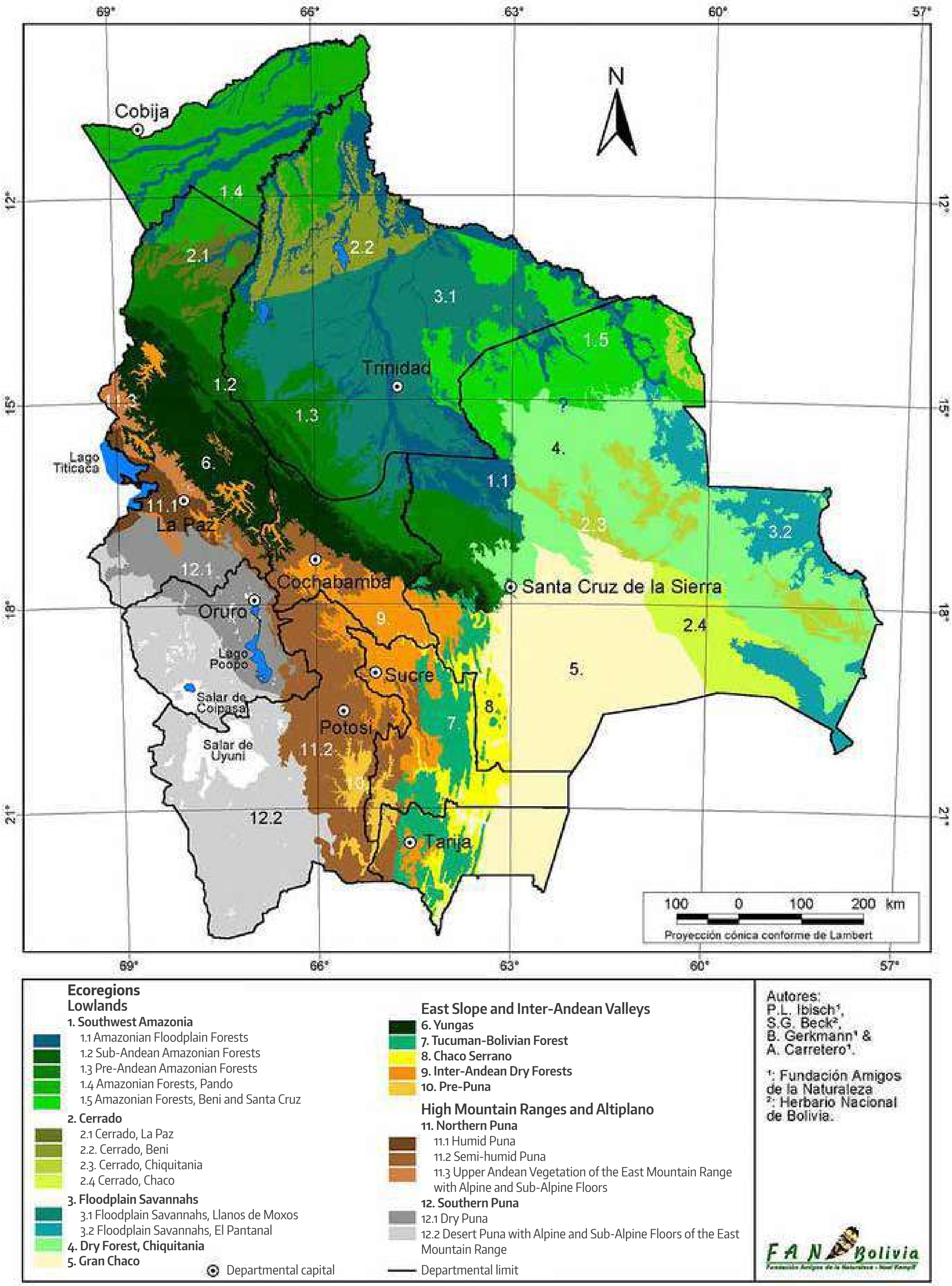
1. National characteristics

1.1. Area of the country, natural resources and environmental and landscape heterogeneity

Bolivia is currently a landlocked country bordering on the North with Brazil, the South with Argentina, the West with Peru, the SW with Paraguay and the SW with Chile. Bolivia has an area of 1,098,581 km^2, occupying 0.2% of the world's surface. Due to its altitudinal gradient, which ranges between 90 and 6,542 meters above sea level (masl), Bolivia is the country with eighth greatest biological wealth. It comprises five biomes, 23 ecological regions and 205 ecosystems. Although its forests account for just 3.5% of the world total, the country is home to 45-55% of the earth's biodiversity (http://bolivianing.com/bolivia). Bolivia is also one of the 10 most diverse countries with respect to vertebrates, with approximately 3,000 species. This mega-diverse geographic space contains one of the world's largest wildlife reserves, home to 422 mammal species (Bolivia has the largest

[1] **Einstein Tejada Vélez,** Full member, National Academy of Sciences of Bolivia, einsteintejada@yahoo.com
[2] **Marcelo Eduardo Arze García,** Executive Director of the Association of Footprints, Welfare and Nature, marcelo.arze@planetahuellas.org
[3] **Mónica Moraes R.,** Full member, National Academy of Sciences of Bolivia and Universidad Mayor de San Andrés, monicamoraes45@gmail.com
[4] **Franklin Bustillos Gálvez,** Full member, National Academy of Sciences of Bolivia, bustillosfrank@yahoo.com
[5] **Daniela Raquel Larrazábal Vélez Ocampo,** MA in Economic Law, dani.larrazabal.v.o@gmail.com
[6] **Andrés Trepp del Carpio,** Full member, National Academy of Sciences of Bolivia, treppcen@entelnet.bo
[7] **Lilibeth Leigue Arnéz,** Former President of the College of Agricultural Engineers of Bolivia. lleigue@gmail.com
[8] **Gonzalo Ávila Lara,** President of the Foundation Universitaria Simón I. Patiño, g.avila@fundacionpatino.org
[9] **Jorge Blajos Kraljevic,** General Manager of PROINPA Foundation, j.blajos@proinpa.org
[10] **Carlos Arturo Mariscal Padilla,** Professor and Former Dean, Facultad de Ciencias Pecuarias Universidad Autónoma del Beni, arturomariscal@uabjb.edu.bo
[11] **Oscar Jesús Cabrera Coca,** Deputy Minister of Civil Defense of Bolivia. oscarcabrerac@hotmail.com
[12] **Jaime Manuel Gutiérrez Guerra,** Agronomist Ingineer expert on Environmental Evaluation, jgutierrez_guerra@hotmail.com

Figure 1. Ecological map of the regions of Bolivia (Ibisch et al. 2003)



population of jaguars and tapirs worldwide), 344 reptile species, 642 fish species, 378 amphibian species and more than 1,450 bird species (http://labiodiversidadenbolivia.com).

More than 17% of the Bolivian territory comprises protected areas and natural parks. The enormous contrast among regions is partly due to the Andes, which in Bolivia is divided into two mountain ranges: West and East. In addition to this natural wealth, the country possesses genetic resources, because of its domestication of species useful for food, medicine, industry and other applications. Bolivia is an immensely diverse country, because it has over 20,000 plant species, 134 of which are timber species and over 3,500 of which are botanical species for medicinal use (http://www.bolivianland.net/).

1.2. Ecoregions and environment, areas

In Bolivia, the various ecoregions, home to enormous biological diversity, are the result of major biogeographic influences in the Andes, the Amazon, the Valleys and the Gran Chaco, regarding both anthropological aspects (Moraes & Beck, 1992; Navarro, 2002), and the forms of agricultural production, which in many ways are also affected by climate change (Tejada, 2011). Based on man's age-old interaction with the environment, intense adaptation mechanisms were produced, creating heterogeneous, traditional and semi-natural anthropic landscapes in the extensive plains of the Beni, the mountainous areas of the Yungas of La Paz and the inter-Andean valleys on the East side of the Cordillera (Navarro, 2002). Several patterns of overuse and uncontrolled colonization affected the long-term productive potential in large areas (such as the high Andean zones of the eastern Cordillera and the lowlands of northern Chaco), which showed signs of degradation and potential transformation as a direct effect of the permanent pressure on resources (Killeen et al., 2005; 2008).

The five enormous biomes of this country are subdivided into 23 mostly agroproductive ecoregions (see **Table 1** and **Figure 1**). These areas include the Altiplano and Las Punas, comprising a large array of mountain ranges, plains and mountains located above 3,500 m with an area of 254,392 km² equivalent to 23.2% of the country's total area. The valleys cover an area of 160,162 km², 14.6% of the area of Bolivia, including the Yungas and mountainous headwaters. The alluvial plains (in the Amazon and Chaco region) have an area of 684,007 km², comprising 62.2% of national territory.

1.3. Productive Territory and Agricultural Capacity

The 2013 Agricultural Census registered 34,970,168 hectares (ha), equivalent to 32.4% of the total area (109,858,100 ha), which contribute to the country's food security and sovereignty. Arable land comprises 7,837,864 ha, 2,763,239 ha of which are planted in summer. This is followed by 2,349,062 ha of cultivated pastures; 1,635,898 ha of resting land and 1,089,665 ha of fallow land; 27,132,304 ha are non-agricultural land. Of this total, forests or mountains account for 13,775,113 ha, natural pastures 11,053,246 ha, other lands 2,153,726 ha and forest plantations 150,219 ha.

As for the main crop groups planted during the 2013 summer season, 43.4% of the area was cultivated with oilseeds and industrial crops (999,369 ha with soybean and the rest with sunflower, sugar cane and peanuts). A total of 31.9% of the area was used for cereal cultivation (390,668 ha with maize, and the remainder with grain sorghum, paddy rice, quinoa and wheat). Tubers and roots were planted on 7.5% of the area (170,447 ha with potato), vegetables on 3.9%, fruit trees on 5.8%, fodder on 6.1% and stimulants on 1.4% (http://www.paginasiete.bo/economia). Bolivia has 872,676 Agricultural Productive Units (UPA), 28.1% of which are located in the Department of La Paz, 20.8% in Cochabamba and 14.2% in Potosí (http://www.ine.gob.bo/pdf/boletin/).

1.4 Main constraints on National Agricultural Productivity

1.4.1 Low availability of irrigation

Only 7.1% of the area-under-cultivation in Bolivia has irrigation systems. Most agriculture remains rainfed, in other words, various crops

Table 1. Bolivia: Eco-regions, altitude, area and land use

Ecological Region	Altitude / Area	Land use
1. Amazonian Flood Forests in Beni, Cochabamba, La Paz, Pando and Santa Cruz: Amazonian forest plain, basins of the Precambrian Shield. In strips and watersheds of very variable size along the rivers.	100-500 m 63,588 km²	Use of wood, growing colonization, use of rubber and wild fruits. Large rivers are the main access roads in the Amazon.
2. Sub-Andean Amazon Forests of Santa Cruz: Sub-Andean zones north of the Andes elbow in Bolivia.	500-1,000 m 23,529 km²	Increased colonization, extraction of wood. Important hydrocarbon zone.
3. Pre-Andean Amazon Forests in Beni and Pando: 100 km from the last Andean foothills.	150-500 m 58,308 km²	Areas of colonization; Small-scale agriculture of large-scale, mechanized (especially Chapare, Cochabamba, and Sara and Ichilo, Santa Cruz) small-scale farmers from the west of the country, many secondary forests. Forest utilization, important oil zone.
4. Amazonian forests of Pando, Beni and La Paz: Amazon plain: in the west slightly waved, towards the east plane with outcrops of the precambrian shield.	100-300 m 71,217 km²	Use of wood, increasing colonization and thus agriculture. Large regions traditionally exploited by non-timber forest resources: rubber and chestnut. Extensive forest area, danger of deforestation (see neighboring side of Acre)
5. Amazonian forests of Beni and Santa Cruz: Plains, Precambrian penillanura.	150-400 m 59,905 km²	Use of timber, colonization and growing agriculture, until mechanized soybean and sunflower farming. Eucalyptus plantations.
6. Cerrado from La Paz: Plains of varying heights and shallows, of acid soils, affected by rainfall and floods, above all, by overflowing rivers of clear water.	180-500 to 1,000-2,000 m 9,837 km²	Very little livestock. Constant extensive agriculture of soybean and sunflower.
7. Cerrado from Beni and Pando: Flat and undulating savannas with differences of level to more than 20 m in the north, termiters floods by rainfall; Strongly weathered, nutrient poor soils, lateritic layers with pisolites	100-200 m 27,171 km²	Little livestock.
8. Chiquitano Cerrado of Santa Cruz: Plains, landscapes of hills and slabs (inselbergs).	120-1,000 m 23,491 km²	Cattle. High frequency of anthropogenic fires favor the expansion of Cerrado Fields at the cost of forests.
9. Chacoan Cerrado of Santa Cruz: Plain with few hills and small hills.	170-1,100 m 24,468 km²	Extense livestock farming. High frequency of anthropogenic fires.
10. Flood savannahs of the Llanos de Moxos in Beni, Cochabamba and santa Cruz: Grasses dominated by grasses and Cyperaceae; Aquatic and marsh plants (yomomo, curichi); Different types of forest islands, open forests (tajibales), palm forests and thorny low (tusecales). Gallery forests along the rivers.	100-200 m 94,660 km²	Livestock, tourism. Historical impact on the ecosystems by the pre-Columbian cultures of Moxos (Mojos) establishing embankments, ridges, channels and dikes.
11. Wetlands of the Pantanal in Santa Cruz: Especially plains with extensive areas of flood and large lagoons by the Paraguay River. Alluvial soils.	100-800 m 33,328 km²	Livestock, tourism.
12. Chiquitano Dry Forest in Santa Cruz: Plains, hills, slabs (inselbergs - Precambrian Shield).	100-1,400 m 101,769 km²	Industrialized agriculture, large-scale livestock farming, logging, mining, transportation of petroleum products (gas pipelines).
13. Gran Chaco in Santa Cruz: Tarija and Chuquisaca: Plain with few hills and small hills.	200-600 m 105,006 km²	Livestock, extraction of wood, firewood, charcoal, oil exploitation.
14. Yungas in Santa Cruz, La Paz and Cochabamba: A region of almost perennial Andean forests on the northeastern slope of the Andes. Partially very steep northeastern wetlands of the Bolivian (and Peruvian) Andes. Dissected valleys.	1.000-4,200 m 55,556 km²	Agriculture (locoto, coffee, coca, citrus, in the timberline especially potato, use of firewood, grazing, increasing colonization.

Table 1. Bolivia: Eco-regions, altitude, area and land use

Ecological Region	Altitude / Area	Land use
15. Tucuman-Bolivian Forest: in Santa Cruz: Tarija and Chuquisaca. Due to thermal and water seasonality (and lower minimum temperatures), they are clearly distinguished from the moist montane forests north of the Elbow of the Andes, which in this work are considered as the Yungas (Bolivian-Peruvian).	800-3,900 m 29,386 km^2	Use of wood, agricultural activity and increasing grazing.
16. Chaco Serrano in Santa Cruz: Tarija and Chuquisaca: Low mountain ranges of the last foothills of the Eastern Cordillera of the Andes, low valleys, foothills.	700-2,000 m 23,176 km^2	Agriculture, livestock, oil exploitation.
17. Dry Inter-Andean Forests in Cochabamba, Tarija, La Paz, Potosi and Chuquisaca: Large variation of deciduous plant formations ranging from dry forests in the Yungas region to the extensive valleys in the central and southern parts of the country. Valleys more or less dissected, small plains.	500-3,300 m 44,805 km^2	Agriculture, livestock, use of firewood / wood; Severe soil erosion problems. Small areas and mostly heavily disturbed in the most unspoilt forests virtually unprotected.
18. Prepuna in Tarija, Potosi and Chuquisaca: Semi-desert of valleys more or less wide to dissected, small plains.	2,300-3,400 m 8,516 km^2	Livestock (especially sheep and goats), some agriculture, severe soil erosion problems.
19. Wet Puna in La Paz: Natural potential vegetation is evergreen forest (dominated by *Polylepis* species) and is now found in less populated areas. Phytogeographically it is a region that shows affinities with the high Andean vegetation of the north of the Andes. Plain with hills around and to the south of Titicaca Lake, standing on the slopes of the Cordillera Real.	3,800-4,100 m 8,869 km^2	Area of cultivation, ridges, livestock of sheep and cattle. Exploitation of minerals; tourism.
20. Semihumid Puna in Cochabamba, Tarija, La Paz, Potosi, Oruro and Chuquisaca: Low mountains, high plateaus, valleys. Andean forests almost completely destroyed.	3,200-4,200 m 67,600 km^2	Livestock area of sheep and cattle, casually crops. Exploitation of minerals; tourism.
21. High Andean Vegetation of the Eastern Cordillera with Nival and Subnival Floors in La Paz and Cochabamba: Glacial valleys with lagoons, slopes, peaks, rocky peaks.	4,000-5,100 m 8,137 km^2	Livestock of sheep and camelids, few cattle. Tourism. Exploitation of minerals; Problems of soil erosion.
22. Dry Puna in La Paz, Oruro and Cochabamba: High aridity, which may inhibit the development of extensive forest vegetation on its lower floors (there are only groves or chaparral areas in small areas with *Polylepis tarapacana* and *P. tomentella*). Low mountains, high altiplanic plateaus, wide valleys of the Desaguadero River.	3,500-4,100 m 35,973 km^2	Livestock area of sheep and camelids. Locally grown quinoa (Chenopodium quinoa) and cañahua (Ch. pallidicaule).
23. Desert Puna with Nival and Subnival Floors of the Western Cordillera in La Paz, Oruro, and Potosi: It borders the Atacama Desert. Poor vegetation cover due to low rainfall and low temperatures is characteristic; There are only biotic elements present in one floor (*Nototriche turritella* in the Western Cordillera). hills/volcanos, extensive plains highlands, valleys with little vegetation, dunes, salares.	3,800-7,000 m 100,204 km^2	Livestock area of camelids, sheep and few cattle. Exploitation of minerals and halogens; tourism.

Source: Adapted from Ibisch et al., 2003 are entirely dependent on rainfall. This limitation is exacerbated by climate change, expressed in different ways, such as the extreme drought experienced during this agricultural management period (2016-2017). Thus, 286,536 Agricultural Production Units, APU, equivalent to 32.9% of the total UPA registered in the country, cultivated 268,844 ha using various irrigation methods (INE, 2016). According to the Rural and Agrarian Problems Unit (UPRA), created by the Center for Studies on Labor and Agrarian Development (CEDLA), this "partly explains the low productivity of the country's agriculture, as well as the scarcity of several agricultural products at certain times of the year, a situation that requires their massive importation on a temporary basis (http://www.elpaisonline.com).

1.4.2 Low public investment in water and agriculture

The amount of public investment allocated to the agricultural sector and water resources is steadily declining. According to data presented by the Jubilee Foundation, based on the 2016 General State Budget (GSB), the budget allocated to the agricultural sector in 2015 was $447 million USD, which fell to $354 million USD in 2016, a reduction of 21%. By 2017, the GSB presented by the Ministry of Economy and Public Finance once again reduced the budget for the agricultural sector, from $354 million USD for 2016 to $197 million USD, equivalent to a 44% decrease. The water sector was assigned a budget of $70 million USD in 2015, which was cut by 21% in 2016, as a result of which this sector was allocated $55 million USD this year. According to the MEFP presentation, the 2017 budget for water resources will be $24 million USD, which means another cut for this sector, now totaling over 56%. The irony is that all this is taking place within a context of severe drought, in which only 7% of the area under cultivation in Bolivia has irrigation systems (HYPERLINK http://www.elpaisonline.com).

1.4.3 Unequal characteristics of irrigation in Bolivia

Most of the farms that use irrigation are located in the regions of the valleys and the Altiplano (94%), concentrating 68.1% of the total area under irrigation (in other words, of the 7.1% mentioned earlier). Due to the importance of APU with irrigation in the valleys and Highland regions and the low level of irrigation in the plains, the average number of hectares cultivated with irrigation is extremely low (0.93 ha/productive unit). Last, UPRA points out that "eleven crops concentrate 71.3% of the total area under irrigation in the country" which are, in order of importance: maize, potato, alfalfa, soy, rice, green bean, onion, peach, wheat, barley grain, and sugar cane, among others (http://www.elpaisonline.com/).

1.5. Demographic Characteristics and Future Trends, Cultural Food Anthropology and Health Considerations

1.5.1. Demographic characteristics

Bolivia's estimated population in June 2015 was 10,825,000 inhabitants (www.ine.gob.bo/pdf/boletin/NP-2015-64-pdf). However, between the 2001 and 2012 Censuses, the population growth rate slowed to just 1.71% per year, compared with 2.05% (1950-1976), 2.11% (1976-1992) and 2.74% (1992-2001), regarded as some of the highest in South America. This sharp decrease is due to a demographic dynamic characterized by:

a. A declining fertility rate, in which average parity fell from 6.7 in 1960 to 3 per woman ages 15 to 49 in 2015 (La Razón, 2013). By 2025, a rate of just 2.5 children per woman is projected, a decline attributed to greater awareness of responsible procreation;
b. The high mortality rate, particularly in the early years of life (0 to 5 years) and from the age of 65 onward, attributed to precarious health conditions and services, exacerbated by the incidence of undernourishment, malnutrition and unsanitary conditions;
c. Growing external migration. The period between the 2001 and 2012 censuses saw the departure of "562,461 Bolivians" (www.ine.gob.bo/pdf/boletin/NP-2015-64-pdf) largely attributed to the lack of opportunities and work in the country;
d. Low population density, since there are only 9.13 inhabitants per km² (2012 Census),

making it the country with the lowest density in South America;

e. Unequal population distribution that concentrates 71% (2015) in just three Departments (La Paz, Santa Cruz and Cochabamba), and
f. Poverty situation. According to FAO, based on data from the National Institute of Statistics (INE), in 2011, "44.95% of the Bolivian population was living in poverty; while 20.87% were living in extreme poverty" (www.fao.org/bolivia).

1.5.2 Future demographic trends

The Bolivian population will show the following trends in the future: declining population growth; decrease in the child and adolescent population (ages 0 to 19); predominance of the adult population (ages 20 to 59) and increase in the elderly population (60 years and over). According to INE (www.ine.gob.bo/pdf), life expectancy in 2015 was 71.3 (68.1 for males and 74.6 for females), and by 2025, it is expected to rise to 76.1. Urban concentration will increase following severe depopulation of the countryside: in 1950, Bolivia was predominantly rural (65%). By 2015, it had become mainly urban (69.1%) and by 2030, it is projected to be 75.2% urban and only 18.8%, rural, which is unthinkable and must be reversed (www.cepal.org/es). Future projection, according to INE, indicates that between 2000 and 2020, the population will increase as follows, by ecoregion: just 36.88% in the Altiplano 71.52% in the Valleys and 108.46% in the Plains.

1.5.3 Cultural anthropology, food habits and productive patterns

What is now Bolivia once comprised essentially agricultural and hydraulic cultures and civilization. However, since the Colonial period, there has been a predominance of extractive, export-oriented primary culture and economy, which prioritized the exploitation of minerals and, more recently, hydrocarbons (natural gas). Although this material and immaterial culture marginalized agriculture, it survived, and agriculture (animal, vegetable and forestry) and agribusiness now flourish in the eastern and southern Regions. In the western and Central Region (Altiplano, Valleys and Yungas), food production is traditional, empirical, single-family and small-scale; with low productivity, and profitability, and unable to fully satisfy their dietary needs. As a result, peasant contingents have not only stopped producing food, but have also migrated to the cities and abroad.

Although Bolivian food habits were traditionally based on natural, nutritious products, they have recently lost ground to foreign fast foods (junk food) and ultra-processed products. The World Health Organization (WHO) in Bolivia stated: "Ultra-processed products are replacing the traditional Bolivian diet. These are foods with little or no nutritional value, almost without natural elements with "a key role being played by advertising, including that targeting children"(*La Razón*, 2015).

1.5.4 Major Food-related Health Disorders

Particularly in cities, "Nutritional disorder remains one of the main factors that trigger preventable diseases" such as gastrointestinal and cardiovascular diseases, diabetes and obesity. In this regard, WHO warns that, "The prevalence of certain illnesses has increased as a result of poor eating habits, which even affect children: Santa Cruz presents the highest rates of diabetes with 300,000 people (15%) and about 400,000 children suffering from diabetes in Bolivia, according to data from the Ministry of Health in 2012 (http://www.eldeber.com.bo).

Undernourishment, malnutrition and eating disorders are largely the result of lack of education, guidance, information and knowledge, as well as the prevailing influence of certain uses, customs and traditions of the local and regional food culture. In the West, the consumption of potatoes and noodles prevails, whereas in the plains, cassava and rice are the main starchy foodstuffs consumed (http://www.eldeber.com.bo).

In the countryside, in order to supplement their meager diet, peasants travel to cities to buy food. And in the subtropical Yungas region, they have stopped producing their food and fruits and turned to coca production for market reasons, and, ironically, import food and fruit. A proportion of the peasant, mining, labor and periurban population chews coca as a supplement and palliative food.

As a result, food and nutrition security and food sovereignty should be treated as a "state matter", since it is unconscionable that Bolivia, with its small population and immense territory capable of producing all types of food, should be considered vulnerable and dependent experience chronic food insecurity.

1.5.5 Higher exports and imports of foodstuffs

According to INE (2017), from 2010 to 2015, Bolivia's main food exports were: soybean, soybean by-products, quinoa and Brazil nuts. In the case of soybean and its by-products, in 2014, a total of $992,774,000 USD was reached. By 2015, this had fallen to $201,554,000 USD, a reduction of 20.3%. Quinoa exports have grown spectacularly, from $46,648,000 USD in 2010 to $63,446,000 USD in 2011, $79,916,000 USD in 2012; $153,259,000 USD in 2013 and $196,637,000 USD in 2014, as a result of the declaration of the International Year of Quinoa, promoted by the UN. However, in 2015, exports declined due to multiple adverse factors involving politics and international price competition, totaling $107,706,000 USD or 54.8% less than the previous year. As a result, Peru, prioritizing the mass production of conventional non-organic and therefore cheaper quinoa, surpassed Bolivia's export volumes by up to 10.75%.

At the same time, Brazil nuts experienced significant growth from $103,713,000 USD in 2010 to $192,027,000 USD in 2015, equivalent to an 85% increase (INE, 2017).

Nevertheless, the country's main exports are not food products. According to information from INE (2017), 80% of Bolivia's exports are currently concentrated in gas and minerals, while the remaining 20% are non-traditional exports. Between 2010 and 2015, food imports in Bolivia accounted for $3,218 million USD and, according to the Bolivian Institute of Foreign Trade (IBCE, 2017), peaked in 2014. In September 2016, a total of 458 products were imported. The main items were wheat flour for $65 million USD, representing 36% of the total imported volume; wheat grain, totaling $11 million USD, accounting for 9%; unroasted malt, totaling $22 million USD, representing 6%; potatoes or yams totaling 1 million, which represents 6%, and fresh apples for the sum of $12 million USD, which represents 5% (IBCE, 2017). The main food suppliers to Bolivia from January in the third quarter of 2016 were Argentina with $156 million USD, followed by Chile with $67 million USD, followed by Brazil with $50 million USD, Peru with $44 million USD and the U.S. with $39 million USD (IBCE, 2017).

2. The Energy Challenge in Food and Nutrition Security

Food and nutrition insecurity is an issue that encompasses a multitude of aspects and disciplines such as demography, population and poverty indices, agroeconomics and the economy of food production. Accordingly, it should not simply be treated in a *multidisciplinary* way, whereby various disciplines traditionally intervene without being fully integrated, collaborating independently in a common project, or in an *interdisciplinary* way, in which different disciplines participate, achieving a certain degree of integration involving the procedures, techniques and practices of each one of them. The problem must be addressed using a *transdisciplinary* approach, which seeks to achieve greater integration, both theoretical and practical and conceptually link its orientations, postulates, practices, analyses and methodologies, in order to create a new, more realistic cognitive map of the issue. It is necessary to have trans-specialized knowledge (http://prof.usb.ve/miguelm), which is a promising way to plan and organize the food and nutrition security of a country such as Bolivia.

The concept of transdisciplinarity points out, for example that the "*food and nutrition security*" variable of a society can be conceived of as a '*characteristic essence*' analogous to energy, in the sense that it can only change its form, degrade to a lower quality or terminal condition, or grow or improve under certain conditions. This causality can therefore be handled through the concepts of laws extended from classic thermodynamics to the thermodynamics of organizational systems, and the logical principles of classical science extrapolated to this science (Trepp, 2017). One of these important flows is energy, which is presented in two different currents in the issue of food and nutrition security. The first has to do with the food intake and nutrition required to maintain biological life. This defines the food power required per person (kcal/day) that must be guaranteed, which in turn defines the second energy stream required, which refers to what is required for food production and must meet minimal conditions of quality, safety, nutrition, economy, competitiveness and efficiency.

From the technical point of view, in agriculture, energy needs and consumption for production depend on the technologies and materials used in the various phases and processes that take place. Likewise, in livestock technical activity, energy requirements and use are conditioned by breeding practices and technologies, and the management and care of the various livestock species used for food. Livestock in turn requires food and nutrition security for these animals, which involves the agricultural production of fodder and other plants for these purposes.

Thus, food security constitutes a specific aspect of the energy planning of a country's rural productive sector, which in turn is part of rural development planning in general. Agricultural energy planning studies the energy requirements for the production of agricultural goods -particularly of food- according to the application of various technologies determined by natural and social ecological factors, as well as cultural and economic agents that condition producers' work and activities.

The organization of food and nutrition security is therefore based on the energy planning of the rural productive sector, which begins with an energy analysis of the production of goods and foodstuffs, regardless of the planning methodology used. The energy analysis in this case consists, broadly, of the determination of energy consumption during food production in a baseline situation, in order to draw up the goals to be pursued and the scenarios to be reached within a specific time frame. Energy consumption by product is determined by "measuring" consumption by time, uses and quantities, according to the different technologies, methods and production tasks applied in the various biogeographic production zones that determine the corresponding energy-consumption patterns.

Energy analysis should be performed as a function of two groups of explanatory variables that make it possible to accurately interpret energy uses: socioeconomic and sociocultural. The first group includes energy infrastructures – boosted by the growing interest of the current government in turning Bolivia into the energy center of Latin America, through the construction of several anti-ecological dams in various parts of the country - and communications infrastructure, including the type of production units, land tenure and importance of the product. The second group considers social organization, instrumental and organic worldviews, physical-natural space management, ecosystem management, technological and energetic rationalities, and sociocultural and socioeconomic human groups (Gallo, 1989).

Energy analysis and planning of food production in the rural productive sector should incorporate a variable that considers the effects of climate change and global warming in order to mitigate their consequences on food security. In this regard, it should be remembered that the Andean civilizations prepared for the food insecurity that could be caused by climatic and meteorological factors by drying agricultural products (especially tubers), which could be safely preserved for about 15 years without losing their properties (http://agroingeniero.blogspot.com). Given the meteorological and climatic hazards that threaten rural production in the future, it would be feasible to adopt similar measures to these ancestral practices of storage and food preservation.

To ensure food security, food production must solve the chronic problems affecting it.

These include mitigating and controlling the limitations of the seasonal practice of rainfed agriculture, which obviously requires the introduction of irrigation. It is also vital to reduce seasonally occurring livestock losses due to extreme drought or floods spanning large tracts of grazing fields.

Greater political stability is required, particularly with respect to the design and support of policies and plans to ensure the consistency, durability and continuity of water supply and control on the one hand and the supply of commercial energy on the other or, failing that, the renewable use of locally available energy sources.

Last, future prospects for food security in the national context are linked to the recovery of food autonomy, since a large part of the agricultural food items and products in Bolivia comes from other countries and enters the country illegally. As long as these circumstances persist, it is pointless to invest intellectual and material efforts in the field of energy planning to ensure food and nutrition security.

3. National Status of Agricultural Research

3.1 Institutional Adjustments, Scientific Research in favor of Food and Nutrition Security, Universities

In the academic field, in 2013, the Vice Ministry of Science and Technology of the Ministry of Education presented the National Plan for Science, Technology and Innovation (PNCTI). In Bolivia, science, technology and innovation are produced by several types of providers: NGO, consultancies, government projects and programs, and public and private research institutions. Accordingly, the PNCTI was developed in a participatory process with significant participation by academia, including public and private universities and research centers, the central government and the productive sector.

The main normative framework for drawing up the PNCTI was based on the following documents: the New Political Constitution of the State, Article 103 of which guarantees the state's commitment to the development of science and scientific, technical and technological research for the benefit of the general interest, allocating the necessary resources and creating the State System of Science and Technology; the Patriotic Agenda to 2025. This Agenda establishes 13 pillars of development, Pillar 4 being Scientific and Technological Sovereignty with Its Own Identity and Pillar 8 being Food Sovereignty Through the Construction of Knowing How to Eat to Live Well; the Institutional Strategic Plan (ISP) of the Ministry of Rural Development and Lands, which establishes in its political mandate the formulation, execution and evaluation of policies related to the country's food security and sovereignty, as well as food safety; and the Avellino Siñani-Elizardo Pérez Law, which establishes, among the aims of education, the promotion of scientific and technological research associated with innovation and knowledge production as the guiding principle for alleviating poverty, social exclusion and environmental degradation, in keeping with the Law of the Productive and Community Revolution, which establishes, "Systems of research, technological innovation and timely information".

The impact achieved by PNCTI in the agricultural sector has been to emphasize the improvement of the scientific infrastructure and basic technology, with researchers and research centers or institutes in the public universities of the country's nine departments. Nevertheless, it is still illusory to think that this good intention has already been fully achieved in all possible institutional spheres. This potential is designed to be extended to several private universities and the National Institute of Agricultural and Forestry Innovation (INIAF), although it has not been fully operationally developed either. In this respect, the national axis (La Paz, Cochabamba and Santa Cruz) has more research centers and a more diversified potential, even though it fails to meet the demand of the sector's small producers. One high-level objective is to contribute food security to food sovereignty by creating Technology and Innovation Centers to improve the productivity and competitiveness of the sector. To date, this is nothing more than a good intention that has failed to be achieved at the National level, much less in regions remote from major capital cities.

Although this Plan is designed to achieve the objectives set in government policies, in relation to security and food sovereignty, the Executive Committee of the Bolivian University (CEUB), in its capacity as Programming, Coordination and Execution Organization, has drawn up its own National University Science, Technology and Innovation Strategy. This strategy places greater importance on the issue than the government does, precisely as a result of the comparative advantages of being able to bring together the best trained professional technicians in the national context, whose level contrasts sharply with that of state institution employees.

This is the case of the University of San Simón (UMSS), for example, whose broad range of academic subjects establishes thematic priorities within key socioeconomic objectives for society, such as food security and sovereignty. These priorities determine the orientation of the allocation of national economic resources and those obtained from international cooperation, assigned to scientific research projects, on the basis of highly competitive schemes.

Although funding for science and technology activities remains an unresolved problem in the country, the objectives are geared toward greater linkage with the sector that requires knowledge. This is reflected in the efforts made to create information and publication networks available at the national and inter-institutional level (Constituent Assembly, 2008, Legislative Assembly, 2010, Executive Committee of Bolivian Universities, 2011, National University Strategy for Science, Technology and Innovation, 2011, DICyT, University of San Simón, 2011, Ministry of Rural Development and Lands, 2010, Ministry of Communication, 2016, Vice Ministry of Science and Technology, 2013). These networks, in addition to providing spaces for meetings, information exchange and greater coordination, provide up-to-date information that makes it easier to obtain clearer views on the global context of a particular situation, such as the status of food security nationwide.

4. Agricultural production, improvement and state of development

4.1 Agricultural Production, Plant Breeding and Their Contribution to Food Security

Food-security policies in Bolivia have historically prioritized a system aimed at autarky or self-sufficiency in the production of the main foodstuffs consumed in the country, taking advantage of the large number of existing thermal floors due to altitudinal differences and its proximity to the Tropic of Capricorn. This means that in the South and Center of the country, especially in the Andean zone, the seasons have different temperatures and hours of light, which, although not very noticeable, are sufficient to allow the cultivation of certain species originating in the Mediterranean and the Middle-Eastern zone, despite the fact that the whole country is located within the world's tropical belt. Bolivia's low population density makes it possible to produce a large proportion of the food consumed, although most of the national surface comprises soils with a limited agricultural vocation.

The North and the eastern region of the whole country is characterized by flat land, with some low hills, covering two thirds of the area; rainfall in the North and the sub-Andean zone is high, decreasing towards the South until it creates a semi-desert zone. This broad plain with a tropical climate contains the following agricultural regions:

1. **Fertile Plain of Santa Cruz.** Covers a flat region with deep, fertile soils produced by the alluvial deposit of the Rio Grande, and constitutes the country's main agricultural region, with the largest amount of capital invested in services for a modern agriculture based on the use of certified seeds. It has the highest concentration of the agri-food industry.

2. **Upper Amazon Region.** Located throughout the Department of Pando, in certain provinces in the North of the Departments of La Paz, Beni, and the NE of Cochabamba, it had natural forests which, since deforestation, have become acidified and are now rarely used for agriculture.
3. **Chiquitanía Region.** Located in the North and East of the Department of Santa Cruz, it has low mountains and acid soils. The main activity in the area is livestock raising. After deforestation, perennial grasses are planted, often associated with crops.
4. **Beni Savannah Region.** Located in the Department of Beni, this is a meadow that is partly flooded some months of the year, with wooded strips or spots, and acid soils. Cattle breeding is the most important economic activity in this part of the country.
5. **Chaco Region.** Extends to the SE of the country, in the Departments of Tarija, Santa Cruz and Chuquisaca. The agricultural zone includes a narrow strip attached to the Andean mountain range. The remainder has a regime of scant rainfall, concentrated in a few months, forming low, thorny canopy forests. In this zone, livestock production is based on browsing.
6. **Andean Region**. Encompasses the South and Center-West of the country with three ecoregions: A) The Altiplano, an undulating plain between 3,400 and 3,700 masl, between the Western and Eastern or Royal Mountain Ranges. Rainfall is greater in the North and scarce in the South. High-Andean species and introduced cold-tolerant species are grown. The low temperatures, water shortage and salinity of the soils in the southern zone limit agriculture in this region; B) Region of the Temperate Valleys. These open and closed valleys have been formed in the Eastern Cordillera, at an altitude of between 1,500 and 2,900 meters, with a temperate climate. This region produces most of the vegetables consumed in the country and temperate fruit trees; C) The Yungas Region is located on the eastern slope of the Andes in the Departments of La Paz and Cochabamba. Food species are grown on some of the gentler slopes, particularly in the Department of La Paz.

In October 2014, the IBCE manager stated, on the basis of data from INE, that Bolivia produces a food surplus, adding that Bolivia's main food import is wheat and flour. "We are a country which, in its food balance with the world, produces an obvious surplus thanks to the export of soybean, sunflower, sugar, chia, quinoa, beans, milk, among other products, so that after the additions and subtractions, we are a country that exports far more than it imports," he said.

According to INE data, food imports from January to August 2014 stood at $477 million USD, while exports generated $729 million USD, yielding a positive trade balance of $252 million USD. The foreign-trade expert noted that although the country imports some vegetables and fruits, this is mainly due to seasonality issues. He pointed out that no country produces all its food or is able to do so without imports.

4.2. Relation between the human population and agricultural production, analysis of the population in a state of malnutrition

According to INE, in 2012 the Bolivian population was 10,351,181 and by 2020, the population is expected to grow to 11,633,371. Based on the latest censuses, the population growth rate is decreasing considerably, although it remains the highest among countries in the region. On the other hand, statistics published by INE show significant productive increases in recent years. **Table 2** shows the percentages of the differences between the average production in agricultural years 1999/2000, 2000/2001 and 2001/2002 in relation to the average of the years 2010/2011, 2011/2012 and 2012/2013. According to the WFP, Bolivia has a chronic malnutrition rate of approximately 25%, which is above the region's average, whereas according to the FAO, it is 15%. According to government sources, chronic malnutrition affects less than 10% of the population.

The statistics also mask another worrying aspect, because the production increase is largely due to the expansion of the agricultural frontier with significant deforestation, rather than to increases in productivity or yields-per-unit area. This situation is obviously not sustainable in the long term. A specific crop analysis during the same period, presented in **Table 2**, shows that in the case of cereals and pseudocereals, the increase in productivity per hectare as a result of the use of improved varieties and better technological management was extremely uneven: rice yield increased by 42%; wheat by 34.1%; sorghum by 7.5% and maize by 4.4%,

Table 2. Percentage increases in most important foods produced in recent years

Cereals and pseudocereals	
Rice	68.0
Wheat	87.2
Maize	75.6
Quinoa	116.7
Sorghum	242.2
Fruit	
Plantain	45.4
Peach	18.8
Tangerines	12.5
Orange	61.2
Pineapple	0.8
Banana	-17.3
Grape	28.6
Tubers and Roots	
Potato	33.2
Yucca	-2.9
Industrial	
Sugar cane	66.1
Sunflower	44.6
Soybean	101.5
Vegetables	
Garlic	51.2
Peas	-9.2
Onion	132.2
Beans	183.3
Broad beans	17.1
Tomato	-50.4

Source: Drawn up by the author based on data from INE

whereas quinoa productivity decreased by 12.9%. Potato, cassava and banana, a significant source of carbohydrates in the country, recorded a decrease in yield of between 11.3 and 11.5%. Fruit trees - such as bananas and grapes - boosted their productivity by 37.3% and 22.4%, respectively, due to the use of improved varieties and better crop technology. Peach and pineapple crops also increased their productivity by 6 to 7%, whereas other crops saw a decline in yields due to diseases and pests and the use of obsolete production technologies. As for vegetables, onion showed a significant increase in productivity (62.4%); bean and garlic yields increased by between 6% and 7%, respectively whereas the other vegetables decreased their harvests per unit area.

The use of certified seed and seedlings varies according to the different areas of the country and by crop. Generally speaking, they are widely used in areas with entrepreneurial or medium-sized farmers, yet scarcely used in areas with subsistence farmers or not at all. Farmers who grow export crops use up-to-date technology, except in the case of quinoa, whose production is based on organic agriculture, which has so far proved unsustainable, due to the limited production of manure and the low amount of biomass produced for processing compost. Public research centers have a greater impact on areas with good or medium agricultural development, whereas achievements in highly populated areas such as the Andean zone and tropical areas with little agricultural development are extremely scarce. Private investments by certain foundations, such as the Patiño Foundation, Fundación PROIMPA and Fundación Valles, contribute with research work to the development of small Andean farmers' agriculture, especially in irrigated valley areas.

4.3 Other considerations that enhance the efficiency of food systems

4.3.1 Prospects and technologies based on increased agricultural production

In order to develop technologies that promote the increase of agricultural production, it is essential to establish policies, programs and institutions that implement technological innovation strategies. In 2008, the government of Bolivia formed the National Institute of Agricultural and Forestry Innovation (INIAF) to oversee the country's agricultural innovation, in order to create technology to increase productivity in the agricultural sector. However, statistics show that during the 2008-2013 period, agricultural production remained practically constant (http://www.ine.gob.bo). The gradual reduction of external and internal financing for research and technology dissemination entities could partly explain the decline in the generation and diffusion of technological innovations (Blajos et al., 2015).

4.3.2 Infrastructure needs

Since mid-2015, Bolivia has experienced extremely variable weather conditions, particularly irregular rainfall regimes. This situation has a direct impact on agricultural production and highlights the lack of productive infrastructure, especially for irrigation. It is essential for the country to design a national irrigation program that not only involves building infrastructure, but is also accompanied by programs to disseminate technology and training in irrigation- system management. Another shortcoming regarding infrastructure is linked to the collection and storage of production. Current infrastructure storage conditions do not make it possible to preserve the seasonal production of diverse crops, which creates inefficiencies that translate into major price fluctuations and postharvest losses.

4.3.3 Postharvest limitations

The inadequacy and precariousness of the systems for the storage and conservation of the main agricultural products in the country are compounded by the increase in postharvest attacks by certain pests and diseases apparently favored by the effects of climate change. At the national level, there are no programs designed to create technological innovations aimed at controlling attacks by pests and diseases, which in turn makes agricultural activity more complicated and inefficient.

4.3.4 Access to food and distribution

The high rates of chronic malnutrition (25% to 27%) and obesity (4 of 10 adults, 3 of 10 students ages 13 to 17, 8 of 100 children under 5) registered in the country reflect the inequitable distribution of food (WFP, 2017). World events in which Bolivia actively participated, such as the International Potato Year (2008) and the International Year of Quinoa (2013) - which, among other things, encouraged the consumption of healthy food - have not had an effect on food quality, particularly by the most vulnerable groups. In addition to its historic dependence on wheat imports, in the past decade, the country has increased its consumption of food from abroad. Several imported products are essential components of the family basket.

4.4 The Livestock Situation in Bolivia and Its Contribution to Food Security

Livestock farms in Bolivia constitute an essential resource for the food security of peasant families who subsist in various ecological environmental conditions, from the Andean highlands, temperate valleys, semi-steppe or humid subtropical territories to the alluvial plains of the Amazonian tropics, adapting and surviving in extreme and variable climates.

Domestic livestock are distributed throughout the country and could be divided into two groups of animals on the basis of their origin: species that originated as a result of the animals introduced by the European conquistadors during the early decades of American colonization (bovines, sheep, goats, swine, equines and poultry) and Native American ones domesticated since the Inca empire period (camelids). Since the last three decades of the 20th century, introduced bovine populations have seen a drastic decline in their populations due to replacement or absorbent crosses with highly selected European and Indian races. However, there are still pure populations of this valuable animal's genetic resource of mixed European and African origin, from Criollo cattle (Gutiérrez & Pereira, 2015) that contribute to food security under extreme climatic conditions.

Table 3. Bolivia: Number of heads of cattle per specialty, by province, Agricultural Census 2013

Province	Cattle population	Specialty		
		Milk	Meat	Oxen
Bolivia	8,315,504	1,129,323	7,020,318	165,863
Chuquisaca	460,682	24,837	400,008	35,837
La Paz	501,753	162,990	332,333	6,430
Cochabamba	371,959	86,995	240,658	44,306
Oruro	79,950	36,548	42,684	718
Potosí	156,870	5,144	116,910	34,816
Tarija	393,650	33,294	339,531	20,825
Santa Cruz	3,598,955	661,258	2,930,688	7,009
Beni	2,631,013	113,074	2,502,840	15,099
Pando	120,672	5,183	114,666	823

Source: National Institute of Statistics (INE, 2015)

Bolivia's cattle-raising systems are largely associated with the subsistence economies of peasant families, with animal resources being grouped together to guarantee sustenance. In valleys and the Altiplano, dairy systems are usually part of the family economy and, very exceptionally, belong to companies or industries. However, both beef and dairy cattle production are found mainly in the Departments of Santa Cruz and Beni, which account for 80% of the country's red meat supply. General data citing the bovine population as the main contributor to food security, can be seen in **Tables 3 and 4** (the latter includes all other domestic animal species).

The main livestock production systems in the Beni are extensive, with cattle being raised in natural grasslands (86%). Zootechnical indexes in farms of this type are low, associated with the two season cycles marked by rainy periods (November-April) and drought (May-October). The climate phenomena known as El Niño and La Niña jeopardize the food security of peasant families, because they threaten the existence of Beni livestock. Livestock losses as a result of certain adverse weather factors, such as floods, can be seen in **Table 5**.

The food security of peasant families is linked to strategies for the conservation of animal genetic resources, which must be included in State Policies to support research on the phenotypic and genotypic characterization of individuals and permit the handling of genetic variation and its protection as world heritage.

5. National Risk Management and Monitoring Strategies to Protect Food Security

5.1. National Early Disaster Warning System (Meteorological and Hydrological Networks)

Due to its diversity of ecosystems and extreme variation of altitudinal, climatic and topographic scenarios, Bolivia has always been susceptible to various modifications and atmospheric alterations that transform the country's soil-climate conditions, therefore its productive conditions. In the past two decades, the recurrence of atmospheric anomalies caused by climate change has hit many parts of the country, generating significant losses in agricultural production, mainly in the sectors of small producers and subsistence farmers, who constitute the most vulnerable rural sector in Bolivian society.

Table 4. Bolivia: Cattle and poultry population, by species, Agricultural Censuses 1950, 1984 and 2013

Species	1950	1984 (1)	2013
Cattle (2)	2,226,629	3,886,463	8,315,504
Sheep	7,223,592	3,156,329	6,267,743
Pork	508,782	571,101	1,415,274
Goats	1,228,856	1,269,003	1,868,512
Camelid (3)	1,178,724	599,864	2,506,435
Horse (4)	622,578	407,426	665,683
Poultry(5)	1,760,191	4,773,635	42,260,347

Sources: National Institute of Statistics (INE, 2015) (1) In the 1984 Census of Agriculture, data from the department of La Paz only comprise the provinces of Franz Tamayo and Abel Iturralde. (2) Includes oxen. (3) Only considers llama and alpaca. (4) Includes horses, donkeys and mules. (5) Includes chickens, ducks and turkeys.

Table 5. Estimated flood losses, subsector cattle of the Province of Beni Bolivia, March 2014

Estimated losses	Number of animals	Amount in USD
Deaths of cattle	289,355	66,435,908
Deaths of horses	3,506	701,200
Deaths of minor species	6,394	319,700
Damage to livestock infrastructure	--	39,964,290
Indirect factors *	--	76,786,370
Animal Rescue Costs	--	37,859,476
Total losses in USD		222,066,944

Source: (FEGABENI, 2014) *Diseases, reduction of animal health indices.

In response to this situation of recurrent crisis, and in order to use preventive actions to mitigate situations that threaten the population's food security, the Bolivian Government, in close coordination with international cooperation, has prioritized the implementation of a National Early Disaster Warning System (NEDWS), involving entities at the Central level of the state, departmental and municipal Risk Management Units (RMU), and technical and scientific bodies that interact in a coordinated way, through standard processes and protocols, to issue warnings with information collected in real time, satellite images and scientific prediction models to manage disaster risk. These mechanisms allow the authorities of the Central, Departmental and Municipal governments to launch preventive and mitigation actions against adverse meteorological, hydrological and other phenomena that affect populations, their livelihoods and agricultural production, which in the long run determine citizens' food security, health and well-being.

NEDWS is a set of procedures and instruments used to monitor a predictable threat or adverse event (abiotic or anthropic), through data collection and processing to generate forecasts or temporary predictions of possible effects. The system's effectiveness is based on the knowledge and prior determination of the existence of various types of risks by ecosystem, the active participation of communities, constant and updated preparation, and an institutional commitment that involves education as an essential factor for raising citizens' awareness and the efficient issuing of warnings. NEDWS systematically carries out eight steps to reduce both human and economic losses and to protect the livelihoods of those affected (**Figure 2**).

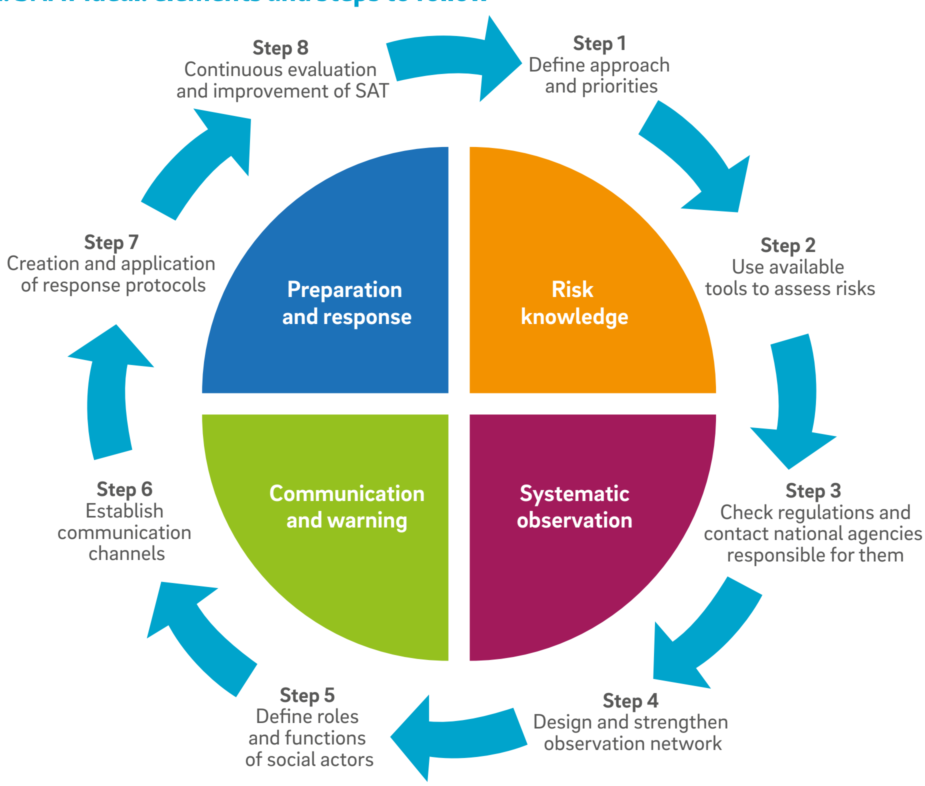
5.2 SNAT Applications to Protect Agricultural Productivity and Food Security in Bolivia

In Bolivia, NEDWS has been recognized since the passage of Law 602 of Risk Management (2014), as part of the SINAGER-SAT Integrated System of Information and Warnings for Disaster Risk Management, a system for the surveillance and monitoring of probable threats to existing vulnerability conditions prior to the occurrence of disasters or emergencies. It provides information on the risk level or scenario, to activate rapidly transmitted prevention and preparation protocols. It also coordinates warning systems for autonomous territorial entities and the monitoring and surveillance systems of scientific technical institutions.

The Viceministry of Civil Defense (VIDECI) is responsible for periodically strengthening NEDWS in conjunction with the various ministries, technical and scientific institutions and RMU, for the analysis of information on threats, vulnerabilities and risk levels or scenarios, surveillance, observation and warning, responsiveness and risk parameters, in order to optimize decision making. Significant technological progress has been made through the generation of available meteorological and hydrological models and the "Dewetra" platform, shared by the National Service of Meteorology and Hydrology (SENAMHI), the Ministries of Environment and Water and the MDRyT and VIDECI, which generates risk scenarios and issues daily Risk Alert bulletins.

Stepped territorialized warning monitoring models are currently being implemented in the country's five main macrowatersheds and rivers, in which monitoring points have been implemented with equipment at hydrometeorological stations, trained personnel from the municipal RMU and the permanent, active involvement of several dozen indigenous communities, who live near the rivers in these basins.

Figure 2. SNAT ideal: elements and steps to follow



5.3 National Observatory on the Country's Food and Nutrition Status

The Agricultural Community Productive Revolution Law (2011) provides for the implementation of an Agro-Environmental and Productive Observatory (APO), a technical entity that monitors, analyzes, generates and disseminates specialized information on the agricultural sector and rural development, to enable the state to make decisions that will guarantee food security and sovereignty and promote the country's sustainable rural development. APO's institutional structure considers the following technical areas:

Price Information System and Internal and External Agricultural Trade

This is a technical management tool for the development of information on food products and their prices, in national and international settings. At the international level, it monitors and analyzes the behavior of commodity prices on the global market.

Analysis and Applied Research for Food Security and Sovereignty

It monitors strategic crops and areas in agricultural production and management and the quality of productive resources, soil, water and national food reserves, in normal and emergency situations.

Systems, Technological Support and Geomatics

It evaluates the various data sources of the agricultural sector, database, texts, plans, and draws up the relational database schemas according to the type of information for public or private use. A Data Warehouse integrates the information generated by APO and the various information sources related to the agricultural sector.

Single Register of Sustainable Family Agriculture (RUNAF)

APO registers and classifies the productive actors organized in sustainable family agriculture and diversified into: Indigenous peasant, intercultural and Afro-Bolivian producer families; Peasant Economic Organizations, Indigenous Peoples and Community Economic Organizations. Those engaged in family agriculture who have registered are assigned a single Operational Register code.

6. Political considerations

6.1 Current Political Situation in Relation to Food and Nutrition Security

To achieve food security and sovereignty, in addition to the policies (DS No. 2167 of the "Food and Nutrition Policy" of 10/30/2014) and State actions (short-, medium- and long-term) urgently requires the participation of science, technology and education in proactive interaction, especially among universities, businesses, farmers, families and the public sector, which will help solve multiple problems of food production and security and provide more scientific, technical, economic and financial assistance. The most pressing need is to use education to combat and solve the problem of undernourishment and malnutrition, by guiding, teaching and encouraging the consumption of foods, for example, nutritious native foods such as quinoa, amaranth, cañawa, tarwi, maize, potatoes and others (fruits, tubers, legumes and vegetables), as well as the fish resources of the Amazon, the Plata and Lake Titicaca basins.

6.2. Current Political Situation Regarding Food Sovereignty

Bolivia has six production laws directly related to food sovereignty, according to the Plurinational Legislative Assembly (2014):

1. Law 071, Rights of Mother Earth, 2010: Its purpose is to recognize the rights of Mother Earth, the obligations and the duties of the multi-national State and society to ensure respect for these rights. Emphasizes the principles of collective welfare, non-commercialization and interculturality.
2. Law 098, Production, Industrialization and Marketing of Quinoa, 2011: Grants national priority to the production, industrialization and community marketing of quinoa, through the technification of

primary production with the respective protection of the areas of cultivation, improvement, conservation, irrigation, postharvest, processing, industrialization and commercialization, as a priority in local, national and overseas markets.

3. Law 144, Productive Community Agricultural Revolution, 2011: Standardizes a process of productive agricultural revolution for food sovereignty, establishing the institutional, political, technological and financial bases of the production, transformation and commercialization of agricultural and forestry products, in a pluralistic economy, prioritizing organic production.

Other related laws are:

4. Law 300, Framework of Mother Earth and Integral Development to Live Well, 2012: Establishes the foundations of integral development in harmony and balance with Mother Earth to live well, guaranteeing the regenerative capacity of components and life systems, and recovering ancestral knowledge in a complementary way to the rights, obligations, duties and objectives of integral development in order to live well.
5. Law 338, Peasant Economic Organizations, Indigenous Peoples and Community Economic Organizations for the Integration of Sustainable Family Agriculture and Food Sovereignty, 2013: Regulates sustainable family farming and diversified family activities carried out by peasant, native indigenous organizations and intercultural and Afro-Bolivian farming families to contribute to food sovereignty.
6. Law 453, Rights of Users and Consumers, 2013: Regulates the rights and guarantees of users and consumers at the national and sectoral level, without limiting the exclusive competence of the municipal level.

6.3 Current Policy and National Climate Change Regulations

Areas of work related to the fight against Climate Change were defined after the United Nations Summit on Environment and Development in Rio de Janeiro in 1992. Bolivia became involved and in April that same year, passed the Environmental Law as the fundamental axis of the policy and the environmental problems derived from disasters (climate change).

The People's Conference on Climate Change and Rights of Mother Earth was held in April 2010, and the Framework Law for Mother Earth and Integral Development for Living Well was passed in 2012. This law refers to the bases and guidelines of "Living well" through the integral development of climate change, and includes six sections, namely: 1) Establishing all types of policies for climate change mitigation and adaptation; 2) Building institutional and technical capacities for monitoring, modeling and forecasting to plan decision-making; 3) Promoting the recovery and application of ancestral knowledge for the development of measures to respond to the impacts of climate change; 4) Building prevention and risk management capacities to cope with climatic events, and 5) Greenhouse Gas Reduction Programs excluding financing mechanisms associated with carbon markets.

Supreme decrees have also been enacted to mitigate and address extreme climate events within the framework of Law 1333 of the Environment. The real problem is that these laws and decrees are a long way from being fulfilled by the population and the state that drafted them. The UN report published in January 2017 states that Bolivia is one of the countries with the least impact on climate change, since greenhouse gas emission is very low (0.03%), compared to other countries. However, it is one of the most vulnerable countries because it suffers this phenomenon most intensely, which increases the frequency and recurrence of extreme adverse events.

Climate change policies are no longer observed. They are weak and contradictory in relation to various economic-development plans that are not environmentally-friendly. Examples of this include the recent creation of a new decree that allows the unconstitutional expansion of the area of coca monocultures in more than 8,000 new hectares, and the plan to build several energy-generating dams to the detriment of ecosystems that are home to thousands of fauna and flora species, including dozens of native indigenous communities, which will be forced to move without any consideration or planning.

7. Abstract and General Recommendations

Bolivia is a country that is immensely rich in natural resources, contains between 45 and 55% of the world's biological diversity, and is capable of producing food not only for its inhabitants, but for the whole of America. The growth of ecological awareness is a crucial element for achieving the survival of species and productive ecosystems in Bolivia, where hundreds of species interact in small spaces due to the country's biological complexity. Priority actions for achieving agricultural sustainability cannot separate productive aspects from considerations that promote respect for the other ecosystem resources involved in its fields and species. Some potential scenarios for better agricultural production for the following decades are based on scientific research to create capacities to achieve the optimal use of new forms of energy. The development of new land-management models and the rational use of resources would make it possible to focus on climate-change adaptation and mitigation strategies, to boost production and ensure that less of what is already produced is lost.

However, as in most countries in the region, Bolivia faces serious constraints, therefore enormous challenges in ensuring its own Food and Nutrition Security with Sovereignty.

Its main difficulties and general limitations are summarized as follows:

- Public policies and environmental norms that are theoretical and not applied to the current productive reality.
- Current national development model based on the industrialization of natural resources.
- Low levels of nutritional education and poor compliance with food safety standards.
- Inequitable and insufficient access to food.
- Lack of incentives and general support for scientific research on agriculture.

More attention should be focused on the integral development of the following aspects:

- Strict, sincere and respectful compliance with the laws and regulations that promote the care of "Mother Earth".
- Greater efficiency in Natural Resource use and management, especially regarding increasing awareness of water-resource management.
- Optimization of agroecological food processes.
- Increased efficiency and effort in the surveillance of food safety, supported by the dissemination, training and awareness of good food with sovereignty.
- Reduction of postharvest losses and waste.
- Better state policies to support universities and research centers to promote the updating, modernization and efficiency of scientific research, which contributes to improving the agricultural production processes without expanding the agricultural frontier.

References

Aguilar, J. C., J. Comboni, C. Romero & R. Eróstegui (2008). Bolivia: Integrated Economic Analysis. Country Economic Report 2008:6. SIDA, Secretariat for Development Issues.

Asamblea Constituyente (2008). Nueva Constitución Política del Estado. Vicepresidencia de la República de Bolivia. La Paz, Bolivia. 152 pp.

Asamblea Legislativa Plurinacional (2010). Ley No. 070 (Ley de la Educación "Avelino Siñani-Elizardo Pérez"). Gaceta Oficial de Bolivia, 20 diciembre, 2010. La Paz, Bolivia.

Asamblea Legislativa Plurinacional. Cámara de Senadores (2014). Compendio de Leyes Productivas afines a la Soberanía Alimentaria. FO. La Paz, Bolivia. 171 pp.

Benites, D.S. (1992). Degradación de suelos y producción agrícola en Argentina, Bolivia, Brasil, Chile y Paraguay. In FAO, Erosión de suelos en América Latina. Santiago de Chile: FAO.

Blajos, J.; Ojeda, N.; Gandarillas, E.; Gandarillas, A. (2014). Economía de la quinoa: Perspectivas y desafíos. Revista de Agricultura. No. 54.

Cabitza, M. (July 20, 2011). Will Bolivia make the breakthrough on food security and the environment? The Guardian. https://www.theguar¬dian.com/global-development/poverty-matters/2011/jun/20/bolivi-food-security-prices-agriculture

Castañón, B.E. (2013). Las dos caras de la moneda: agricultura y seguridad alimentaria en Bolivia. Fundación Tierra, La Paz. http://www.ftierra.org/index.php?option=com_mtree&task=att_download&link_id=32&cf_id=61

CEUB (2011). Estrategia Universitaria Nacional de Ciencia, Tecnología e Innovación (2012–2015). IV Conferencia Nacional Ordinaria de Universidades, La Paz, Bolivia, noviembre 2011. 90 pp.

DICyT UMSS (2011). Marco Conceptual. La investigación en la Universidad Mayor de San Simón 2012-2021. Vicerrectorado UMSS. Cochabamba, Bolivia. 26 pp.

Dirección General de Planificación (MDRyT) (2010). Plan Estratégico Institucional 2011-2015. Estado Plurinacional de Bolivia, Ministerio de Desarrollo Rural y Tierras. La Paz, Bolivia.

FAO (Organización de las Naciones Unidas para la Alimentación y la Agricultura) (2014). Estado de la Inseguridad Alimentaria en el Mundo. Rome, Italy.

FAO (Organización de las Naciones Unidas para la Alimentación y la Agricultura) (2015). Estado de la Inseguridad Alimentaria en el Mundo. Rome, Italy.

FEGABENI (2014). Estimación de pérdidas y daños económicos en el sector ganadero Beni Bolivia. Trinidad Beni: FEGABENI-AB CREA.

Fundación Milenio (2013). Informe de milenio sobre la economía, Gestión 2012, No. 34. Bolivia. http://www.fundacion-milenio.org/infor¬me-de-milenio-sobre-la-economia-gestion-2012-no-34/

Gallo, G.; A. Campos; F. Hartmann; A. Panduro; H. Romero & A. Trepp (1989). Energía y métodos de producción agropecuaria en Bolivia – 1ra. Parte: Altiplano y Valles, 2da. Parte: Valles Bajos y Llanos", Cap. I: Elementos del estudio. Ministerio de Planificación y Coordinación / Dirección de Ciencia y Tecnología MPC / DICYT-Bolivia, Instituto De Economía Energética IDEE-Argentina, United Nations University UNU-Tokyo.

GCP-FAO (2009). http://www.fao.org. [Online] Informe nacional sobre el estado de los recursos fitogenéticos para la agricultura y la alimentación. Available at: http://www.fao.org/docrep/013/i1500e/Bolivia.pdf Retrieved January 2017.

Gutiérrez, L. & Pereira, J.A. (2015). Caracterización genética de bovinos criollos de "Vallegrande" mediante marcadores autosómicos, mitocondriales y del cromosoma y en la Provincia Florida, Valle Grande Santa Cruz, Bolivia. Doctoral dissertation. Santa Cruz, Universidad Autónoma Gabriel René Moreno.

Ibisch, P. L., S. G. Beck, B. Gerkmann & A. Carretero (2003). 3. La diversidad biológica, pp. 47-88. In: Ibisch, P. L. & G. Mérida (Editores). Biodiversidad: La Riqueza de Bolivia. Fundación Amigos de la Naturaleza, Santa Cruz.

INE (Instituto Nacional de Estadística Bolivia) (2015). Censo Agropecuario 2013 Bolivia. Available at: http://www.ine.gob.bo/pdf/cna_BOLIVIA_final.pdf Retrieved January 2017.

INE.gob.bo. Available at: http://www.ine.gob.bo

INE (Instituto Nacional de Estadistica) (2017). Available at. http://www.ine.gob.bo/

Jemio, L. C. (2015). Producción, superficie sembrada y rendimientos del sector agrícola (2005-2013). Publicación Digital, Blog Desarro¬llo Sobre la Mesa. Published February 18, 2015. Fundación INESAD, Bolivia. http://inesad.edu.bo/dslm/2015/02/produccion-superfi¬cie-sembrada-y-rendimientos-del-sector-agricola-2005-2013/

Killeen, T. J., T. Siles, L. Soria & L. Correa (2005). Estratificación de vegetación y cambio de uso de suelo en los Yungas y Alto Beni de La Paz. Ecología en Bolivia 40(3):32-69.

Killeen, T. J., A. Guerra, M. Calzada, L. Correa, V. Calderón, L. Soria, B. Quezada & M. K. Steininger (2008). Total historical land-use change in Eastern Bolivia: who, where, when, and how much? Ecology and Society 13(1): 1-36. [Online] URL: http://www.ecologyandsociety.org/vol13/iss1/art36/

Malloy, M. (2016). Estado de situación: Bolivia, seguridad alimentaria y economía agrícola. Fundación Alternativas, La Paz.

Moraes R. M. & S. Beck (1992). Diversidad florística de Bolivia. pp. 73 111. M. Marconi (Editor). Conservación de la Diversidad Biológica en Bolivia. CDC Bolivia/ USAID Bolivia, La Paz.

Naciones Unidas en Bolivia (2017). PMA – Programa Mundial de Alimentos. Available at: http://www.nu.org.bo/agencia/programa-mundial-de-alimentos-pma/

Navarro, G. (2002). Conceptos generales y bases metodológicas. pp. 2-49. En: Navarro, G. & M. Maldonado (Editores). Geografía Ecológica de Bolivia - Vegetación y Ambientes Acuáticos. Fundación Simón I. Patiño, Cochabamba.

Navarro, G. S. & W. Ferreira (2007). Leyenda explicativa de las unidades del mapa de vegetación de Bolivia a escala 1:250 000. Rumbol, srl., Cochabamba. 65 pp.

Ormachea, S. E. (2009). Soberanía y seguridad alimentaria en Bolivia: políticas y estado de situación. La Paz, CEDLA. 100 pp.

Prudencio, J. (2014). ¿Renunciar a la seguridad y soberanía alimentaria por comercializar más? Análisis del "Plan del Sector. Desarrollo Agropecuario 2014-2018. Hacia el 2025".

Prudencio, J. (2015). Bolivia: un nuevo modelo de desarrollo agroalimentario basado en las exportaciones agrícolas. http://web.research-4dev.com/images/pdfs/LIBROS/12.pdf

PNUD (Programa de las Naciones Unidas para el Desarrollo) (2008). Informe temático sobre desarrollo humano "La otra frontera": Usos alternativos de los recursos naturales en Bolivia. La Paz.

Tejada, E. (2011). Experiencias exitosas de Gestión de Riesgos de Desastres en el Sector Agropecuario para la Adaptación al Cambio Climático. Organización de Naciones Unidas Para la Agricultura y la Alimentación (FAO), Cooperación Italiana en Bolivia. 160 pp.

Trepp del Carpio, A. (2017). "Variables e hipótesis. Cómputo energético y análisis de los resultados". Capítulo 3 En: Organizatividad y complejidad – La extensión de la termodinámica clásica y de los principios clásicos de la ciencia. Academia Nacional de Ciencias de Bolivia.

Trepp del Carpio, A. (2017). "La ampliación de la ciencia y termodinámica clásicas". Capítulo 4. En: Organizatividad y complejidad – La extensión de la termodinámica clásica y de los principios clásicos de la ciencia. Academia Nacional de Ciencias de Bolivia.

Urioste, M. (2011). Concentración y extranjerización de la tierra en Bolivia. Fundación Tierra, Bolivia. http://www.bivica.org/upload/con¬centracion-tierra.pdf

Urioste, M. (2012). Concentration and "foreignisation" of land in Bolivia. Canadian Journal of Development Studies 33(4):439-457.

Viceministerio de Ciencia y Tecnología (2013). Plan Nacional de Ciencia Tecnología e Innovación del Estado Plurinacional de Bolivia- Sector Desarrollo Agropecuario. Ministerio de Educación. La Paz, Bolivia. 128 pp.

http://bolivianing.com/bolivia

http://labiodiversidadenbolivia.blogspot.com/2015/07

http://www.bolivianland.net/.

http://www.paginasiete.bo/economia/2015/8/2/bolivia-tiene-276-millones-hectareas-cultivables-65194.html 02/08/2015

http://www.ine.gob.bo/pdf/boletin/NP_2015_69.pdf 01 08 2015

http://www.elpaisonline.com/index.php/blogs 18/01/2017).

www.ine.gob.bo/pdf/boletin/NP-2015-64-pdf

www.fao.org/bolivia/fao-en-bolivia/bolivia

http://www.eldeber.com.bo/el-63-de-los-bolivianos-tiene-mala-alimentacion/130406221748. Roxana Escobar, El Deber, August 7, 2013.

www.opinion.com.bo/articulos/2011/0813/noticias

www.cepal.org/es

Food and Nutrition Security in Brazil

Mass soybean harvesting at a farm in Campo Verde, Mato Grosso, Brazil © Shutterstock

Brazil

Coordinators
Evaldo Ferreira Vilela and Elibio L. Rech Filho

Participants
Geraldo Bueno Martha Junior
Eliseu Roberto de Andrade Alves
Mauricio Antônio Lopes
Élcio Perpétuo Guimarães
Paulo Renato Cabral
Cleber Oliveira Soares
Grácia Maria Soares Rosinha
Antônio Márcio Buainain
Marilia Regini Nutti
Geraldo Magela Callegaro

The impressively fast growing Brazilian Agricultural Production for domestic consumption and export is rooted in the intensive agricultural technology generation and adaptation by the dynamic Brazilian Agricultural Research System. This phenomenon has been widely admired, but only imitated by developing countries to a limited extent

Summary

Evaldo Ferreira Vilela[1] and Elibio Leopoldo Rech Filho[2]

In the past 40 years, the agricultural public and private sectors of Brazil have been working in close collaboration, to promote one of the most impressive and successful sustainable agricultural developments in a middle income country. Brazil has become an example of a food secure country and one the of world's most important agricultural export countries. Mention should be made of the outstanding role played by the agricultural research technology developed by Brazilian research organizations, led by the agricultural research system encompassing agricultural universities, the Brazilian Agricultural Research Organization (EMBRAPA) and the state agricultural research organizations.

This comprehensive executive summary outlines the future challenges and opportunities for the Brazilian agricultural sector in terms of science, technology and innovation, to keep agriculture improving its performance in a world that faces the enormous challenge of feeding a hungry population now and in the following decades. These challenges and opportunities were identified by a select group of highly qualified Brazilian researchers who have spent a lifetime generating and adapting new technology for the development of the Brazilian agriculture sector.

1. Brazil's National Characteristics

Geraldo B. Martha Jr.[3] and Eliseu Roberto de Andrade Alves[4]

Brazil's geographic, demographic and human capital characteristics

Brazil's geographic area is one of the largest in the world, totaling 8,515,767 km² distributed among 5,570 municipalities (IBGE, 2016a). Brazil makes a major contribution to global social and environmental services through its large expanses of land and water, representing 13.2% of the world's potential arable land (FAO, 2000) and 15.2% of the World's Water Resources (WRI, 2008). Over time, the country's

1. Chapter Coordinator; Professor at the Federal University of Viçosa (UFV); President of the Foundation for Research Support of the State of Minas Gerais (FAPEMIG); and Member of the Brazilian Academy of Sciences (ABC).

2. Chapter Coordinator; Senior Researcher at Embrapa Genetic Resources and Biotechnology; Professor at University of Brasilia; and Member of the Brazilian Academy of Sciences (ABC).

3. Senior Researcher at Embrapa, Coordinator of Embrapa Labex-USA.

4. Senior Researcher at Embrapa, and Senior Advisor to Embrapa's CEO.

diverse climate regimes (from tropical to subtropical), combined with this natural capital, have created six biomes ranging from semi-arid to the Amazon rainforest. Brazil also has enormous biodiversity: nearly 60,000 of the world's 250,000 species of higher plants are native to Brazil (Lopes, 2012).

In 2014, Brazi had a total of 203.2 million people (IBGE, 2016b), with approximately 85% living in urban areas (IBGE, 2011). The workforce in the country totaled 98.1 million people in 2014, of which 13.9 million were enrolled in the agricultural sector (IBGE, 2016b). In the Brazilian economy, 32.9% of the workers were illiterate or had an incomplete elementary school degree, compared to a shocking 74.2% of workers in the agricultural sector who were illiterate or had failed to complete elementary school. The share of college-educated people also sharply contrasted with workers and those engaged in the agricultural sector: 14.3% of the total workers in Brazil had a bachelor degree compared to only 1.6% of workers in agriculture – which nonetheless is much higher than the 0.5% of college-educated workers engaged in agriculture in 2004 (IBGE, 2016b).

Brazil's agricultural value chains and contributions to UN's SDG #2

Over the past four decades, Brazil eventually became self-sufficient in food production and successfully improved the population's food security. In the recent past, the share of food secure population in Brazil increased from 60.1%, in 2004, to 74.2%, in 2013. During this period, the share of the population experiencing severe food insecurity decreased by a significant 8.7% per year, plummeting from 15% of the Brazilian population, in 2004, to 7.2% of the 2013 population (IBGE, 2016c).

This outstanding achievement reflected the fact that food production increased at a higher rate than food demand and, consequently, real food prices for consumers have significantly decreased in the past four decades. Currently, consumers pay roughly half the amount for a food basket than they did in the 1970s (**Figure 1**). Given Brazil's central role in world agriculture, this achievement undoubtedly contributed to global food security, one of the outstanding "United Nations' Sustainable Development Goals".

Furthermore, the fact that aggregated Brazilian agricultural production grew predominantly through yield increases, instead of area expansion (**Figure 2**) has decisively contributed to the generation of impressive land-saving effects that have enabled millions of hectares to be free from cultivation in the past 60 years. Thus Brazilian agriculture has not only become more competitive over the past 40 years, but has become more resilient and sustainable through the lens of sustainability (Martha & Alves, 2017).

Brazil's challenges in food and nutrition security

The future will pose challenges for sustaining the country's food security achievements over the past 15 years. During this period, Brazil effectively reduced poverty among its citizens. Whereas 9.4% of the population was below the $1.25 USD extreme-poverty line, in 2004, this share sharply decreased to 3.1% in 2014. The share of the population below the $3.10 USD poverty line was 24.9% and 8.5% for 2004 and 2014 (Osorio, 2014). Both extreme poverty and poverty were reduced by over 10% per year, reflecting the economic growth of the period.

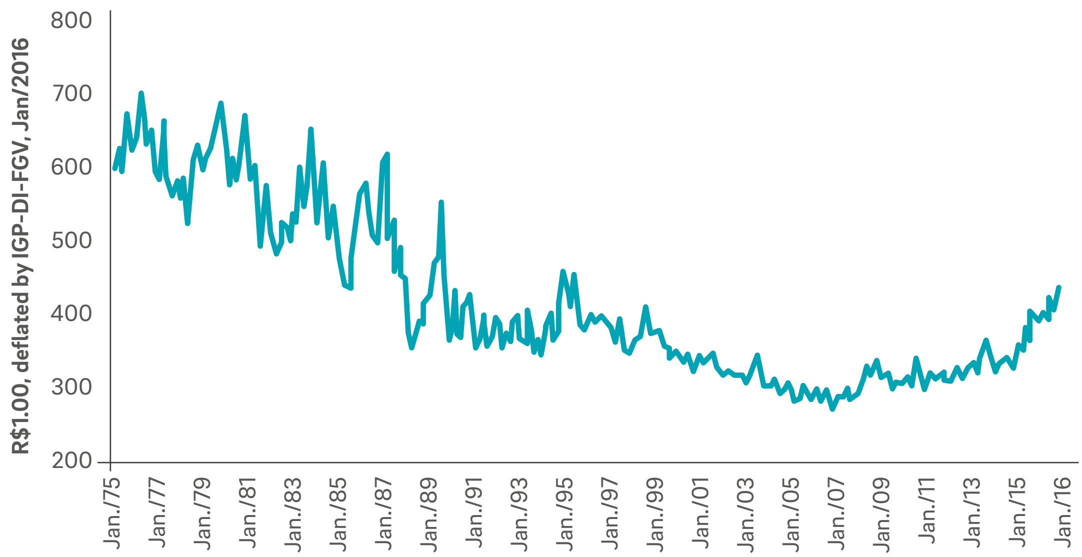
Economic growth is not everything, but it is certainly a key element in sustained food and nutrition security. Based on the World Bank's GDP per capita (PPP, constant 2011 international dollar) database, in 2004-2014, average per capita income increased by 2.4% in Brazil, from $11,968 to $15,162. However, after a peak of $15,281, in 2013, per capita GDP in Brazil decreased at a rate of 2.7% per year, to $14,454, in 2015. The economic situation measured in terms of per capita GDP deteriorated in 2016, as Brazil's GDP continued to shrink, making it difficult to maintain the food security achievements of previous decades.

To a certain extent, these economic pressures could be relieved if agricultural production maintained the rate of the past 40 years during which it consistently increased the agricultural output available to the Brazilian population at a higher rate than food demand (Martha &

Alves, 2017). The resulting income-effect of demand could benefit the Brazilian population, especially the poorest sectors, and decisively contribute to the country's food and nutrition security goals.

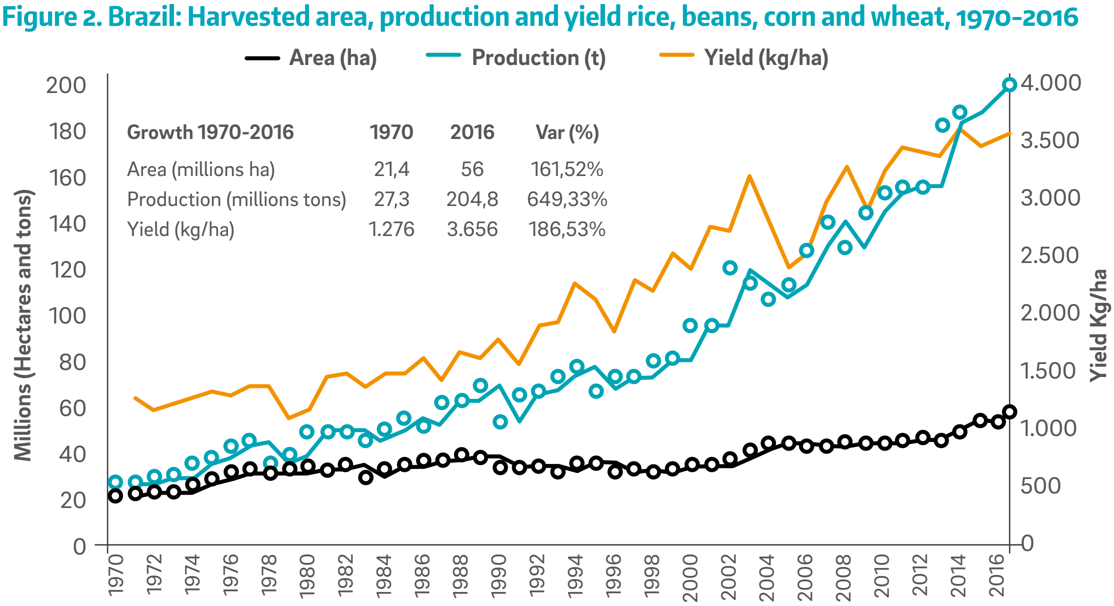
However, knowledge and technology will only be adopted on a large scale if a minimal level of reading and math skills is achieved. For example, at the farm level, modern inputs (seeds, fertilizers, pesticides, etc.) cannot be properly calculated, nor can machinery and equipment can be adequately adjusted for operation, without minimal knowledge of math and reading/interpretation skills to use the instructions manual. At a higher training level focusing on decision-making, basic theoretical knowledge, the use of scientific methods are eventually required (Rodríguez et al., 2008)

Figure 1. Real Prices of staple food for the city of Sao Paulo, Brazil (R$ 1.00)



Source: Diese. Reference Source Embrapa/SGL

Figure 2. Brazil: Harvested area, production and yield rice, beans, corn and wheat, 1970-2016



Source: IBGE. Reference source Embrapa/SNE to depart from the generally-accepted "rule of thumb" and make the necessary adaptations to the local production system.

The generation of knowledge and technology to address the future challenges of Brazilian agriculture and food security is a very clear goal to be pursued. Increasing investment in agricultural research and development is a decisive step toward that end. Furthermore, strengthening human capital at different levels is required for a more inclusive approach and to avoid any long-term restrictions on achieving higher technological agricultural production in the future.

2. Institutional Setting

Maurício A. Lopes,[5] Geraldo B. Martha Jr., Evaldo F. Vilela

Science-based Agriculture in Brazil

A virtuous cycle that expanded and strengthened tropical agricultural research began in Brazil in the 1970s. The government's commitment to supporting science-based agriculture was positively received by society. The private sector promptly adopted new knowledge and technologies to boost agricultural production. The sharp drop in food prices over the past four decades, along with associated lower price volatility, in addition to providing food security to Brazilian population, also contributed to alleviating inflationary pressures.

Technology generation and adoption in Brazilian agriculture has been a continuous process. Currently, technology already explains 68% of the agricultural product (Alves et al., 2013). In the future, the "technology-dependence" of agricultural value-chains is expected to increase to even higher levels and these "science for innovation approaches" must design alternatives for "real-world" challenges and opportunities (Embrapa, 2014).

Institutional Development. Research and Development (R&D) Organizations

Brazil improved its research structure and capacity substantially by developing a two-tier system of federal and state-based agencies, called the "National Agricultural Research System (SNPA) (Lopes, 2012). Over the decades, the SNPA (**Figure 3**) has been responsible for designing, implementing, developing and promoting a wide array of knowledge and technologies to contribute to innovation in agricultural value chains. SNPA includes State agricultural research organizations, universities (agricultural colleges) and Embrapa.

Embrapa was founded in 1973, with the aim of serving as the "research arm" of the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA). The model conceived by Embrapa is centered on capacity building and on excellence research centers. To facilitate interaction with farmers and society, the model chosen was an agency with a nation-wide mandate, decentralized in the territorial dimension and organized as centers researching products, resources and themes. Several State Governments also established their own agricultural research organizations in the 1970s and 1980s and Embrapa was assigned the additional mission of coordinating SNPA.

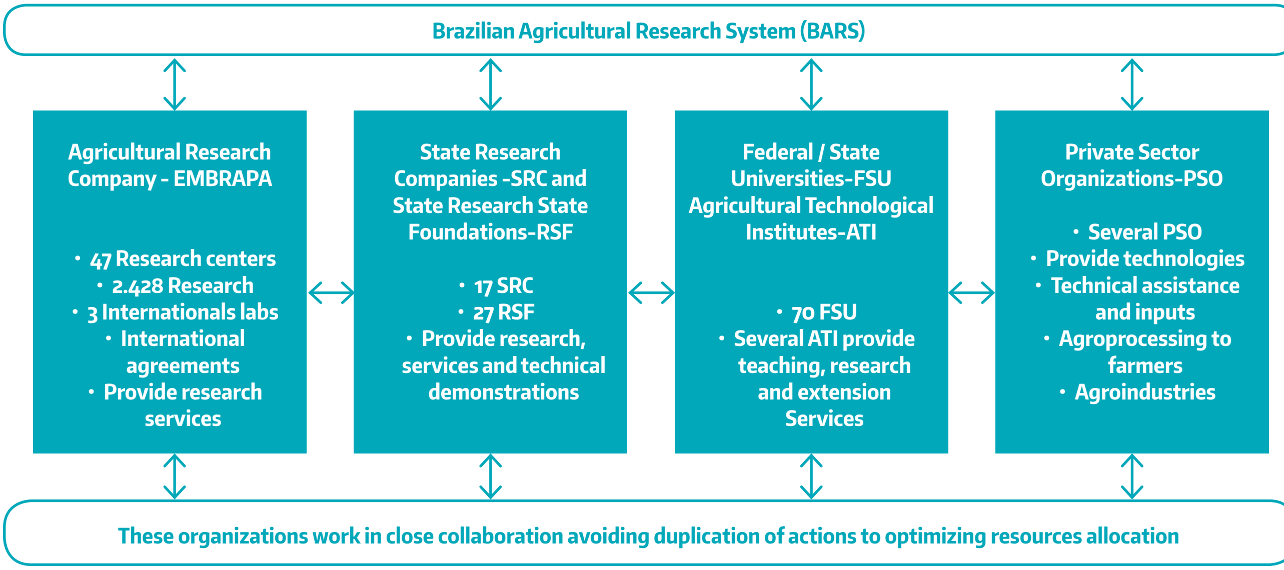
The Brazilian Agricultural Research System (**Figure 3**) led by Embrapa became one of the largest agricultural research networks in the tropical world. In 2013, Embrapa represented 42% of SNPA's research capacity, followed by the State Research Organizations (29%), Agricultural Colleges (26%) and non-profit organizations (3%). Full-Time research Equivalents in 2013 (FTE – 5,869.4) consisted of 72.5% of researchers with doctoral degrees, 21.5% with master degrees, and 6.0% with bachelor degrees. Nearly 60% of those researchers were concentrated in the 41-60-year cohort (Flaherty et al., 2016).

The Role of Human Capital

A major determinant in the successful development of Brazilian agriculture was the development and strengthening of human capital, in which education played a pivotal

5. President and Senior Researcher of Embrapa, Brasília.

Figure 3. Organization of the Brazilian Agricultural Research System (BARS)



Source: Prepared by the Author.

role. However, as discussed by Sowell (2015), education is important, but it may not be a reliable proxy for human capital, since human capital also demands the development of marketable skills and knowledge that directly affects economic outcomes. Human capital is increasingly in demand in an economy that is becoming both technologically and organizationally more complex (Sowell, 2015), such as agriculture and its value chain.

Embrapa is a good example of persistent investment in human capital and its pay-off. Since Embrapa's inception in the early 1970s, over a thousand of its employees have been sent abroad to be trained at the world's finest agricultural colleges. This strategy also helped stimulate creativity and establish an environment that encouraged coexistence and interaction among peers and different stakeholders. The basic idea is that Embrapa will always be prepared to capture, interpret and internalize the signals from a complex society as well as the international market, since the need for interaction across national borders will increase (Alves, 2010; Martha Jr. et al., 2012). Typically, Embrapa has shown a benefit/cost ratio for society's investment ranging from 8:1-12:1 over the years.

The Role of Brazilian Universities in the Development of Tropical Agriculture

Beginning in the 1960s, the development of the current Sustainable Tropical Agriculture was marked by the contribution of Brazilian universities focusing on Agricultural Sciences, which led to the implementation of specialized graduate courses in the country.

Inspired by the American "Land-Grant Colleges", the Federal Universities of Viçosa (UFV), and Lavras (UFLA) and the Luiz de Queiroz College of Agriculture (University of São Paulo), among others, have been making a major, contribution to the development of the Brazilian agricultural sector. This has taken place through a partnership with EMBRAPA, via the "Brazilian Agricultural Research System" comprising several research networks established with other universities and institutions in the country and abroad. These universities, which rank high in evaluations of Latin-American and global universities, have always undertaken basic and applied research, to meet the technological demands of the production of vegetable and animal products under local soil and weather conditions. They have gained renown for creating research environments that are relevant to the social and economic advancement of the country.

Over the past three decades, in the State of São Paulo alone, investments in agriculture and livestock farming research amounted to an annual average of 417 million Brazilian Reais, including federal resources, with special attention being paid to research on sugar cane and beef and dairy cattle. During the same period, an average of 415 million Brazilian Reais (R$3.15/US$1.00) was invested in higher education in the agriculture field, most of it allocated to USP, UNICAMP and UNESP. The return on public investments in human capital is comparable to the results obtained in the US, where each dollar invested generates up to $13 USD in revenue.

The teaching-research-extension trilogy, inherited by Brazilian agricultural universities from the cooperation with the American Land-Grant Colleges, greatly favored the training of professionals in higher education, especially in master -and doctoral- degree programs to work in the agriculture sector.

Brazilian universities are directly responsible for the significant growth of scientific production in various fields of knowledge in the country, since they concentrate the largest number of Ph.D.'s and most of the research infrastructure. Over the past 20 years, the number of articles published per million inhabitants in the country grew from approximately 20 to 182, above the world average of 170 articles per million inhabitants, and agricultural sciences made an unquestionable contribution to this progress.

In 2016, agricultural sciences accounted for 270 graduate programs in Brazil, including 204 traditional master-degree programs, 46 Ph.D. programs and 20 professional master programs. The number of doctoral students graduating from Brazilian universities grew by 486% between 1996 and 2014. In 2014, 50,200 master and 16,700 doctoral students, including those in the agricultural sciences graduated from the country's universities.

Concluding Remarks

Enormous challenges still lie ahead. The future of Brazilian agriculture will eventually be shaped by multifunctional concepts, methods and applications far beyond the current conventional views of agriculture as a system dedicated to the production of food, feed, fiber, feedstock, energy and environmental services. Innovations in R&D organizations and collaboration networks will need to correctly interpret future needs and evolve accordingly.

Over the past four decades, agricultural research in Brazil has relied on the Brazilian Agricultural Research System. A broader, more comprehensive alliance is now being considered under the auspices of the Brazilian Ministry of Agriculture, Livestock, and Food Supply. This Alliance for Agricultural Innovation in Brazil seeks to reinforce the multi-institutional environment, so that research and innovation processes will be further strengthened to better accommodate the articulation, alignment and synergy between the actors involved in the research and innovation processes. This approach should generate an innovative dynamic capable of attracting new public and private funding sources and leverage the knowledge generated by agricultural research, adding more value to the entire value chain.

It is worth noting that the ability of technologies to foster agricultural competitiveness is not only limited by scientific knowledge, but also by non-technological factors. Bottlenecks in logistics, storage and transport infrastructure, the availability and cost of energy, among other factors, may work as headwinds to technology adoption.

Last, but certainly not least, increasing production through more efficient use of resources will necessarily entail greater investment in human capital. Furthermore, it should be noted that no organization or even country has all the solutions needed to fully and adequately respond to the challenges and opportunities ahead. This means that Brazilian agricultural R&D Organizations must strengthen partnerships and alliances within and beyond the country's borders. Enhancing cooperation will therefore be essential to establishing a sustainable path for agricultural value chains and the emerging bio-economy.

3. Resources and Ecosystem Characteristics: Plant Production, Genetics and Biodiversity

Élcio Perpétuo Guimarães[6]

Introduction

Glancing through various documents on global issues such as food security, sustainability, climate change effects and biofuels shows that Brazil is part of the problem, but also part of the solution. There is no doubt in people's minds that this country is the world's food basket and a place where lessons can be learned. Brazil's agricultural production grew exponentially in recent decades, mainly due to the application of research results and technology. Nevertheless, there are negative factors associated with it, such as the overexploitation of natural resources and excessive use of agrochemicals (Brazil is currently the world's largest user of agrochemicals).

The latest statistics on Brazilian grain production show another record: total grain production in 2016-17 exceeded 227.9 million metric tons, with soybeans accounting for the largest amount, with 110.1 million tons, followed by maize with 91.5 million and rice with 11.9 million (Conab, 2017). It is impossible to talk about food production in the country without mentioning how Brazil improved its resource and ecosystem management. FAO 2006 data show that from 1975 to 2005, the area-under-cultivation declined by 1.91% (from 695 to 681.7 million hectares) while productivity grew by 84.7% (from 1.76 to 3.26 thousand/hectare). Again, the main driving force to obtain these results was the use of science and technology.

The major challenge for the country in the coming decades is to sustain growth with a minimal expansion of the area-under- cultivation and maximal productivity increases. The role of science and technology is to produce innovations that will enable the country to produce more in a sustainable manner, increase nutritional quality, and respect the environment more and its various biomes (**Map 1**); all in a world increasingly affected by climate changes we do not yet fully understand.

Plant production

Going back in history, we see that the continuous increase in productivity was the key element that enabled societies to flourish. In the beginning, hunters needed 2,500 hectares to feed one person; in Egyptian agriculture 10% of this area fed 750 people, whereas in today's agriculture that same 10% feeds 3,600 people (Paterniani, 2001).

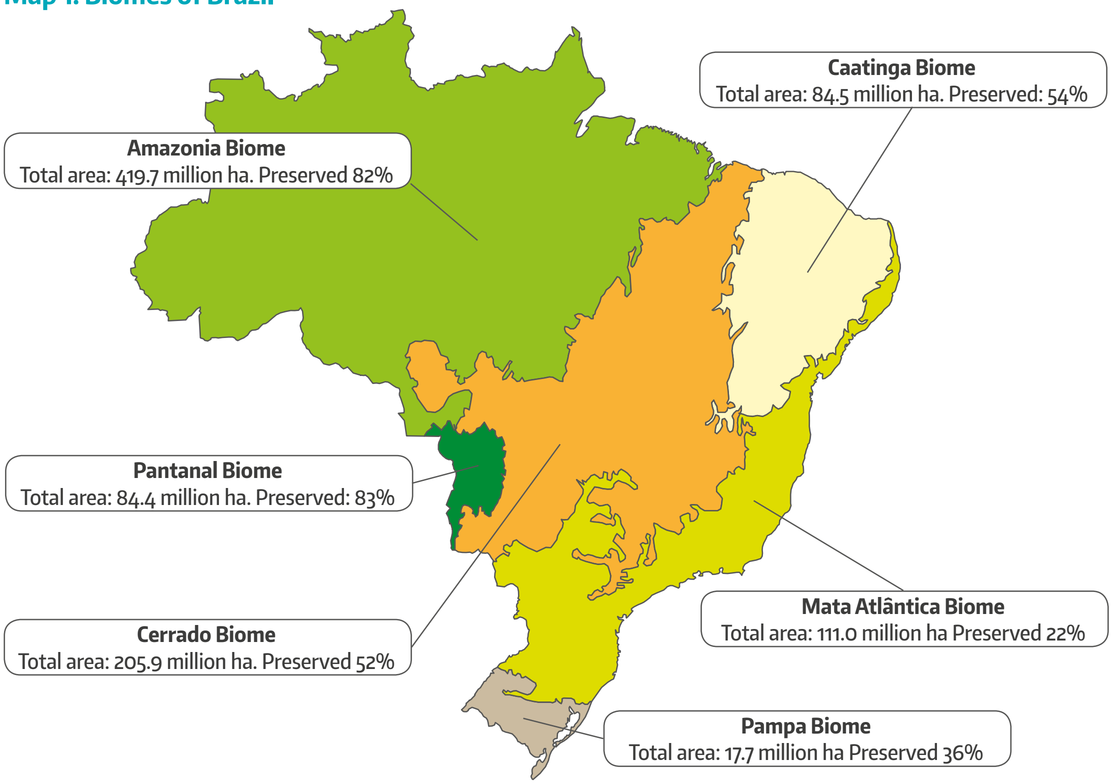
In the 60s and 70s, the aim was to cultivate one crop a year and to achieve the highest possible production. To achieve this, high fertilization levels were used generally in combination with overexploitation of natural resources. As time went by researchers developed more complex agricultural systems, achieving year-round land use. In these systems, crops are integrated with livestock, and in some cases the forest is also incorporated (Balbino et al., 2012). Farmers also came up with creative responses to increase and sustain food production, such as the zero-till system, which exerted an impact on the whole country. In general, the increase in complexity was not only associated with an increase in production, but finding more sustainable ways to run agricultural and livestock systems.

The land-use change caused by the expansion of livestock and agriculture posed a series of challenges for research, the main one being the lack of sustainability due to pasture degradation and monocropping (Aidar and Kluthcouski, 2003), which are still waiting for better answers from science. In general, these challenges linked to the sustainability of production systems are not related to the static view where systems are considered sustainable when production is kept at the same level, but to the dynamic view where systems evolve to adjust to society's demands.

The intensification, integration and increased complexity of the agricultural production system brought problems of pests, such as the white fly, which is currently a major problem in common

6. Senior Researcher at Embrapa Rice and Beans, Goiania, Goias, Brazil. Email: elcio.guimaraes@embrapa.br

Map 1. Biomes of Brazil



Source: Projeto Biomas (CNA/Embrapa); MMA.

beans, but also affects soybeans and other crops, forcing farmers to constantly use chemicals. The continuous exploitation of the soil's chemical and physical capacity is also a major issue. The challenge for research is to understand how to balance complex systems in such a way that extraction is neutralized by the addition of chemical elements, without entailing high costs for farmers or the environment. A major issue involves keeping and improving the soil's organic matter (Neufeldt et al., 2002). In the Cerrado ecosystem, a major limitation for sustainability is the low levels of organic matter in the soils. Accordingly, research designed to increase and sustain the organic matter in soil must have a high priority. This is also true for other ecosystems, such as Caatinga for example.

On the subject of Caatinga, water use efficiency is a challenge in the Northeast (NE), where sugar cane and fruit production are major components of the production systems and water shortage has become a major issue. This is also true for rice production in South and Central Brazil. Despite the importance of these production regions for the country and the severity of water shortages, science has not yet been able to understand this complexity and come up with solutions that not only protect the ecosystem, but also help farmers increase productivity. The development of varieties that use water efficiently and water-saving technology are key elements for consideration.

Looking at the country as a whole, agriculture and livestock changed Brazil from a food-insecure country to a major food exporter in a few decades, in addition to accounting for a quarter of its Net Domestic Product (NDP). This production comes from various ecosystems (**Map 1**), which have been contributing to the nation's production in different ways. The Cerrado ecosystem developed exponentially and in less than five decades became the largest agricultural production area in the country. The major challenges here are related to infrastructure and logistics, but science is still struggling with the development of intensified and sustainable systems. No-till farming was a step in the right direction, but the prevalence of commodity crops such as soybean and maize, is still a major topic. Developing intensive, sustainable production systems is the main issue here. In the Southern region of Brazil, where agriculture has a longer history, sustainability and intensification of production systems are also major challenges. In the Caatinga region, water enabled farmers to become market-oriented, whereas in the past, the major focus was on family production. The development of irrigation systems enabled the production of commercial crops and diversification from cassava to sugar cane and fruit. Water-use efficiency is undoubtedly the main area for research. There is a need to invest in varieties that are more tolerant to water stress and in more efficient irrigation systems. The Amazon ecosystem has very particular characteristics meaning in the long run, agriculture has a less important role to play than the exploitation of local and native species. Extensive livestock and soybean production in deforested areas are currently major contributors to production. As with other ecosystems, sustainability is the main issue, while the development of integrated production systems is the main challenge.

Science is moving swiftly in the direction of offering tools to farmers to understand the behavior of their production systems, in all ecosystems, in real time, by integrating crop behavior with soil and water conditions. Today, drones fly over farms to obtain information on where and how interventions are needed to prevent crops from diseases and insects (Fonarce et al., 2014).

These data are analyzed and computers provide information on better ways to manage the problem. Machines tell us where, how and how much fertilizer to apply considering the soil characteristics, making precision agriculture part of farmers' lives. Automation is contributing to better management of the production system and allows more complex systems to be productive and sustainable. All these innovations are already part of Brazil's agricultural systems.

However, looking ahead, Brazilian agriculture is not only expected to focus on producing more and better food, feed, fiber and fuel, but also to contribute to climate change mitigation, while minimizing environmental impact.

Genetics

In today's world, the responsibility for feeding its population lies in the area of genetics. Its contribution is not only linked to food production but also to fiber, feed and fuel. Since the inception of genetics, breeders have been using this knowledge to develop improved varieties on an annual basis. They have been seeking methods and tools to allow them to make specific changes in the genome and increase their efficiency in producing better varieties.

Before talking about today's new opportunities, it is noteworthy that the application of Mendel's laws allowed us to increase productivity exponentially, mainly for the major crops. It also made it possible to develop varieties that are more resistant to diseases and insects, and more tolerant to abiotic stresses. However, the complexity of today's cropping systems and the need for faster, better responses to the limiting factors are posing additional challenges for breeders.

Recently, as a result of the advances in life sciences, this challenge seems to have been overcome and genetic modifications have set new boundaries to breeding. Today, discussions about synthesizing a human genome continue to be held. In 2010, the creation of artificial life was reported, in the US, by the J. Craig Venter Institute (JCVI) (Gibson et al., 2010), which gives us an idea of how fast the field is advancing. Going back to the last century, we all remember the advent of transgenesis and how it drew the world's attention to how gene manipulation techniques could offer alternatives for improving crops' capacity to resist pests, but also how a technique could be an element for contributing opinions to different and extreme positions in the use of science to support agriculture.

Transgenic crops resistant to herbicides and insects achieved savings in chemical applications and effectively contribute to better environmental management. In the near future, science will do more, yet without the polemics related to transgenic technology.

Life science technology is developing extremely quickly. In 2003, when the human genome was completed, the estimated cost was nearly $4 billion USD and the entire project took ten years. Today there are companies inviting you to have your genome sequenced for approximately one thousand dollars in a single afternoon.

The genome-editing tool called CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology will revolutionize the way breeding is done. The technology is based on enzymes, which work like molecular scissors, cutting and inserting genes into an organism in a controlled way (Cong et al., 2013). This makes it possible to develop new varieties targeting new genes for resistance and tolerance to environmental stresses, such as drought, flooding, cold and heat, and improved nutritional contents.

Despite these advances in genetics and opportunities to improve the use of resources and ecosystem characteristics, Brazil is still struggling with the basics. A glance at the number of public breeders and institutions working with plant breeding in the country shows that these numbers are not increasing and that in many cases, they are declining; fortunately, private breeding is flourishing (Geraldi, 2012). However, this growth has been observed in commodity crops, such as soybean and maize, whereas for non-commodity crops there are fewer experts and investments (Ramalho et al., 2010). Cassavas and beans, for example,need more attention and investment, which must come from the public sector.

The increase in environmental changes requires a better understanding of our resources and ecosystems characteristics, which brings us to the next topic: the need for better conservation and use of the country's biodiversity. The application of genetic tools to manipulate plants becomes a high priority, but since the problems are more complex, more complex scientific teams will therefore be required. The challenge is to form teams of experts to solve problems; it is necessary to combine breeders with physiologists, geneticists, biotechnologists, entomologists and pathologists, all working together and focusing on how to manage the resources in the various ecosystems better.

Genetics has developed exponentially, private investments in important commercial crops also grew significantly, and it is now up to us to make the case for increasing investment in food security crops and crops that are important for farmers not in the major leagues.

Biodiversity

Biodiversity can be defined as the total amount of genes, species and ecosystems in a given area, region, country or even the world. The concept of biodiversity refers to three areas: the first related to the diversity among species; the second linked to the variability within species or genetic variability, which is the building block for breeding programs, and the third associated with ecosystems.

In 1992, in Rio de Janeiro, Brazil, representatives from over 150 countries signed the Convention of Biological Diversity (CBD), an agreement that expresses concerns related to genetic diversity losses worldwide and the need to join efforts and resources to prevent these losses. It is commonly understood that there is no single country self-sufficient in plant genetic resources (Convention on Biological Diversity, 1992).

The logical question to ask is, "Why are these losses a concern". The short answer to this question is, "Biodiversity is fundamental for providing ecosystem services", which in turn is essential for human well-being. Biodiversity is responsible for food security, health, clean water and energy production.

In February 2008, the Norwegian Government opened the world's largest seed-storage security facility "The Svalbard Global Seed Vault", designed to ensure against seed losses in other genebanks during regional or global crises (Fowler, 2016). This initiative was proposed with the aim of preserving the world's plant genetic diversity.

Brazil is among the most diverse countries in the world. Brazilian flora is the most diverse with approximately 55,000 species accounting for a quarter of the of the world's total number of species. The country's Cerrado, Atlantic Forest, and Amazon ecosystems are the richest plant bioms on earth. This biodiversity must be used for it to have significance for the country and the world; preservation must be a priority, but rational use must be part of national development strategies.

Brazil has been taking advantage of native and exotic genetic diversity to improve its main crops and provide choices for farmers to adapt to ecosystem changes. Even though breeders tend to focus on improved materials to maintain their breeding programs, native or wild genetic resources are crucial to national breeding strategies since they provide opportunities for new genes to be part of the genetic pools managed by breeders and solutions to cope with current and potential limitations (preventive breeding).

Despite the current legislation, which does not encourage the use of national wild genetic resources, breeders are still taking advantage of opportunities and using local diversity. The main crops where Brazil has wild relatives present in the different biomasses are Arachis, Manihot, Anacardium, Hevea, Oryza, Ipomoea, Solamun and several tropical fruits such as passion fruit. An additional challenge to breeding programs is that in practical terms, national legislation does not encourage the exchange of genetic resources with other countries, hampering the advance of those programs.

In recent decades, taking advantage of biotechnological tools, assessment of genetic diversity through molecular markers was undertaken for almost all relevant crops worldwide. These studies showed how to develop conservation strategies and more importantly, provided a better understanding of how to use this genetic diversity to develop improved varieties.

In addition to the previously mentioned benefits, diversity is also valuable for tourism. In Brazil, the exploitation of diversity as a source of income related to tourism is limited and concentrated in the South of Brazil, where the wine circuit is a good example. However, interest in this type of tourism is expanding worldwide and in Brazil, efforts should be made to leverage its enormous biodiversity. Only 10% of Brazilian flora and fauna have been described and registered (25% of the world's known plant species are found in Brazil).

Biodiversity is crucial for Brazil to continue its pathway in agricultural growth. Therefore, more flexibility and speed to exchange genetic resources are required for the country to be respected in the international arena. It is also essential to implement better strategies to collect, conserve and use genetic resources.

4. Technology and Innovation

Geraldo B. Martha Jr., Elibio Rech, Mauricio A. Lopes, Evaldo F. Vilela, Paulo Renato Cabral,[7] Cleber Oliveira Soares and Grácia Maria Soares Rosinha[8]

Brazilian agriculture and technology

The development of Brazilian agriculture over the past four decades and its positive outcomes in terms of competitiveness and sustainability have been widely recognized as a success story (Economist, 2010; Pereira et al., 2012). By and large, technology generation and adoption were key drivers in the modernization of Brazilian agriculture (Martha & Alves, 2017). Despite such progress, it is essential to advance even further along the sustainability path and to solve localized drawbacks in agricultural production (Fedoroff, 2015), and environmental and social claims (Rech & Lopes, 2012; Erb et al., 2016). It is also necessary to recognize and support "science for innovation approaches" to design feasible alternatives for "real-world" challenges and opportunities in the future.

Brazil has an abundant supply of natural resources, which have been largely protected by the enormous land-saving effects, resulting from the productivity gains in Brazilian agriculture in the past decades. An obvious key issue for the future of agriculture in Brazil is to improve the understanding of the country's biodiversity and biome characteristics and functioning (Rech & Arber, 2013), and efficiently incorporate this knowledge into agricultural systems to achieve greater production with increasing resilience and

7. President of the Institute for Innovation. Brazil.

8. Senior Researcher at Embrapa Beef Cattle. Brazil.

sustainability. Through this approach, strategies to improve ecosystems services could be better designed, and society's overall well-being will be improved while at the same time maintaining high levels of protection of Brazilian biomes. Since human perceptions and choices ultimately determine polices, decisions and courses of action they cannot be disregarded.

Broadly speaking, two major approaches in technology development can be identified: land-saving and labor-saving technologies. In the former case, biochemical advances are central, whereas mechanical technologies will be key in the latter situation. Outputs in both cases will eventually be influenced by people's ability to understand and successfully implement novel methods, tools and courses of action in a desirable direction and in a timely manner.

Land-saving technologies

Agricultural production is the result of increased area and/or increased productivity. Generally, a combination of both factors explains observable production levels over time. A key issue for future agriculture will be to promote land-saving technologies, since these approaches can greatly increase agricultural output without the need to increase the area-under-cultivation. Understanding the extent to which the rate of yield gain can be accelerated and effectively implemented by farmers, to achieve greater production, is nonetheless essential.

However, remarkable scientific advances are taking place in various fields of knowledge. Genetics typically represents as much as 40% to 50% of the contribution to yield increases in agriculture (the remainder being achieved by fertilizers and other chemicals). Therefore, many important biological functions explored through modern biotechnology can be gradually incorporated into agricultural value chains.

Great progress has already been made in genomics, cell functioning and bio-informatics. Indeed, recent advances reflect the consolidation of modern biotechnology, in genetic engineering, genomics through integrated genetic improvement by metabolic engineering, advanced reproductive technologies and animal cloning. These advances, in turn, have the potential to transform markets and increase the possibilities of developing and consolidating a dynamic bio-economy in the country (Embrapa, 2014).

Synthetic biology (Medford & Prasar, 2016; Nielsen et al., 2016), a result of the convergence of the digital world and the biological world, will pave the way for an unusual range of biopharmaceuticals, bio-inputs and bio-products (Martin et al., 2003; Rech & Arber, 2013). The new technology of genome editing called CRISPR-Cas9[9] (Zhang et. al, 2013) will have a paradigm-breaking effect on plant research, genetic engineering and crop breeding and promises to revolutionize the science of genetic modification. This technique will soon make it possible to edit genomes just as one edits a text, by removing or modifying parts of the DNA of the plant itself to modulate desirable traits.

From an agricultural systems perspective, Brazilian agriculture is dependent on imported materials and/or products derived from non-renewable sources. Fertilizers and crop protection inputs (together with improved agricultural practices) have transformed agriculture in the tropics. Nevertheless, these inputs may represent as much as 50% of production costs. Biological Nitrogen Fixation (BNF), which fixes nitrogen from the atmosphere and makes it available for plant production, as well as other "bio-input approaches", could translate into positive economic results for farmers and agricultural value chains, with fewer negative impacts on the surrounding environment.

Labor-saving approaches

Demographic trends including an aging population and sustained migration from rural areas to the cities have been identified (UNPD, 2015). Labor in agriculture is, thus, expected to become increasingly scarce. Insufficient schooling years and technical training limit laborers' ability to deal with more complex technologies and will further exacerbate labor scarcity in rural areas.

9. "CRISPR stands for Clustered regularly-interspaced short palindromic repeats, and represent segments of bacterial DNA that, when paired with a specific guide protein, such as CAS-9 (e.g., CRISPR-associated protein 9), can be used to make target cuts in an organism genome" (Collins et al., 2016).

These signals clearly reflect the increased demand for automation, mechanical technologies and robots in agricultural value chains to better manage the labor shortage and pressure on salaries, positively contributing to labor-productivity growth. The advancement of Big Data and precision agriculture (or site-specific management systems) will not only require novel mechanical/automation technologies, but also demand intensive and sophisticated managerial innovations in Informations and Communications Technologies (ICT).

Climate change, bio-economy and non-technological factors

Enormous challenges still lie ahead as agriculture is simultaneously forced to focus on competitiveness and sustainability. Climate change, for instance, affects agricultural value chains and may place pressure on all its components, e.g., from natural resources, to farm and industrial production and competitiveness, and ultimately to consumers.

In the long run, climate change impacts on Brazilian agriculture are expected to translate into a complex spatial dynamics of reduction and expansion of agricultural areas, in a challenging (and unpredictable) production environment. In this context, strengthening research and innovation systems is essential to allow technological progress to advance at least at the equivalent rate at which the climate imposes negative changes on the production environment. In this scenario, negative consequences could be avoided, or at least kept at acceptable levels (Embrapa, 2014). More research is needed to mitigate the effects of extreme weather events, increase systems' resilience and allow adaptation to new scenarios of heightened biotic and abiotic stress, as well as energy insecurity.

The future, however, also promises enormous opportunities for strengthening comparative advantages, income generation and job possibilities in Brazilian agricultural value chains. Bio-economy is a good example. The broad variety of biomass (such as sugar cane, sweet sorghum, tropical fodder palm-trees and co-products) offers real opportunities for the development of value chains based on high value-added materials and substances targeted for food, feed, flavors and non-food uses (chemical and biochemical, medical and pharmaceutical, nutritional and energy). Chemical-bio-catalytic processes lead to the development and use of microbial catalysts that directly convert raw materials into a range of products and chemical intermediates which, in turn, can be subsequently converted into new products with high value-added potential (Embrapa, 2014).

Fostering a bio-economy strategy in the country would eventually boost the growth of associated capital-goods industries, engineering services and biomass suppliers in food, feed, chemistry and pharmaceutical value chains, and create opportunities for expanding higher value-added exports. Both the search for greater efficiency and production linkages in well-known sectoral dimensions, as well as the search for novel biodiversity uses, in order to deliver innovative products and processes, associated with increased productivity and higher-quality jobs, should be pursued (Embrapa, 2014).

It is also important to realize that the ability of technologies to foster agriculture competitiveness is not only limited by scientific knowledge, but also by non-technological factors. Bottlenecks in logistics, storage and transport infrastructure, availability and cost of energy, among other factors, may act as severe headwinds to technology adoption.

The Role of Youth Innovation for Sustainable Food Production

Brazilian research increasingly takes place within a network, which has encouraged multi-disciplinarity and made it possible to break down the barriers that previously isolated subjects. Today, robotics and agriculture work together, as do computing and microbiology and other fields. In turn, the gap between universities and industry is narrowing due to a growing startup movement. Small companies created by students and their mentors, motivated by dreams of starting their own businesses, have been turning the results of doctoral research projects and their patents into business. This is a new technology-transfer model that brings knowledge generated by research to the market. Faster and less costly, it makes patents created through projects into a reality, fast-tracking innovative products and processes. Startup culture has the ability to solve market problems, encouraging projects to incorporate a market focus into their methodologies, which may involve a challenge or a problem that affects agriculture activities or its producers.

In this context, the Youth for Sustainable Food Award, a strategic initiative for the Forum for the Future Institute, seeks to align the perspective of young talents in Brazilian universities and their entrepreneurial capabilities, in a scenario of opportunities created by the need to increase the production, productivity and nutrition effects of grains, fruit, meat and other food products. The Youth for Sustainable Food Award is a cornerstone for the discovery of new talents which, once nurtured and monitored, will be able to generate technological solutions, as well as small companies with enormous potential for the agricultural and livestock system. The World Bank's decision to expand The Youth for Sustainable Food Award from Brazil to the whole of Americas reflects the Bank's effort to create opportunities at a critical moment for a region that needs to generate wealth. Through this strategy, the country will enable the materialization of ideas and technologies through the following process:

Project Promotion at universities and research centers

Selection and presentation of awards for the best projects

Pre-acceleration of projects from idea/technology to market tests

Acceleration of proposals that show market compliance

Following the selection and awarding process, the pre-acceleration stage, which includes market and management consulting, offers groups the opportunity find out about the value chain where the technology will be inserted, as well as the target market and the tests required for the implementation of technologies that will contribute to the production of sustainable food, from a food and nutrition security perspective. At the acceleration stage, projects that have demonstrated market compliance, that is, the technology and knowledge that have proven practical and feasible for implementation will be supported. Projects that have reached this stage will undergo tests to determine their market acceptability and technology prototyping with the final customers. The connection to the final-customer demands from the methodology and the ability to speak with agroindustries – producers and suppliers of agricultural supplements, seeds, fertilizers, vaccines, livestock feed and others – involves enormous coordination with R&D teams from companies that take an interest in innovation and the development of new business.

Through this strategy, recently graduated Ph.D. students, for example, will receive the necessary support to effectively bring the results of scientific and technologic research to society. Recent examples of successful startups in biological pest control, for example, include PROMIP (predatory mites) from ESALQ/USP (Faculty of Agronomy of the States University of São Paulo - Brazil), and RIZOFLORA (biological nematicide) from the Federal University of Viçosa. Both companies were recently sold to investors.

Animal Agriculture
The role of biotechnology

Research, Development and Innovation (R&D&I) have contributed to improving quality protocols from good agricultural practices to integrated production systems through traceability and certification. The target is to establish and enhance crop-livestock-forest integration technologies to develop future-bearing technologies (biotechnology, nanotechnology, genomics, proteomics, bioinformatics), provide tools for Information and Communications Technologies (ICT), advance precision livestock farming, explore energy efficiency in production systems, reduce GreenHouse Gas (GHG) emissions, reclaim pastures, and develop technologies for genetics, nutrition, animal health and farm management (Soares, 2014).

In this context, biotechnology has made an outstanding contribution and could continue to contribute to increase animal productivity in Brazil (**Figure 4**) through the increasing use of animal-breeding biotechnologies (traditional artificial insemination, artificial insemination at fixed times, embryo sexing, manipulation and transfer and animal cloning). It also will continue playing a role through the improved use of molecular marker panels for production phenotypes in beef and dairy cattle and the use of enzymes and microorganisms that improve ruminant and monogastric digestive efficiency, and the use of genomic selection associated with EDP (Expected Differences on Progeny), which accelerates the breeding and genetic improvement of livestock.

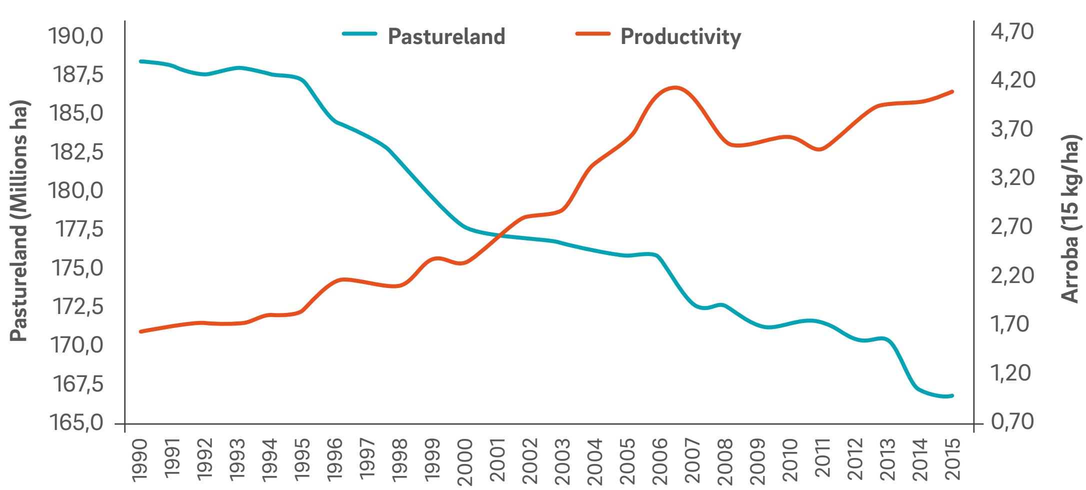
Pest and diseases

One of the major challenges for food security is preventive Veterinary Medicine to address the risk of biological pathogens, especially those that are easily dispersed as well as exotic ones. Moreover, the search for ante-mortem diagnostic methods, the development of inputs for prevention, surveillance and the control and treatment of diseases play a key role in food security, as well as in controlling the spread of diseases in production, biohazards and those leading to sanitary barriers. In this context, advanced biology, whether through biotechnology, or nanotechnology and bioinformatics has advanced greatly in Brazil, making effective contributions to animal production. Moreover, this process should be stressed in the future actions of Research&Development&Innovation (R&D&I), to ensure sustainable increases in yield and the agri-food production system.

Advanced biology techniques have been routinely used to develop materials and tools for animal health. Pathogens causing diseases that affect food value chains, such as viruses, bacteria and parasites, have been diagnosed, monitored and prevented using the most modern approaches in future-bearing sciences. New genes, proteins and other biological inputs (enzymes, carbohydrates, glycoproteins, amino acids, chimeras, etc.) of these and other strategic pathogens have been used for diagnostics and vaccines (Melo et al., 2015; Viale et al., 2016). Advances in these techniques must be capitalized by research organizations to stay ahead in the development of agricultural sciences.

A major contribution of these technologies has been mapping the resistance and susceptibility of animals to TSE, diseases with a high impact on the economy of countries producing animal protein since they are of great

Figure 4. Brazil: Pastureland vs Productivity of Beef Cattle, 1990-2015



Source: Agroconsult, based on IBGE and indicators.

concern to global food security, especially scrapie in sheep and goats and Bovine Spongiform Encephalopathy (BSE) in beef and dairy cattle. These tools not only help genetic selection, but also breeding programs, epidemiological risk analysis, prevention and programs of these and other diseases (Galvão et al., 2012; Gonçalves et al., 2016). This innovation is a great example of how biotechnology and innovation have helped ensure food and nutrition security in Brazil. Using these technologies has helped the country continue to be rated as having negligible risk for BSE from the World Organization for Animal Health (OIE, 2016). This ensures nutrition, health and the safety and quality of food for domestic consumption and export. The Brazilian agricultural research system will continue addressing the challenges to keep agricultural production increasing over time, by generating and adapting novel technologies to increase agricultural production in a sustainable way.

Prospects for novel agriculture products

Worldwide, the agricultural sector primary mission is to produce food, fiber and energy in a sustainable manner, without impacting biomes, striving for the conservation of biological and natural resources. This is the appeal of sustainable tropical agriculture. Within this approach, Brazilian R&D Organizations have been developing technologies and should continue along this path to food sustainable production, through integrated Crop-Livestock-Forest Systems (ICLFS), sustainable farming, the modern "Carbon-Neutral Brazilian Beef" concept, and other sustainable technologies.

These systems constitute innovations in Brazilian agriculture and are the pillars not only for increasing yields, with the aim of saving/optimizing land use while adding value to products, but also for mitigating Greenhouse Gas Emissions (GHG). They are therefore the most robust technologies for the future of sustainable agriculture in the tropics. Animal welfare is another highlight of Brazilian cattle systems. It makes it possible to reach and supply the most demanding consumer markets, which are interested in beef from grazing systems, also called "grass-fed beef" and "grass-fed milk" where it is crucial to turn an intangible feature (welfare) into a tangible one (final product quality). Research organizations must now address the challenge of mastering and generating innovative production systems to ensure food security domestically and abroad.

In this context, emphasis has been placed on multifunctional production systems such as ICLFS, which, in addition to helping reclaim low-yield degraded areas and pastureland, offer direct and indirect benefits to animals, such as providing shade and improving microclimate and local environmental conditions. These aspects have a positive impact on animal welfare and have become closely associated with prime end-products. According to the type of trees (native and exotic) and spatial arrangements (single, double or triple tree rows), there is a decrease of 2°C to 8°C in local temperatures within ICLFS systems, when compared with pastures without trees. As a direct result of the thermal comfort provided, there is improvement in productive and reproductive performances (Karvatte Jr. et al., 2016).

These concepts have contributed to the implementation of sustainable livestock-production systems, especially regarding environmental aspects, through the introduction of a forestry component, capable of neutralizing the methane emitted by cattle. This adds value to beef and other products generated in these systems. It also attempts to confirm the strategic importance of sustainability for associated supply chains (beef, grains and forestry), to promote the use of integrated systems, therefore optimizing the use of inputs and production factors, with positive effects. The "Carbon-Neutral Brazilian Beef" label is a trademark concept that certifies that a given beef load had its GHG emissions neutralized during the farming phase by cultivating trees under integrated silvopastoral (forestry-livestock) or agrosilvopastoral (crop-livestock-forestry) systems. The whole production process is parameterized, audited and certified. Therefore, research should continue attempting to obtain new labels for other products and adding value for agricultural production in worldwide markets.

Technologies such as these are realities in Brazilian cattle production systems, which together have created green cattle farming, a new revolution in the way sustainable beef, milk and their products are produced in the tropics, while contributing to a virtuous carbon cycle.

Other major challenges

The United Nations Organization called for Brazil together with the Southern Cone to supply 40% of world's food demand over the next few years. Sustainable increases of yields is a known alternative for increasing the world's food supply, without clearing new land. This is the basic concept to be further developed by the tropical sustainable-agriculture systems. In this regard, Brazilian private and public institutions have been tackling the challenge of developing sustainable farming practices such as integrated crop-livestock-forestry systems and the "Carbon-Neutral Brazilian Beef" initiative, among other emerging sustainable technologies.

Moreover, food safety throughout the beef production chain, ensuring improved health and nutritional standards, is another important challenge for ensuring food security worldwide. It is necessary to support future-bearing technologies, especially those related to biotechnology, nanotechnology, synthetic biology, and ICT, among other tools. Furthermore, agricultural sciences seek to develop cultivars, breeds and superior genetics for the large-scale production of fortified foods with improved nutritional quality and nutraceuticals.

5. Increasing Efficiency of Food Systems Chains

Antônio Márcio Buainain[10]

Introduction

Future demographic and economic scenarios indicate that the production chains of Brazilian agribusiness will be subjected to a great deal of pressure, and will have to address the two-fold challenge of quantity and quality. On the one hand, the system will have to produce agricultural products and raw materials in sufficient quantities to meet growing demand, while complying with the quality standards and characteristics required by markets and society in general. On the other hand, the increase of agricultural production will be contingent on a set of increasingly demanding and taxing restrictions and regulations posed by a new group of existing institutions, concerned with the competitiveness of global production chains, sustainable use of natural resources, social production relationships, preservation of biodiversity and equity (Buainain, 2014).

This new context implies radical changes in the growth pattern of agricultural production and in the dynamics of agribusiness production chains. Until recently, supply growth was based on two axes: the incorporation of new lands and technological innovation, with little concern for the sustainable use of natural resources - with the exception of the successful dissemination of direct planting techniques, which currently benefit over 33 million hectares (**Figure 5**) of areas-under-cultivation. Forests rich in hardwood and precious biodiversity were burned to give rise to fragile pastures resulting from a logic focused more on land appropriation than the creation and consolidation of wealth.

Similarly, technological innovation focused on increasing productivity and/or reducing costs, especially by reducing labor. However, this dynamic was based on a short-term microeconomic vision, with practically no concern for negative externalities and the lack of broader sustainability. Thus, many chemical inputs that were important for increasing production also polluted the environment, leaving toxic residues in food products and creating other negative effects. In many locations, inadequate use of irrigation resulted in soil salinization and water-table pollution, making them practically infertiles. Moreover, excessive mechanization and trampling due to intensive livestock farming compacted soils, causing erosion and fertility losses.

In practice, the production systems adopted so far resulted in a vicious circle that demanded the incorporation of increasing amounts of land and technology to offset losses in productivity

10. Ph.D. in Economics Associated Professor at the Economics Institute of the University of Campinas, State of São Paulo, Brazil, and Senior Researcher at the National Institute for Science and Technology in Public Policies, Strategy and Development – INCT-PPED.

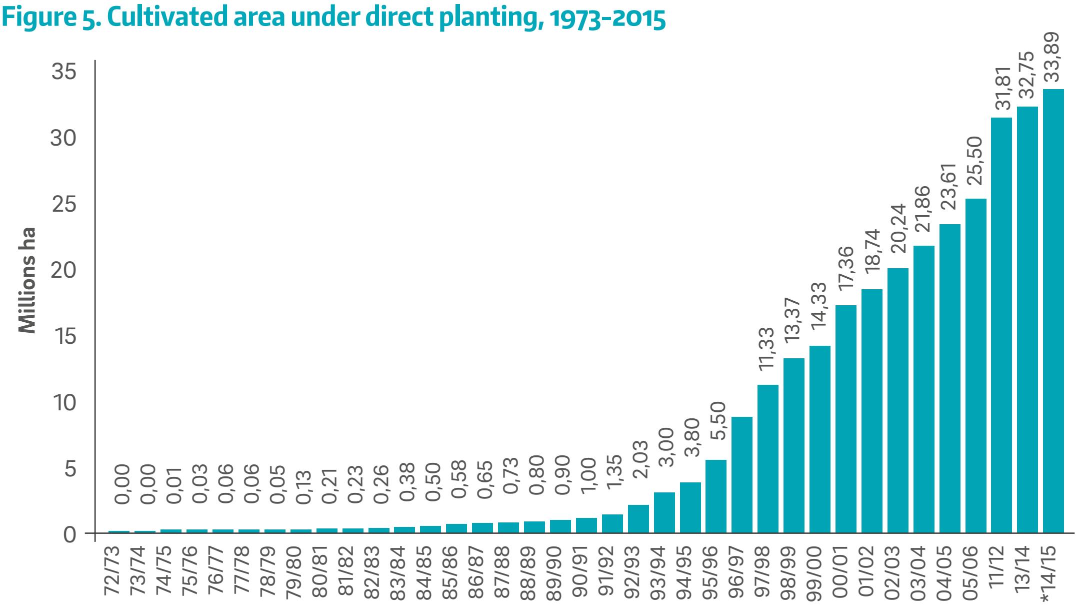
caused partly by the very low productive system and technology employed. Efficiency was not the focus, not beyond a strictly micro point of view, and even then, was limited to the short- and medium-term. It seemed it would always be possible to compensate for the loss in fertility through the incorporation of new land and new technology, and to make up for negative externalities with innovation. The aim here is obviously not to criticize the past, particularly since this took place within a different historical context, but to recognize the unsustainability of that production pattern and identify future challenges and opportunities for a paradigm shift.

Challenges and opportunities to increase the efficiency of food chains

In the current situation, marked by severe environmental and institutional restrictions, systemic efficiency takes a central role when it comes to addressing the food challenge. In contemporary society, it is no longer possible to only consider technical parameters to inform decisions regarding what, how much, how and for whom to produce. We must bear in mind the fact that nowadays, these decisions must obtain social approval through a wider and more complex mechanism than markets, which in the past enjoyed practically sovereign powers when it came to approving or rejecting decisions from economic agents.

In this new context, it is not enough for a technology or a productive plant to be efficient from the technical and economic standpoint. They must also be pre-approved by society, whose opinions are represented by interest groups, social movements, advocates for specific causes, consumer protection organizations, NGO, and public and private regulatory agencies. This dynamic places certain constraints on the traditional expected results of technological efficiency, since decisions made by the public and private sectors are based on contexts that emerge from the power play involving stakeholders which would not necessarily pass any tests considering rationality, cost-benefit and economic feasibility. These decisions are often full of contradictions and antagonisms, but are still legitimate in the context of democratic societies. This means the challenge of increasing the efficiency of agribusiness production chains is not limited to technical aspects, and must necessarily incorporate their social, environmental and political dimensions; and also, that this operation requires reconciliation of conflicting interests.

Figure 5. Cultivated area under direct planting, 1973-2015



Source: Embrapa/SGI.-September/2016

Despite the progress made by Brazilian agribusiness, there are still enormous opportunities to increase efficiency, at every stage of the production chain, from producer to the final consumer. In farms, increasing efficiency in agriculture involves the following lines of action:

i. Investment in the expansion of the innovation frontier, focusing on working with the most dynamic, technologically advanced producers, reducing waste and external consequences and improving the conservation of natural resources; and creating economies of scope by using and re-using waste and recovering by-products. We can already see some positive and promising trends in this field, such as 356-day agriculture, which enables nearly continuous use of the land through the year, the partial and full use of crop-livestock-forest integration systems, and precision agriculture. On this front, investment in R&D are the most important, although not the only, determinant of potential and real efficiency gains.
ii. Investing in the increase of average efficiency, exploring internal frontiers through efficiency gains for producers who are lagging behind. This will probably be a more complex challenge than the first. The relative delay is not caused by the lack of appropriate technology for the conditions faced by producers/regions with lower efficiency, but to the lack of conditions for innovation, which involves a wide range of variables and the environment itself, which is not conducive to innovation. The effort here is to focus on the key factors that hamper the incorporation of innovations that are already widespread in the country, such as financing, rural extension and technical assistance, training, market access and institutional strengthening.
iii. A key source for increasing system efficiency is the incorporation of resources that are currently idle but have the potential to be used. Some of these idle resources, abandoned because of previous unsustainable use or due to becoming economically unfeasible, for various reasons, could be efficiently reincorporated into production, using means made available by the technical and scientific progress made in the past 25 years. There are also resources that were never part of the system, such as idle lands in the suburbs and urban and domestic allotments. This involves the use of "neglected resources", which were redundant in the previous context of abundant resources, and whose utilization has been made feasible by new institutions and their determinants. This is a new agriculture, already a reality in many urban areas and countries, which tends to grow as restrictions on deforesting increase and the sustainability paradigm is implemented.

Another source of efficiency increase is the infrastructure and logistics of agribusiness chains, which have an enormous deficit with various effects on efficiency (Oliveira, 2014). From a micro point of view, the most important factor is the deficit in storage capacity, which prevents producers from taking advantage of market changes to buy and sell inputs and products at the best possible time. Likewise, effective access to electric energy in rural areas would enable significant efficiency gains for producers, especially in activities where refrigeration is relevant, such as the production of dairy products, fruits and vegetables.

From a more systemic point of view, beyond the limits of the farm, the greatest deficit and potential source of efficiency gains lies in transportation logistics. This deficit has many implications beyond elevating costs with inputs and reducing the price paid to the producer, due to the application of a discount on the reference price, equivalent to transport costs. It is also responsible for production losses along transport corridors, quality losses, animal welfare losses and high risks, including the risk of contamination, adulteration, theft and accident, which cannot always be compensated for by costly insurance. This is one of the reasons for the presence of extensive livestock farming in many areas, and for the infeasibility of small-scale production in others. In fact, small producers, who could use these resources in an intensive, sustainable and efficient manner, are excluded from it due to their inability to access the markets. Contrary to common belief, the problem is not the scale, but rather the logistics of transport, which involves high costs, therefore limiting the feasibility of transactions with higher-scale producers. The availability of a wide road network, including local roads, would reduce this disadvantage and make the intensive utilization of resources possible for small- and medium-scale farmers.

There is a very high level of waste at all levels of the food chain. This begins with the producer, who wastes some of the harvest/production due to handling issues, lack of infrastructure, information access. It happens again during transportation from the farm to commercial points, with grains falling off trucks, cold cargo compromised during transport routes and cargo theft. During storage, technical breaks may also be higher than justifiable, due to poor drying, precarious facilities and power outages. During processing, many products are still only partially used. This could be greatly improved, with considerable efficiency gains associated with economies-of-scope. In addition, in the distribution stage, the waste can be shocking. To see this, all you have to do is to visit the facilities of the Central Market Distribution Center (CEASA) at the end of the day, or walk by the waste containers of a supermarket chain. This loss is not limited to fruits and vegetables, as may be assumed, but also includes expired food products and storage problems in commercial venues themselves. Finally, we have the consumer, especially those with higher incomes, raised in a culture of abundance and high inflation, who do not concern themselves with the goal of avoiding food waste.

Final remarks

Any analysis of the possibilities of increasing efficiency in the Brazilian food-production system must consider one of the main sources of loss of the efficiency in international competitiveness in the national agricultural food system, due to the Brazil Cost. This cost includes excessive bureaucracy, a logistics deficit, high interest rates and high transaction costs related to judicial insecurity and institutional risks, which affect Brazilian society and its economy. Macroeconomic policies, marked by the legacy of inflation and the tension between fiscal responsibility and populist expansionism, maintain a certain bias of taxation over agricultural production, leading to pecuniary losses for producers and consumers.

In conclusion, there are opportunities for efficiency gains at every stage of the agribusiness chain. These opportunities represent an enormous frontier for production expansion and must be explored as part of the sustainable development challenge. The challenges we face today demand new institutional agreements to mobilize resources and powers that exist far beyond the capacities of the state. In this regard, it is the State's duty - an innovative duty in the Brazilian context - to create a favorable environment for the innovation of encouraging the sustainable mobilization of resources from the private sector to finance and enable actions consistent with the country's macro strategic objectives; and to promote public-private cooperation and partnership in research and development, overcoming the traditional view that places the main burden either on the state or on the private sector. In the case of Brazil, the efficiency and sustainability of the agri-food system is also linked to the capacity of decreasing the structural heterogeneity characteristic of agriculture and of incorporating a significant number of producers who were left on the sidelines of the progress that occurred in the past few decades, and which could be viable with the support of steady improvements in institutional arrangements and consistent policies (Vieira Filho and Gasques, 2016).

6. Health Considerations

Marilia R. Nutti[11] and Cleber Oliveira Soares

Foodborne Diseases

There are approximately 250 types of FoodBorne Diseases (FBD), many of which are caused by pathogenic microorganisms responsible for serious public health problems and significant

11. Senior Reseacher at Embrapa Food Technology.

economic losses. The syndromes resulting from the ingestion of food contaminated by these microorganisms are known as FBD (WHO, 2003; Popkin & Larsen, 2004). FBD can be identified when one or more persons present similar symptoms after eating food contaminated with pathogenic microorganisms, their toxins, toxic chemicals or harmful objects, forming a common source. In the case of highly virulent pathogens such as *Clostridium (C.) botulinum* and *Escherichia (E.) coli* O157: H7, it is assumed that a sole case can be considered an outbreak (WHO, 2004; Claro et al., 2015). Most outbreaks have been linked to the intake of foods with good appearance, and odor without any visible organoleptic change. This is because the dose infecting foodborne pathogens is usually less than the amount of microorganisms needed to degrade food. These facts make it difficult to trace food outbreaks, since consumers find it difficult to identify the source of FBD.

The lack of a specific association between the other foods and etiologies highlights the potential roles of cross-contamination, environmental contamination and the role of the infected food handler along the food chain from farm to fork (Claro et al., 2015). In Brazil, the epidemiological profile of FBD is little known. Only a few states or municipalities have statistics and data on etiological agents, the most commonly affected foods, and populations and high-risk populations. According to the available data on outbreaks, they are usually of bacterial origin, involving *Salmonella* spp., *E. coli, Staphylococcus aureus*, *Shigella* spp., *Bacillus cereus* and *Clostridium perfringens* (Ministério da Saúde, 2011).

Food security, the sound health of herds, the safeness and security of supply chains, biosecurity of food and the risk of bioterrorism have become matters of global concern. At the same time, the development and intensification of animal breeding, health and nutrition management through genetic improvement programs, better husbandry practices and the generation of more efficient inputs contribute to increasing yields while promoting food quality and safety in Brazil.

Meat, milk and their derivatives are the most important dietary components for humankind and are strategic for the Brazilian economy, since Brazil is a major producer of animal protein and the world's largest beef exporter (Abiec, 2016). However, these foods account for most of the pathogens transmitted to humans, causing FBD. In Brazil, with a population over 200 million people, 6,632 FBD outbreaks, with 118,104 patients and 109 deaths, were reported between 2007 and 2016. Most of these outbreaks were caused by bacteria, *Salmonella* spp. being the main agent, followed by *E. coli* and *S. aureus* (BRAZIL, 2016).

Among ruminants, Transmissible Spongiform Encephalopathies (TSE) is a matter of worldwide concern. These rare diseases caused by prions that affect humans as well as domestic and wild animals. They are neurodegenerative and lethal, with long incubation periods. Bovine Spongiform Encephalopathy (BSE) is the most important TSE, since it is considered a zoonosis. Since the diagnosis of BSE in several countries in Europe and North America, and the hypothesis of a relationship between this bovine disease and Creutzfeldt-Jakob Disease (CJD), as a new variant of a similar disorder in humans, biosafety in the cattle production chain has become a focus of attention for both consumers and the beef industry. In this context, and despite the occurrence and record of BSE in the world, including the Americas, risks of existence and occurrence of this serious disease in Brazil are insignificant.

Brazilian beef and milk production systems are almost exclusively based on pastures, resulting in a comparative advantage through relatively low production costs as well as a competitive advantage from farming "green cattle", which is a safe product, with quality features highly valued by the market. Thus, the country is exploring the potential of cattle farming in pastures, while ensuring sound animal health and preventing TSE in Brazilian herds. Given these productive and technical factors, Brazil has been classified by the OIE (World Organization for Animal Health) as a country with negligible risk for BSE (OIE, 2016).

Transition/Overconsumption

Since the second half of the 20th Century, favorable conditions for the occurrence of infectious diseases have been gradually replaced by a favorable scenario for the occurrence of Chronic Non-Communicable

Diseases (NCD) including obesity, diabetes mellitus, CardioVascular Disease (CVD) such as hypertension and strokes, and certain types of cancer related to excessive/unbalanced food consumption and/or insufficient physical activity. Chronic NCD are increasingly becoming significant causes of disability and premature death in both developing and newly developed countries, placing additional burdens on already overtaxed national health budgets (WHO, 2003). This scenario is visible in both developed countries and developing countries, including Brazil (Popkin & Larsen, 2004). In this context, the 2003 Global Strategy of the World Health Organization (WHO) for Diet, Health and Physical Activity reinforces the need for improvement of the world food-consumption pattern, focusing the reduction in the consumption of foods with high energy, low levels of nutrients and high levels of sodium, saturated fats, trans fats and refined carbohydrates (WHO, 2003; WHO, 2004). The Global Strategy indicates that to achieve the best results in preventing chronic diseases, the strategies and policies that are applied must fully recognize the essential role of diet, nutrition and physical activity (WHO, 2003).

Claro et al., 2015, found that studies on Brazilians'' eating habits trends in the last decades emphasize the increase in the consumption of meat and industrialized foods (soft drinks, cookies and frozen meals) and the reduction in the consumption of pulses, roots and tubers, fruits and vegetables. Based on these facts the Ministry of Health developed, along with other measures, the 2011-2022 Brazilian Strategic Action Plan to Combat Chronic Non-Communicable Diseases (NCD) in 2011, and re-edited the 'Dietary Guidelines for the Brazilian Population: Promoting a Healthy Diet', in 2014. (Ministério da Saúde, 2014).

The 2011-2022 Strategic Action Plan to Combat Chronic Non-Communicable Diseases (NCD) in Brazil, from the Ministry of Health, prioritizes the reduction of the population's exposure to risk factors, and incentives for protective factors, aiming at expanding measures to protect health: creating spaces for engaging in physical activity, prohibiting cigarette advertisement, creating smoking-free places, in addition to supporting healthy lifestyles for a better quality of life and well-being among the population (Ministério da Saúde, 2011). The latest edition of the "Dietary Guidelines for the Brazilian Population: Promoting a Healthy Diet", in 2014, emphasizes the consumption of *in natura* or minimally processed foods, especially vegetables, over soft drinks and sweets.

Preventive actions against NCD to promote health should take into account diet, nutrition and physical-activity factors, suggesting an alliance between the Ministry of Health, the Ministry of Agriculture and the Ministry of Education, in terms of their respective roles in establishing dietary guidance, policies regarding production of healthier foods and advocacy for healthier diets and physical activities.

Nutrition-sensitive Interventions

The acceleration of progress in nutrition requires effective, large-scale nutrition-sensitive programs (Ruel & Alderman, 2013). So far, most efforts to fight micronutrient deficiency in developing countries have focused on providing vitamin and mineral supplements for target populations and on fortifying foods with these nutrients (Nutti & Viana, 2015). Targeted agricultural programs can complement these investments (Ruel & Alderman, 2013).

The introduction of bio-fortified crops – varieties bred for increased mineral and vitamin content – could complement existing interventions and provide a sustainable, low-cost way of combatting malnutrition. In Brazil, research and development of bio-fortified foods have highlighted a unique aspect - Brazil is the only country where eight different crops are studied at the same time, namely squash, rice, sweet potatoes, beans, cowpeas, cassava, maize and wheat in an attempt to obtain more nutritious cultivars with good agronomic qualities and market acceptance (Nutti & Viana, 2015).

The project has been prioritizing the states of Maranhão, Piauí and Sergipe, due to their low Human Development Index (HDI) compared with the other states. Approximately 200 researchers, technicians and partners are engaged and 11 cultivars have been developed with higher iron, zinc or pro-vitamin A since 2005. Around 120 demonstrative units have been implemented, reaching an average of 20,000 people. By 2018, the target is to reach 1 million households, equivalent to approximately 4 million people (Nutti & Viana, 2015).

Nutrition-sensitive programs can help create an environment in which young children can grow and develop to their full potential. When combined, early child development and nutrition interventions show promising synergistic effects that could lead to substantial improvements in efficiency, effectiveness and cost effectiveness (Ruel & Alderman, 2013).

7. Policy Considerations

Geraldo B. Martha Jr. and Cleber Oliveira Soares

Introduction

Brazilian agricultural policies have traditionally prioritized rural credit, agricultural research and rural extension. Rural extension, in fact, lost impetus in the 1980s and in the 1990s, and had a poor outcome from the 2000s onward. These policies were largely designed and implemented to alleviate the distortionary pressures imposed on the agricultural sector by the policies implemented to protect Brazil's national industry, especially from the 1960s to mid-1980s. After that period, the scope of agricultural sectoral policies was thoroughly reviewed and curtailed to accommodate the lack-of-resources reality brought about by the country's severe macroeconomic crises in the 1980s and 1990s (Martha & Alves, 2017).

In the past two decades, a set of novel policies and actions were implemented to improve the planning and financing of agricultural production in the XXIst century. The Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA), in coordination with other key ministries, has been able to offer opportunities to finance investments in cooperatives, machinery purchasing, irrigation systems and storage facilities. Increasing emphasis has also been placed on risk management (insurance) and marketing approaches.[12]

Policies targeting family and medium-sized agriculture, as well as policies to foster the adoption of better and improved agricultural practices, with reduced negative impacts on the wider environment, have gained increased attention. For example, one of the major policies for Brazilian agriculture over the past five years has been MAPA's Low Carbon Agriculture - ABC Program. The funding of this Program is intended to enable farmers to invest in technologies to increase systems' resilience, to improve the conservation of natural resources and to reduce the intensity and overall Greenhouse Gas Emissions (GGE) in Brazilian agriculture. This program has become a world reference in recent years.

Food policies have been implemented to offer nutrition assistance by providing affordable food for the poor population. Additionally, the nutritional perspective (malnourishment versus obesity), considering consumers' diets and their quality, has been a growing trend in policy-making (Embrapa, 2014).

Until the late 1990s, incentives for Brazilian agriculture were negative because of the transfer of resources from agriculture to other sectors – particularly to industry. On the basis of the the Organization for Economic Cooperation and Development (OECD)'s data, it is possible to calculate that the annual level of incentives to Brazilian agriculture – the Producer Support Estimate (PSE) – averaged only 1.6% of farms' gross incomes from 1995 to 2014. This clearly indicates Brazilian agriculture's enormous vulnerability to market signals, meaning that technologies and production decisions, whatever the goal (food and nutrition security in domestic market or abroad, biomass for energy or bio-industry, etc.), will strongly respond to farmers' perception of relative prices.

12. For example, tools and mechanisms to avoid dramatic fluctuations in farmers' income and consumer prices (minimal pricing policies, governmental stocks, etc.) were part of the agricultural policy portfolio. For details, please see MAPA's agricultural policy approach at http://www.agricultura.gov.br/politica-agricola.

Brazil's National Food and Nutrition Security Plan

Over the past decades, Brazil successfully transformed its agriculture and significantly improved the availability of high-quality food for its population (**Figures 3 and 6**). Nevertheless, the share of the population facing severe food insecurity in the country still amounted to 7.2% of the population in 2013 (IBGE, 2016). This situation must obviously be addressed to achieve a complete food-security scenario in Brazil.

Brazil launched in 2011 the first National Food and Nutrition Security Plan. Following the analysis of results and achievements for this first policy cycle, an updated and reviewed plan was made available in 2016 - the "Second National Food and Nutrition Security Plan".[13] The plan derived from the 5th National Conference on Food and Nutrition Security, held in November 2015, under the coordination of the National Council for Food and Nutrition Security (CONSEA).

The Second "National Plan for Food and Nutrition Security" has a time horizon from 2016 to 2019, and consists of 121 goals and 99 related actions that were structured according to nine major challenges: (1) to promote universal access to adequate and healthy food, prioritizing the population under a food and nutritional insecurity condition; (2) to combat food and nutritional insecurity and to foster the productive inclusion of vulnerable population groups, such as traditional communities and persons and other vulnerable populations; (3) to promote the production of healthy and sustainable food, the structuring of family agriculture and the strengthening of agroecological production systems; (4) to supply and provide regular access to adequate, healthy food to the Brazilian population; (5) to promote and protect adequate and healthy food for the Brazilian Population, with strategies for food and nutritional education and regulatory measures; (6) to prevent and control injuries and health problems due to poor diets; (7) to improve water availability and access for the population, especially the rural poor; (8) to consolidate the implementation of the "National Food and Nutrition Security System (SISAN)" through improved federal management, intersectoral relationships and social participation, and (9) to support initiatives for promoting sovereignty, food and nutritional security and human rights to adequate food, and democratic, healthy and sustainable food systems at the international level, through dialogue and international cooperation.

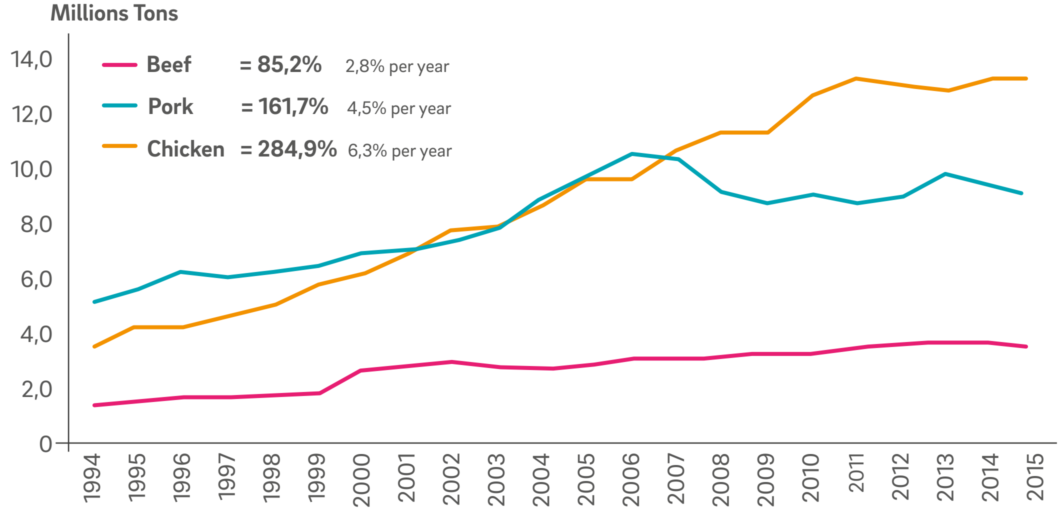
Policies-at-large

During the modernization of agriculture, the sector progressively became more exposed and affected by generic policies, such as monetary policies, the exchange rate and income policies. As "macro-prices" change they eventually translate into fairly challenging investment perspectives for entrepreneurs (business and financial risks) and ultimately, into the success of businesses. By reducing risks, more stable, predictable and sound generic policies will in due course favor investments along the agricultural value chains. From the perspective of the agricultural sector, strengthening the insurance system and its effectiveness is a top priority.

The research-driven strategy behind Brazilian agriculture offered the necessary flow of knowledge and technologies, which in turn, provided farmers with the tools they needed to transform traditional agriculture into a highly competitive, increasingly sustainable sector based on science and technology. Strengthening investment in agricultural R&D will be crucial to Brazil's prospects for agricultural production and sustainability, food and nutritional security and macro-economic stability and economy growth. An important approach to be emphasized and pursued is to sizably increase the private sector's investments in agricultural R&D activities. Sometimes the private sector will undertake R&D activities on its own but sometimes this will happen in partnership with the public sector. In the end, the overall objective is to make Brazilian agriculture more resilient to upcoming biotic and abiotic challenges, and better prepared to leverage future opportunities (Martha et al., 2016).

13. For details, please see information available at: http://www4.planalto.gov.br/consea/comunicacao/noticias/2016/plano-nacional-de-seguranca-alimentar-e-nutricional-ja-esta-disponivel-na-internet

Figure 6. Brazil: Beef, Chicken and Pork Production, 1994-2015



Sources: Conab. Reference Source: Embrapa/SGI.

Last, but certainly not least, the ability of technologies and human capital to foster agricultural sustainability and competitiveness is not only limited by scientific knowledge and marketable abilities, but also by non-technological factors. Bottlenecks in logistics, storage and transport infrastructure, the availability and cost of energy, among other factors, such as the lack of qualified human capital in agriculture, will work as headwinds to successful technology adoption, agricultural expansion and a more food-secure scenario. Perhaps less evident, is the need to focus on reducing market imperfections to ensure that modern technologies will be effectively adopted on different scales and in a more inclusive way on Brazilian farms.

8. Further Challenges and Achievements

Geraldo Magela Callegaro[14]

A comprehensive analysis of the main science and technology indicators for agricultural research and development in Brazil presented in the EMBRAPA-IFPRI study[15] made it possible to trace the evolution of the impacts of technologies and the overall contributions of Embrapa to Brazil's agricultural development.[16]

According to the study, during the 2006–2013 period, agricultural R&D spending rose by 46% due to growth at Embrapa and in the higher-education sector, particularly among federal universities. At 1.8%, spending as a share of Agricultural GDP is the highest in Latin America. Brazil employs the largest number of qualified agricultural researchers with doctorates in Latin America, and its 73% share of researchers with doctoral degrees is the highest by far. A complete fact-sheet[17] on agricultural research and development in Brazil, among other facts, shows that the country leads investment in R&D&I and the number of highly qualified researchers.

Embrapa is widely referred to as a successful case of investment in R&D&I and of its experience of sharing with other countries to improve food and nutrition security as well as to boost

14. International Consultant on Agricultural Development.

15. http://www.asti.cgiar.org/brazil

16. ASTI, IDB & EMBRAPA. Agricultural R&D Indicators Factsheet, April 2016. See https://www.asti.cgiar.org/pdf/factsheets/Brazil-Factsheet.pdf

17. ASTI, IDB & EMBRAPA. Agricultural R&D Indicators Factsheet, 2006-2013. April 2016.

farmers' incomes and foreign exchange revenues for strengthening the economies of developing countries.

On another front, the National Project for Technological Innovation for the Improvement of Animal and Plant Health, financed by the National Research Council (CNPq) used a new approach to tackle animal and plant sanitary and health issues. It created a strong nationwide-applied research network with State and Federal Universities: the Ministry of Agriculture, Livestock and Supply; Ministry of Health; National Agency for Sanitary Surveillances (ANVISA); State Secretariat of Health; Secretariat of Agriculture; Research State Organizations, and Farmers' Associations.

As a result, several research actions and training activities benefited many production areas and professionals trained nationwide. A couple of professional Master Programs in Animal and Plant Health and Sanitary Issues are now in place at several universities across the country, taught by many experts, including some from developing countries.

Despite these achievements, some constraints continue to block future technology adoption and research implementation, as outlined below.

Challenges and options for improving R&D&I

Key constraints on the future of technology, research and innovations for agricultural development involve institutional and managerial decisions waiting for action by governments at the federal and state levels.

National and international regulations for procuring equipment, spare parts and biochemical materials for in-house laboratory and field trials need revisions and improvements regarding some of their cumbersome purchase procedures. This would avoid long delays in the acquisition of inputs for research activities. Although Embrapa and other research organizations and universities have pressured public authorities to remove these awkward regulations for a long time, however, the results have been disappointing.

There is also a need to enhance national and international public-private partnerships for the design, preparation, financing, continuation, monitoring and evaluation of research projects for generating and adapting technologies and innovations to increase the competitiveness and sustainability of the main global production chains underway in the country and abroad. These partnerships should include organizations for technical cooperation such as FAO, PNUD, IICA and some national and international financial institutions such as the World Bank, IDB, and EU. Both cases would result in synergies, to facilitate the efforts of Embrapa to assist developing countries to implement much-needed institutional reforms to strengthen and consolidate agricultural research organizations.

Imports of new inputs and technologies should be facilitated, and researchers should be allowed to participate in short-term capacity-building programs in international research and teaching organizations to update staff on new techniques for their current research projects in Brazil and abroad. Even though some years ago, Embrapa created a set of international offices in certain high-tech countries, this initiative should be enhanced to allow for the participation of a larger number of researchers, including those from state research organizations, to become an efficient instrument for the prompt absorption of new knowledgment, technology and innovations.

Embrapa should make more of an effort to help developing countries reform and strengthen their agricultural research organizations to enable them to become sustainable and highly proactive and reactive to farmers' technological demands. This should provide farmers with suitable technologies to boost their agriculture production, mainly in terms of staple foods to improve food and nutritional security, in countries with widespread malnutrition that are highly dependent on domestic agricultural production, due to the lack of foreign exchange to import staple foods.

Challenges regarding logistics

Several agricultural and livestock production areas in Brazil are in the Center-West, North and NE regions, with less developed infrastructure for storage, agro-processing and transportation facilities, which cause great losses in the quality and quantity of agricultural production. This type of infrastructure is urgently needed to improve farmers' income and lower the prices of consumer products, in both national and international markets. Although farm level agricultural production costs are much lower than those of their competitors, the prices of Brazilian commodities are still less competitive in international markets, because of the regressive effects of the so-called '*Brazil cost*'.

Several policy measures are attempting to address the Brazil cost, including the national plan for the construction and improvement of roads and railroads; reductions in the administrative and social cost of labor; privatizations and concessions of roads and railroads, among other measures. However, the results of these measures have been limited due to the lack of investment, delays in the revision and approval of friendly regulations and the lack of continuous, coordinated pressure from stakeholders.

Population's access to food

An efficient network of supermarkets and other types of commercial stores facilitates the distribution of all kinds of food products, including their availability in rural areas. The Bolsa Familia Program operates a cash transfer, through a bankcard, which provides poor families with a monthly amount to complement their income to buy food. However, if an adult family member gets a formal job, with a fixed salary, the amount of the cash transfer declines or the family may no longer be entitled to the grant, depending on the new income of the family, as part of the exit strategy from the Program.

Challenges and opportunities of climate change

Climate change has been a deterrent to maintaining or even increasing hydroelectric energy production to meet demand in almost all states, resulting from the reduction and/or irregular distributions of rainfalls year round. This situation has put pressure on the public sector to investing technologically advanced power plants and on alternative sustainable energy sources, mainly solar and wind, to increase the national electricity supply.

Climate change is therefore an opportunity for the development of energy saving technologies and innovations through new instruments for capturing solar and wind energy, for household, industrial and agricultural consumption, in a situation of lower hydroelectric generation, due to the reduction of the volume of water in rivers. In fact, in the past ten years, electricity from wind power plants has been growing at over 15%/year, becoming an important alternative source of energy to offset the losses in the electricity supply from hydroelectric power plants. However, the slow construction of power lines for transmission of this electricity is blocking its supply, acting as a disincentive for further private investment.

Food and nutrition security by gender

In general, gender impacts food and nutrition security in two ways. The first, and most common one, is when the man is the head of the household. In this case, the allocation of income for food and nutrition is based on his own criteria, with or without the woman's participation, which may have regressive effects on the availability of the recommended daily allowance of nutritional food for the family. In the second case, having a woman as the head of the family, working in or outside home, improves the family's food and nutritional security, assuming that she is committed to the well-being of the family, which is usually the case.

Food production for human consumption and other uses

Brazilian agricultural production supplies national and international markets for human and non-human consumption. In general, the bulk of agricultural production from medium and large farmers is used for human consumption, agro-processing and for livestock feeding, while the remainder of production is exported. Since the largest proportion of exports of agricultural production is in natura, any increase in agro-processing would increase the revenue for production chains. There is therefore great scope for increasing investment in agro-processing facilities.

There is no significant competition in production areas for sugarcane or areas assigned for the production of staple foods, in the state of São Paulo and the coastal areas of the NE region, where there are sugar cane plantations. The same is true for rice in the states of Rio Grande do Sul and Goias; and black and red beans in the inland states of Minas Gerais, Bahia, and elsewhere. This is so, because large areas of these crops are grown in various geographic locations, with little competition for land.

In general, in the Center-West, North and NE regions, small low-income farmers allocate the largest proportion of their production of staple food for self-consumption, because of their eating habits and the need to maintain stocks for food security, in the event of future harvest failures, because of unexpected droughts.

Capacity building for skilled and non-skilled labor

Private and public middle and high schools and universities provide formal training for those wishing to work in the agricultural sector, in agricultural campuses distributed across the country. The same is true of the non-formal short-term training provided by public and private organizations, which includes the National Service for Capacity Building for Rural Activities (SENAR), in the Ministry of Agriculture, Livestock and Supply (MAPA), and the National Service for Small Business (SEBRAE), in the Ministry of Development, Industry and Trade.

Major technological achievements of the Brazilian agricultural sector

Some of the key achievements of the agricultural sector that contributed for a deep transformation of traditional Brazilian agriculture are as follows.

Crop and livestock genetics improvements

This resulted from long-term plant and animal genetic improvement programs. As an example, the breaking of the photoperiod of soybeans production, from mid-October to mid-November, allowing widespread soybeans production, all over the country, and all year round. This strongly contributed to become Brazil one of the largest producer of this cereal in the world. Other genetics improvements occurred in cereals, livestock, orange and some fruit trees leading the country to very high production positions in the world.

Improvements in pest management

Biological control of virus in soybeans production resulted in huge cost savings in pesticides use, including positive effects on environmental protection, with substantial gains in yields and production of healthy cereal for human and animal consumption. There were others biological controls in other crops, like the white fly in melons and some fruit trees, with important pecuniary and productivity gains, cum environmental protection.

Soil management

The direct planting currently widespread adopted in more than 33 million hectares of cereal production had important progressive effects on soil protection, conservation and improvement of its physical, chemical and biological conditions overtime. This is one of the most important achievements for sustainable agricultural production around the world.

Agricultural-Livestock-forestry production systems

These kinds of integrated production systems are good examples of well-balanced, sustainable, and profitable production mixed, with widespread use across the country, by several types of farmers, with improvements on soil, water and vegetation conditions, mainly in tropical rain forest areas and also in others areas of the country.

Sustainable development of savannahs

The development of technological packages for crops and livestock production allowed for sustainable and competitive integration of Brazilian savannahs (Cerrados) into the national production system, creating one of the most important agricultural production *el dorado* in the world, covering large areas of Center-West, North and NE regions of Brazil.

Development of key production chains

Regular investment in agricultural research, production and marketing extension permitted the development and improvement of key production chains, such poultry, hogs, corn, cereals, fruit, and cattle, among others. These production chains ensured food and nutrition security for national consumers and provided a large surplus for export. The increase in the domestic supply of such products, strongly contributed to a continuous decline in the real prices of the food basket, working as a positive income effect for consumers. Moreover, the development of these key production chains became a reference for many developing countries, and it is widely referred to as an example of good agricultural-production practices in the tropics.

Basic public supporting services for development

It is worthnoting the cases of a set of successful supporting services, that have given farmers access to basic services, including technologies and innovations, through the National Program for Family Agriculture (PRONAF); National Service for Small Business (SEBRA); Rural Credit for medium and large farmers; Rural extension; Agricultural research through Embrapa, Universities, Teaching and Research Institutes, and State Organizations. These services are currently benchmarks for certain developing countries, because of their orientation to small, medium and large family farmers.

References

Section 1. Brazil's National Characteristics

Alves, E.R.A.; Souza, G.S.; Rocha, D.P. Marra, R. Fatos marcantes da agricultura brasileira. In: Alves, E.R.A.; Souza, G.S.; Gomes, E.G. (Eds.) Contribuições da Embrapa para o desenvolvimento da agricultura no Brasil. Brasília: Embrapa, 2013. p.13-45.

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa, 2014. 194p.

FAO. Food and Agriculture Organization. Land resource potential and constraints at regional and country levels, World Soil Resources Report, 90. Rome: FAO, 2000.

IBGE. Instituto Brasileiro de Geografia e Estatística. Área territorial brasileira. Available at < http://www.ibge.gov.br/home/geociencias/cartografia/default_territ_area.shtm > Accessed on November 29th, 2016a.

IBGE. Instituto Brasileiro de Geografia e Estatística. Indicadores sociais municipais: uma análise dos resultados do universo do censo demográfico 2010. Available at: http://www.ibge.gov.br/home/estatistica/populacao/censo2010/indicadores_sociais_municipais/indicadores_sociais_municipais.pdf Acessed on Feb. 15th, 2011.

IBGE. Instituto Brasileiro de Geografia e Estatística. Uma análise das condições de vida da população brasileira 2015. Available at < http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/indicadoresminimos/sinteseindicsociais2015/default_tab_xls.shtm > Accessed on November 29th, 2016b.

IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa Nacional por Amostra de Domicílios. Segurança Alimentar: 2004/2013: Brasil, grandes regiões e unidades da federação. Available at < http://www.ibge.gov.br/home/estatistica/populacao/seguranca_alimentar_2013/default_xls_2013.shtm > Accessed on November 29th, 2016c.

Lopes, M.A. The Brazilian Agricultural Research for Development (ARD) System. In: Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings. Paris: OECD, 2012. p.323-338.

Martha Jr., G.B.; Alves, E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C. (Eds.) The Oxford Handbook of the Brazilian Economy (forthcoming, 2017).

Osorio, R. Desigualdade e pobreza. In: Calixtre, A.; Vaz, F. (Orgs.) PNAD 2014 – breves análises. 2014. p.7-11.

Rodríguez, A.; Dahlman, C.; Salmi, J. Knowledge and innovation for competition in Brazil. Washington, D.C.: World Bank, 2008. 247p.

WRI. World Resource Institute. World resources 2008: the roots of resilience – growing the wealth of the poor. Washington, D.C.: WRI, 2008.

Section 2. Institutional Setting

Alves, E. Embrapa: a successful case of institutional innovation. Revista de Política Agrícola, v.19, Special Issue, p.64-72, 2010.

Alves, E.R.A.; Souza, G.S.; Rocha, D.P. Marra, R. Fatos marcantes da agricultura brasileira. In: Alves, E.R.A.; Souza, G.S.; Gomes, E.G. (Eds.) Contribuições da Embrapa para o desenvolvimento da agricultura no Brasil. Brasília: Embrapa, 2013. p.13-45.

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa, 2014. 194p.

Flaherty, K.; Guiducci, R.C.N.; Torres, D.P.; Vedovoto, G.L.; Ávila, A.F.; Perez, S. Brazil: Agricultural R&D Factsheet, 2016. Available at www.asti.cgiar.org/brazil

Lopes, M.A. The Brazilian Agricultural Research for Development (ARD) System. In: "Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings. Paris: OECD, 2012. p. 323-338.

Martha, Jr. G.B.; Contini E.; Alves, E. Embrapa: its origins and change. In: The regional impact of national policies: the case of Brazil. Edited by Baer W. Northampton: Edward Elgar Publishers, 2012.

Martha Jr., G.B.; Alves, E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C.R. (Eds.) The Oxford Handbook of the Brazilian Economy. (2017, forthcoming).

Sowell, T. Wealth, poverty and politics: an international perspective. New York: Basic Books, 2015. 328p.

Section 3. Resource and Ecosystem Characteristics: Plant Production, Genetics and Biodiversity

Aidar, H. e Kluthcouski, J. 2003. Evolução das atividades lavoureira e pecuária nos cerrados. In: Kluthcouski, J.; Stone, L.F. e Aidar, H. (ed.). Integração lavoura-pecuária. Santo Antônio de Goiás: Embrapa Arroz e Feijão. p.25-58.

Balbino, L.C.; Cordeiro, L.A.M.; Oliveira, P.; Kluthcouski, J.; Galerani, P.R. e Vilela, L. 2012. Agricultura sustentável por meio da Integração Lavoura-Pecuária-Floresta (iLPF). Informações Agronômicas 138:1-19.

Conab. 2017. Acompanhamento da safra brasileira de grãos. V.4 – Safra 2016/17-N. 7 – Sétimo Levantamento, abril 2017. 160p.

Cong, L.; Ann Ran, F.; Cox, F.D.; Lin, S.; Barretto, R.; Habib, N.; Hsu, P.D-; Wu, X.; Jiang, W.; Marraffini, L.A. and Zhang, F. 2013. Multiplex genome engineering using CRISPR/Cas systems. Science 339 (6121): 819-823.

Convention on Biological Diversity 1992. https://www.cbd.int

Fonarce, K.M.; Drakeley, C.J.; William, T.; Espino, F.; and Cox, J. 2014. Mapping infectious disease landscapes: unmanned aerial vehicles and epidemiology. Trends in Parasitology 30(11): 514-519.

Fowler, C. 2016. Seed on Ice: Svalbard and the Global Seed Vault. 160p.

Geraldi, I.O. 2012. Contribution of graduate programs in plant breeding to the education of plant breeders in Brazil. Crop Breeding and Applied Biotechnology S2: 1-6.

Gibson, D.G.; Glass, J.I.; Lartigue, C.; Noskov, V.N.; Chuang, R.Y.; Algire, M.A.; Benders, G.A.; Montague, M.G.; Ma, L.; Moodie, M.M.; Merryman, C.; Vashee, S.; Krishnakumar, R.; Assad-Garcia, N.; Andrews-Pfannkoch, C.; Denisova, E.A.; Young, L.; Qi, Z.Q.; Segall-Shapiro, T.H.; Calvey, C.H.; Parmar, P.P.; Hutchison, C.A.; Smith, H.O. and Venter, J.C. 2010. Creation of a bacterial cell controlled by a chemically synthesized genome. Science 329 (5987): 52-56

Neufeldt, H.; Resck, D.V.S. and Ayarza, M.A. 2002. Texture and land-use effects on soil organic matter in Cerrado Oxisoils, Central Brazil. Geoderma 197(3-4): 151-164.

Paterniani, E. 2001. Agricultura sustentável nos Trópicos. Estudos Avançados 15 (43): 303-326.

Ramalho, M.P.; Toledo, F.H.R.B. e Souza, J.C. 2010. Melhoramento genético de plantas no Brasil. In: Compendio em melhoramento genético de plantas no Brasil. Ramalho, et al. (Ed). p.17-37.

Section 4. Technology and Innovation

Aalves, F.V.; Almeida, R.G.; Laura, V.A.; Silva, V.P.; Macedo, M.C.M.; Medeiros, S.R.; Ferreira, A.D.; Gomes, R.C.; Araújo, A.R.; Montagner, D.B.; Bungenstab, D.J.; Feijó, G.L.D. Carne Carbono Neutro: um novo conceito para carne sustentável produzida nos trópicos. Brasília, DF: Embrapa, 2015 (Embrapa Gado de Corte. Documentos, 210). Disponível em: <https://www.embrapa.br/gado-de-corte/busca-de-publicacoes/-/publicacao/busca/carne%20carbono%20neutro?>

CICARNE. Centro de Inteligência da Carne. Disponível em: <http://www.cicarne.com.br/> Acessed on December 29th, 2016.

Collins, J.P.; Heitman, E.; Achee, N.L.; Chandler, V.; Delborne, J.A.; Gaut, B.S.; Higgs, S.; Kaebnick, G.E.; Kingiri, A.; Landis, W.; Riddiford, L.; Tait, J.; Taneyhill, L.A.; Travis, J.; Turner, P.E.; Winickoff, D.E.; Sawyer, K.; Thévenon, A.; Miller, R.; Sharples, F.; Kolesnikova, A. Gene drives on the horizon: advancing science, navigating uncertainty, and aligning research with public values. Washington, D.C.: The National Academy of Sciences, Report in Brief, Jun. 2016. 4p.

Economist. Brazilian agriculture: the miracle of the cerrado. The Economist, August 26th, 2010. Available at < http://www.economist.com/node/16886442 > Accessed on August 28, 2010.

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa, 2014. 194p.

Erb. K.-H., Lauk, C., Kastner, T., Mayer, A., Theur. M.C., Haber, H. Exploring the biophysical option space for feeding the world without deforestation, Nature Communications, DOI: 10.1038/ncomms11382. 2016.

Fedoroff, N.V., Food and a future of 10 billion. Agriculture and Food Security. DOI 10.1186/s40066-015-0031-7. 2015.

Galvão, Cleber E.; Rosinha, Grácia Maria S.; Sanches, Cristiane C.; Elisei, Carina; Araújo, Flábio R.; Feijó, Gelson L. D.; Almeida Torres, Roberto Augusto; Soares, Cleber O. Polymorphisms of Intron 1 and the Promoter Region at the PRNP Gene in BSE-Free Caracu Cattle. Biochemical Genetics, v. 1, p. 1-13, 2012.

Gonçves, Aline N.D.; Soares, Cleber O.; Sanches, Simone C.; Reis, Fernando A.; Rosinha, Grácia Maria S. Genotypic profile of Pantanal creole sheep regarding susceptibility or resistance to scrapie. Pesquisa Agropecuária Brasileira, v. 51, p. 684-687, 2016.

IPCC–Intergovernmental Panel on Climate Change, 2006, IPCC. Guidelines for National Greenhouse Gas Inventories. Japan: IGES, v. 4, 2006.

Karvatte Jr., N.; Klosowski, E.S.; Almeida, R. G.; Mesquita, E. E.; Oliveira, C. C.; Alves, F.V. Shading effect on microclimate and thermal comfort indexes in integrated crop-livestock-forest systems in the Brazilian Midwest. International Journal of Biometeorology, v. 60, p. 1-9, 2016.

Martha Jr. G.B; Alves E.; Contini E. Land-saving approaches and beef production growth in Brazil. Agricultural Systems, v.110, p.173-177, 2012.

Martha Jr. G.B; Alves E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C. (Eds.) The Oxford Handbook of the Brazilian Economy (forthcoming, 2017).

Martin, V.J.J., Pitera, D.J., Withers, S.T., Newman, J.D., Keasling, D. Engineering a mevalonate pathway in Escherichia coli for production of terpenoids. Nature Bitoechnology 21, 796-802.

Medford, J.I., Prasad, A. Towards programmable genetic circuits. The Plant Journal, 87, 139-148. 2016

Melo, Elane S.P.; Souza, Ingred I.F. ; Ramos, Carlos A.N.; OsórioAna Luiza A.R.; Verbisck, Newton V.; Aráujo, Flábio R. Evaluation of the use of recombinant proteins of Mycobacterium bovis as antigens in intradermal tests for diagnosis of bovine tuberculosis. Archivos de Medicina Veterinaria, v. 47, p. 273-280, 2015.

Nielsen, A.A., Der, B.S., Shin, J., Vaidyanathan, V.P., Strychalski, E. A., Ross, D., Densmore, D., Voigt, C.A. Genetic circuit design automation. Science, 352, DOI: 10.1126/science.aac734.

Nemhauser, J.L., Torii, K. U. Plant synthetic biology for molecular engineering of signalling and development, Nature Plant, DOI: 10.1038/NPLANTS.2016.10

OIE – Organização Mundial de Sanidade Animal (2016). Estatus de los países miembros respecto de la encefalopatia espongiforme bovina. Resolución N° 20 (84ª Sesión General de la Asamblea Mundial, mayo de 2016). Disponível em: http://www.oie.int/es/sanidad-animal-en-el-mundo/estatus-sanitario-oficial/eeb/estatus-sanitario-oficial/. Acesso em 12 dez. 2016.

Pereira, P.A.A.; Martha Jr., G.B.; Santana, C.A.; Alves, E. The development of Brazilian agriculture: future technological challenges and opportunities. Agriculture and Food Security, v.1, n.4, 2012.

Rech, E.L., Arber, W. Biodiversity as a source for synthetic domestication of useful specific traits. Annals of Applied Biology 162:141-144. 2013.

Rech, E.L., Lopes, M.R. Insights into Brazilian agricultural structure and sustainable intensification of food production. Food and Energy Security 1:77-80. 2012.

Soares, Cleber O. PD&I alavanca a pecuária sustentável. Agroanalysis, v.43, n.11, p. 41. 2014.

UNDP (United Nations Population Division). World population prospects – The 2015 Revision: Highlights and tables. New York: UNDP, 2015.

Viale, M.L.; Zumárraga, M.J.; Aráujo, F.R.; Zarraga, A.M.; Cataldi, A.A.; Romano, M.I.; Bigi, F. La genómica de las micobacterias. Revue Scientifique et Technique - Office International des Épizooties, v. 35, 2016, p. 215-240.

Zhang, Y., Zhang, F., Li, X., Baller, J.A., Qi, Y., Starker, C.G., Bogdanove, A.J., and Voytas, D.F. (2013). Transcription activator-like effector nucleases enable efficient plant genome engineering. Plant Physiology 161, 20–27.

Section 5. Increasing Efficiency of Food Systems Chains

ABAG, 2015. Logística e competitividade do agronegócio brasileiro. SP: ABAG, 260p

Buainain, A.M. Alguns condicionantes do novo padrão de acumulação da agricultura brasileira. In Buainain, Alves, Silveira e Navarro (Editores Técnicos). O mundo rural no Brasil do século 21: a formação de um novo padrão agrário e agrícola. Brasília, DF: Embrapa, 2014, 211-240p, 1182 p.

Oliveira, A. L.R. A logística do agronegócio: para além do "apagão logístico". In Buainain, Alves, Silveira, e Navarro (Editores Técnicos). O mundo rural no Brasil do século 21: a formação de um novo padrão agrário e agrícola. Brasilia, DF: Embrapa, 2014, 337-370 p,1182íp.

Veira Filho, J.E. e Gasques, J.G. Agricultura, transformação produtiva e sustentabilidade. Brasília, DF: IPEA, 2016, 391p.

Section 6. Health Considerations

ABIEC - Associação Brasileira das Indústrias Exportadoras de Carne. Exportações Brasileiras de Carne Bovina. Janeiro a Dezembro de 2015. Disponível em: http:llwww.abiec.com.br/downloadlrelatorio-anual-2015.pdf. Acesso em 12 dez. 2016.

BRASIL (2016). Secretária de Vigilância em Saúde. Surtos de Doenças Transmitidas por Alimentos no Brasil. Disponível em: http://portalsaude.saude.gov.brlimages/pdfJ20161junho/08/Apresenta--o-SurtosDTA-2016.pdf>. Acesso em: 12 dez. 2016.

Claro, R.M. et al. Unhealthy food consumption related to chronic noncommunicable diseases in Brazil: National Health Survey, 2013. Epidemiol. Serv. Saúde, Brasília, 24 (2), abr-jun 2015.

Ministério da Saúde (BR). Secretaria de Atenção à Saúde. Departamento de Atenção Básica. Guia alimentar para a população brasileira: promovendo a alimentação saudável. 2. ed. Brasília: Ministério da Saúde; 2014.Ministério da Saúde (BR). Secretaria de Vigilância em Saúde. Departamento de Análise de Situação de Saúde. Plano de ações estratégicas para o enfrentamento das Doenças Crônicas Não Transmissíveis (DCNT) no Brasil 2011-2022. Brasília: Ministério da Saúde; 2011.

Nutti, M. R., Carvalho, J.L.V. de, Progress of Biofortification in Brazil. In: Reunião de biofortificação no Brasil, 5. p. 242-246, 2015, São Paulo. Anais. Brasília, DF: Embrapa, 2015. T515.

OIE – Organização Mundial de Sanidade Animal (2016). Estatus de los países membros respecto de la encefalopatia espongiforme bovia. Resolucion No. 20 (84th Sesión General de la Asamblea Mundial, mayo de 2016). Disponível em http://www.oie.int/es/sanidad-animal-en-el-mundo/estatus-sanitario-oficial/eeb/estatus-sanotario-oficiall Acesso em 12 dez. 2016.

Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. Int J Obes Relat Metab Disord [Internet]. 2004 Nov [cited 2015 Jan 8];28(Suppl 3):S2-S9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15543214

Ruel, M. T., Alderman, H. Maternal and Child Nutrition Study Group. (2013). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet, 382(9891): 536-551.

World Health Organization. Diet, nutrition and the prevention of chronic diseases: report of a Joint WHO/FAO Expert Consultation. Geneva: World Health Organization; 2003.

World Health Organization. Integrated prevention of noncommunicable diseases: global strategy on diet, physical activity and health. Geneva: World Health Organization, 2004.

Section 7. Policy Considerations

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa. 2014. 194p.

IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa Nacional por Amostra de Domicílios. Segurança alimentar: 2004/2013: Brasil, grandes regiões e unidades da federação. Available at < http://www.ibge.gov.br/home/estatistica/populacao/seguranca_alimentar_2013/default_xls_2013.shtm > Accessed on November 29th, 2016.

Martha Jr., G.B.; Alves, E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C. (Eds.) The Oxford Handbook of the Brazilian Economy (forthcoming, 2017).

Martha Jr., G.B.; Pena Júnior, M.A.G.; Marcial, E.C.; Castanheira Neto, F.; Torres, L.A.; Nogueira, V.G.C.; Chervenski, V.M.B.; Silva, G.T.S.; Wosgrau, A.C. Cenários exploratórios para o desenvolvimento tecnológico da agricultura brasileira. Brasília, DF: Embrapa, 2016. 26 p.

Section 8. Further Challenges and Achievements

ASTI, IDB & EMBRAPA. Agricultural R&D Indicators Factsheet, 2006-2013. April 2016.

Special Feature

Factors Relating to Gender and Food Security / Insecurity

Frances Henry, Emeritus Professor and Co-Chair of the IANAS Women for Science Program. Eduardo Bianchi, Argentina. Professor and researcher at the Argentine Business School. Fiorella Bianchi, Argentina. professor and researcher at the National University of Buenos Aires. Mónica Moraes R., Bolivia. Professor emeritus at the Institute of Ecology - Botany Unit (National Herbarium of Bolivia). Zulema Lehm A., Bolivia. Wildlife Conservation Society-Bolivia. Susana Raffalli, Venezuela. Caritas Association of Venezuela. María Tapia, Venezuela. Institute of Food Science and Technology, Central University of Venezuela.

Introduction

This chapter is based upon the premise that the global conditions of food security and especially food insecurity cannot be understood without reference to the important role of gender[1] in society. Food security, a "condition in which all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"[2] is one of the most important social conditions in the modern world affecting millions of people. The problems associated with food security and insecurity have been examined and studied at some length especially in the development literature.[3] Women are intimately connected to the growth, preparation, manufacture and dissemination of food beginning within the family. Women also play a major role in agricultural and other food producing and it is now recognized that the inclusion of the role of gender is critical to the understanding of how strategies need to be developed for producing and distributing enough food to maintain the world's population.[4] It is therefore essential to examine the role of gender in food production but the term itself is fairly recent in the social science literature and it can therefore be somewhat confusing.

We begin this chapter therefore with an overview of its meaning and the various uses to which it has been put. We then provide a case study of a Bolivian Indigenous community that highlights the importance of women in decision-making followed by a case study of the contemporary crisis in food management due to political changes in contemporary Venezuela. The concluding section of the chapter highlights the important but adverse relationship between gender inequality and food insecurity.

Definition of "Gender" and Gender Related Terms

People are born male or female but the society into which they are born decides the characteristics of each sex. What it means to be 'masculine' or 'feminine is therefore a function of the socio-cultural and historical factors that structure the thinking of society.[5] As children grow and develop they learn the roles appropriate to its sex; females learn to be women and males learn to be men. Gender rules also structure

1. This chapter defines gender primarily in terms of masculine and feminine but we recognize the role of more fluid gender identities, trans and intersex genders.

2. FAO 2006: www.fao.org/about/en

3. Trade Reforms and Food Security: www.fao.org/docrep/005/y4671e/y4671e06.htm

4. www.fao.org/fileadmin/templates/gender/docs/FAO_FinalGender_Policy_2012.pdf

5. Gender Socialization - Boundless https://www.boundless.com

the relations between the sexes which often place women in lesser social positions than men. Gender refers not to men and women in themselves but to the relations between the sexes, in both perceptual and material senses. While biological factors affect sex differences in the minds and bodies of people, these are further acted upon by the social environment, and the concept of gender emphasizes the social relations between the sexes rather than a static identity. It calls for attention to cultural, social, political and moral processes which attribute values to these relations, often placing women in subordinate social positions. Gender, like age is one of the central organizing concepts of all societies past and present and consequently it plays a huge role in the governance of food and nutrition security. They are most frequently the ones who produce, purchase, handle, prepare and serve food for the family and in community institutions.

Focussing on gender, then, invites the examination of the interactions of differences and commonalities, and of biological factors and elements of the socio-cultural context, that in interaction lead to structural disadvantages. Inequitable relations place various groups of both women and men in a disadvantaged and subordinate position in relation to others with respect to availability, accessibility, adequacy, acceptability and agency regarding food and nutrition security. The pursuit of equity in food security aims at correcting these imbalances and their structuring effects around food and nutrition processes.

The Many Divisions of "Gender"[6]

While gender is the all embracing term, it can be further divided into a number of specific ways in which it functions. **Gender Roles** refer to the tasks and behaviors that a society deems appropriate for men, women, boys and girls whereas **Gender Relations** refers to the rights and responsibilities of men and women to each other. **Gender Equality** exists when men and women enjoy equal rights, opportunities whereas **Gender Equity** means impartiality and fairness in the treatment of women and men and includes rights, benefits and opportunities. **Gender Discrimination** is the exclusion or restriction made on the basis of gender which prevents the enjoyment of full human rights and **Gender Mainstreaming** is a very generalized term which applies to all strategies designed to achieve gender equality.

With respect to the relationship of gender to food security and insecurity, the Food and Agriculture Organization of the United Nations has taken the lead in identifying objectives which would lead to greater gender equality in food production especially in agricultural societies.[7] These include:

- Women participate equally with men as decision-makers in rural institutions and in shaping laws, policies and programs.
- Women and men have equal access to and control over decent employment and income, land and other productive resources
- Women and men have equal access to goods and services for agricultural development and to markets
- Women's work burden is reduced by 20% through improved technologies, services and infrastructure
- Percentage of agricultural aid committed to women/gender-equality related projects is increased to 30% of total agricultural aid.

Thus, while it is well known that women have less power over local resources than do men and their contributions are often minimized it is now also increasingly being recognized that more gender equality between men and women in many areas of the world, especially where food resources are limited, would lead to more growth and development.

We now turn to the case studies.

6. http://www.fao.org/gender/gender-home/gender-why/why-gender/en/

7. http://www.fao.org/news/story/en/item/128104/icode/

Case Study 1

Women's Access To Decision Making Among The Tacana People In Bolivia

The Tacana people live in the lowlands of Bolivia in the departments of Pando, Beni and in the north of the department of La Paz.[8] Historically the Tacana people had social norms to guarantee the sustainability of natural resources, developing modalities of land use, hunting methods and cultural practices that were based on social control and their cultural beliefs.[9] These practices have undergone changes over time because of the establishment of missionary villages, the commercial booms of quina and rubber in the Amazon region, as well as the exploitation of wood, the export of feline and saurian (lizard) skins, as well as the entry of colonists who affected the traditional production systems of Tacana people.[10]

At present the Tacana people and especially in Tumupasa (La Paz department) are in the process of constructing new forms of control and norms in compliance with Bolivian laws, but based on historical practices for the access and use of natural resources, based on its parent entity CIPTA (Indigenous Council of the Tacana People) that represents 20 communities with 3,773 inhabitants (47% women), and the Indigenous Council of Tacanas Women (CIMTA) whose purpose is to promote the organization of women in the various communities. They have an organizational structure which includes an equal number of men and women as well as a special secretary of gender.[11] In practice, however, and despite the equal representation of men and women in CIPTA and in its assemblies, some inequality remains to the detriment of women.

Tacana women generally participate in decision levels at the indigenous Tacana council and are responsible for representing organized groups of mothers, artisans and producers. They are part of the delegations that visit the communities to organize workshops and follow up on the projects and activities they lead. In work sessions women always participate, question and propose, at the same level as men.

CIMTA's communal organizations and artisans group involve women of different ages, who, according to the projections of the Tacana directives and councils, are constantly organizing training activities in other communities, enhancing the community work and disseminating actions that are generated by the Tacana council. They are in charge of the elaboration, weaving and carving of raw material (woods, fabrics, seeds, among others) for the supply of handicrafts that are commercialized to produce income for the artisans who make the product. The CIPTA also assigns an outlet or store site for these products to be sold.

Useful Palms, Food And Handicrafts By Tacana Women

There are approximately 100 species of palm trees in Bolivia of which almost 60% are considered useful by the people because they produce food fit for humans to consume.[12] The daily activities of the people in the area of Tumupasa includes the use of harvested products of their

8. Tejeiro, J. 2010. Regionalización y diversidad étnica cultural en las Tierras bajas y sectores del subandino Amazónico y platense de Bolivia. P.C.A. Ingenieros Consultores S.A. Plural. Editores, La Paz.

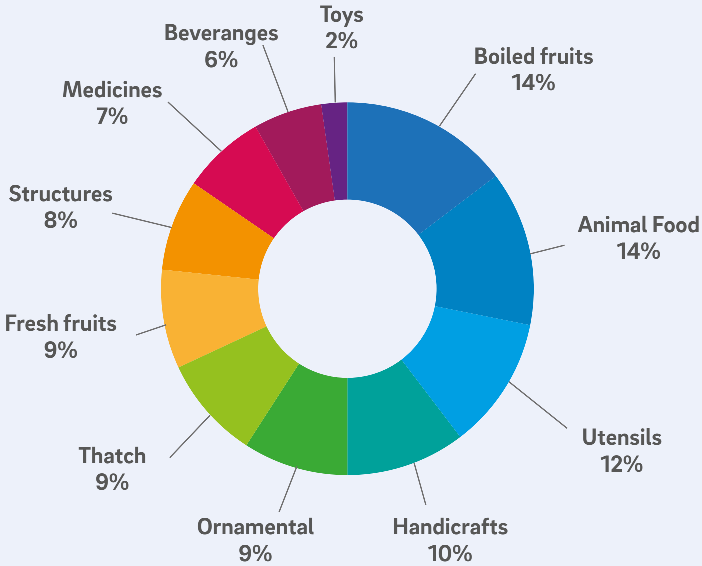
9. Hahn, A. & K. Hissink. 2000. Los Tacana. Datos sobre la historia de su civilización. APCOB, Plural editores, La Paz; Díez Astete, A. 2011. Compendio de etnias indígenas y ecorregiones: Amazónica, Oriente y Chaco. Centro de Servicios Agropecuarios y Socio-Comunitarios (CESA). Plural editores, La Paz. 618 p.

10. CIPTA-CIMTA (Consejo Indígena del Pueblo Tacana – Consejo Indígena de Mujeres Tacana). 2014. Plan de gestión territorial indígena del pueblo Tacana. Tumupasa. 197 p.

11. CIPTA (Consejo Indígena del Pueblo Tacana) & WCS (Wildlife Conservation Society). 2005. Estrategia de desarrollo sostenible de la TCO-Tacana con base en el manejo de los recursos naturales. USAID Bolivia, La Paz. 308 p; CIPTA-CIMTA (Consejo Indígena del Pueblo Tacana – Consejo Indígena de Mujeres Tacana). 2014. Plan de gestión territorial indígena del pueblo Tacana. Tumupasa. 197 p.

12. Moraes R., M. (ed.). 2014a. Palmeras útiles de Bolivia - Las especies mayormente aprovechadas para diferentes fines y aplicaciones. Herbario Nacional de Bolivia, Universidad Mayor de San Andrés, Plural editores, La Paz. 148 p.

Figure 1. Useful palms per category (Tumupasa, Bolivia)



environment – such as palms - and the use of these products has been transmitted through the generations.[13] Although today there is a tendency to replace construction materials largely due to the increasing process of semiurbanization in Tumupasa, the customs and traditions of using palm materials for carving tools, roofing and building houses are still maintained.

Between 2013 and 2014, an ethnobotanical research study was constructed by interviewing 12 key informants, (but only one woman) from the Tacana community in Tumupasa, aged 36-67 years. Of 23 useful palms for the Tumupasa area - which translates into 79% of the total number of palms in the area, 18 are native species and the rest are introduced to Bolivia from another region of the country or other continents.[14] There are fourteen native species of regional importance each providing a source for construction materials or food for the region. Several species are multipurpose because they have more than four uses. Twelve palms offer 4-8 categories, four with 2-3 categories and seven are used for a single category.

According to Cartagena et al. (2014),[15] eleven categories of use for Tumupasa palms were identified, for example food for human consumption consisted of three subcategories (fresh fruits, boiled and beverages). In addition, among the materials for construction, roof and structure (framework, beams and walls) are merged into one (**Figure 1**).[16] For eight categories, then food is the most important with 29%, followed by construction materials (17%), then food for the fauna (14%).

The most widespread use in the region is the sweet tasting raw edible fruit of the Motacú palm and the Chima palm, which is cooked with salt. Fans and baskets of motacú are also woven into utensils and crafts, as well as the carved ivory seeds). Also typical is the preparation of beverages prepared with Majo and Asaí fruits. The roofs made of of Jatata palm, asaí and motacú are very characteristic and long lasting (18-25 years).

The many species of palms provide food, drink and shelter. Both women and men are involved in these processes and the preparation of food and marketing is shared by the family. The designing and dyeing of clothing, as well as the weaving of handicrafts derived from palm trees is handled and managed by women in the 20 Tacana communities (**Photo 1**). Women also decide the prices of the products they make as well as their transportation to local markets. Weaving leaves of Jatata palm roofs is done by both men and women but the cutting palm trunks for construction purposes is exclusively the work of men. Both activities are organized by groups of Tacana families and the products are made to quality standards as specified by their customers.

13. Cartagena, T., A. Pardo Apana, J.D. Terrazas Achimo, N. Medina Gonzales, C. Cartagena Cuajera, L. Marupa, Amutari, T. Quitihuari, J. Gonzales Fresi, M. Marupa Navi, L. Beyuma, F. Quenebo, J. Gonzales Marupa & M. Moraes R. 2014. Palmeras útiles de Tumupasa. pp. 19-28. In: Moraes R., M. (ed.) Palmeras de Tumupasa en La Paz, Bolivia. Universidad Mayor de San Andrés, Graphic Team srl., La Paz.

14. Ibid.

15. Ibid.

16. Ibid.

Thus the Tacana have developed strategies to manage food production and house construction that includes women and men in equal numbers. The role of the women in this community and their decision- making authority has contributed to a fairly good standard of living providing adequate food from the environmental resources at their disposal.[17]

This case study provides a good example of a group of Indigenous people whose traditional lives have been changed but who nevertheless have developed administrative structures to manage the growth and use of the botanical plants in their environment; but the uses of these palms are the result of traditional knowledge transmitted from generation to generation. Not everything has changed and that is what allows the Tacana Indigenous people to maintain their cultural uniqueness.

Case Study 2

External Factors (Political) Affecting Food Security And Nutrition By Gender

An attempt to look at the relationship between gender, especially women, and food security/ nutrition is presented in the context of political factors prevailing in Venezuela using the “Sentinel Site Monitoring System of the Nutritional Situation” by Caritas de Venezuela, to examine some effects of these factors by gender.

Some aspects of the national context: Severe inaccessibility to food affected by high inflation

In 2015 The Central Bank of Venezuela reported high inflation rates of 180.9%. The International Monetary Fund projected figures of 720.5% in 2017 and 2,068.5% in 2018. There is also a high dependence on food import, policy which has been reduced by the fall in oil prices that along with strict controls on the economy decreased agricultural/livestock production with a growing shortage of staple foods. The Government implemented restrictive policies to fight scarcity: regulation of prices of staple foods, rationing systems that generate long queues in front of food stores and supermarkets under the custody of military personnel, biometric fingerprint registration, identity documents terminal digit (one day/week/person), Local Supply and Production Committees (CLAP) integrated by government organizations and party members that sell regulated staple foods without periodicity, controls, or transparent criteria. As a result, the population has developed strategies to find the scarce regulated staple foods, and the practice of reselling with price increases up to 1,500%, called "bachaqueo" emerged.

17. It should be noted however that Tacana women working in agriculture, are paid 6% less than the wages of men. In commercial associations the Tacana women's participation only reaches 30%. Although much progress has been made by the Tacana people there is still a long way to go to reach effective gender equity

Photo 1. Tacana woman in Tumupasa

The nutritional deterioration is dramatic indicating the existence of severe food insecurity and is on the way to becoming an emergency in geographical areas of the country and in groups at greater risks. The damage done to the diet that has occurred which is becoming increasingly insufficient and of low quality including fewer calories and proteins will lead to a serious nutritional situation and health risks like growth retardation in children, anemia and diabetes.[18] Family survival strategies have appeared: decreased quality/quantity of food, deprivation, destitution of family resources to meet food needs, family fragmentation to ensure food for all members. Lower empowerment of women has increased discrimination and their exposure to poverty and the decline of employment levels. According to official epidemiological bulletins, 30% more children died before their first year and 64% more women died during pregnancy or within 42 days after delivery in 2016 compared to 2015. Caritas de Venezuela (2017)[19] has systematically generated the most recent data on malnutrition: 11.4% of acute under nutrition (emaciation) in children <5 year, detected in 31 vulnerable parishes in four counties at sub-national level in which Caritas operates for nutritional monitoring. Data were analyzed in order to see the effect of the food/nutrition crisis on women and children by gender. Some indicators identified by Caritas de Venezuela in its sentinel sites are presented next.

Inequalities Around The Access To Food And Food Consumption

In 2013, The National Statistics Institute estimated a gender pay gap of 18% on average. In 2015, female unemployment was 3 times higher than that of men. Between 2001 and 2011, poor households headed by women went from 29% to 39%, of which 52.8% have three or more children, even if 30% of them have a couple, women are head of households. In 2013 there were 107 women/100 men in poverty and 112 women/100 men in extreme poverty. Poverty increased from 48% to 82% in 2016,[20] and it weighed more heavily on women who as family heads have to wait in long queues to get scarce amounts of food/medicine. According to the Latin American Study of Nutrition and Health,[21] 93.9% of Venezuelans do not meet the recommendations of caloric requirements, the caloric intake of women being 1749.1 Kcal/day and 2059 Kcal/day for men. Caloric intake decreased significantly with increasing age in women.

The Inequality Around Coping Strategies In The Face Of Food Insecurity

In a high proportion of households interviewed about their food security situation, it was evident that families had already been using coping strategies to deal with food deprivation. These include: eating less food and doing without specific foods (70% -80% households), stop eating for another person in the family to eat (53% of households), and spending the whole day without eating (48% of households). Among households that use these strategies, the most frequently mentioned person when referring to those who stop eating family food were women (33% households). 56% of households responded that "adults" and "elders" sacrifice their food but did not specify if these were women. Since approximately 60% of households in the country's poorest parishes are women, it can be inferred that they are operating as buffers or “shock absorbers” against family food deterioration. Deferring their own food intake leads to a reduction of their own nutritional well-being.

Caritas' sentinel sites system for nutritional surveillance operates through nutritional care

18. UPR. Universal Periodic Review (2016). Gender equality and Women rights. Fact Sheet 2nd Cycle UPR Venezuela 2016. Available in: https://goo.gl/k4gXE6

19. Caritas de Venezuela (2017). Monitoreo de la Situación Nutricional en Niños Menores de 5 años. VENEZUELA. Distrito Capital, Vargas, Miranda y Zulia. Octubre 2016 – Abril 2017.

20. ENCOVI - Encuesta sobre Condiciones de Vida Venezuela 2016 (2016). Alimentación, Educación, Pobreza, Salud, Seguridad personal y Trabajo. Available in: www.fundacionbengoa.org/noticias/2017/encovi-2016.asp

21. Ramírez, G.; Herrera-Cuenca, M.; Vásquez M.; Landaeta-Jiménez, M.; Hernández, P.; Meza, C.R; Kovalskys, I.; Gómez, G. and Fisberg, M. on behalf of the ELANS Study group (2017). The Impairment of Food Patterns in Venezuela: Preliminary Results from the Latin American Study of Nutrition and Health (ELANS) –Venezuelan Chapter. Abstract submitted to the Food Nutrition Conference and Expo (FNCE) 2017. (In press).

fairs. Analysis of the coverage of these fairs indicated that 40% of the children brought to evaluation and nutritional consultation on care days, are under 6 months, and among them, 60% are boys and 40% are girls. That is, of 10 babies brought for evaluation and attention, only 4 are girls and 6 are boys. For a 50% male/female birth rate in the country, this proportional difference may be reflecting attention-seeking behavior pattern in which girls are disadvantaged. The relationship male/female in terms of attendance to health and nutritional consultation in follow ups decreases a bit, but is maintained, as the age progresses: 55% of the children over 6 months brought to health activities are boys and 45% are girls.

The Inequality Around the Nutritional Status

Acute malnutrition, as measured by the evaluation of weight according to height as a measure of wasting was found to be more frequent in boys than in girls. Of every 100 children found to be wasted according to their height, 58 were boys and 42 were girls. This type of nutritional damage can be recovered quickly, that is, it is easily reversible if it is not prolonged in time.

Chronic malnutrition, as measured by height-for-age assessment, which expresses whether the child has grown normally in his early growth period showed more deterioration in girls than in boys. Out of 100 children with growth retardation (stunted) due to chronic nutritional deficits, 53 were girls and 47 were boys. This type of nutritional damage - when it occurs prior to the age of 2 and in countries with health, food and nutritional conditions like those of Venezuela – may become irreversible, with detrimental metabolic, cognitive and affective consequences for life. According to these figures, girls are the ones with the worst burden.

When a girl or a boy has already been slowed by growth retardation, it is more difficult to notice if they are wasted. In girls and boys with growth retardation, wasting does not settle so easily because of the metabolic mechanisms of adaptation to chronic nutritional deprivation. It may be the reason that, if girls are more likely to show growth retardation, boys appear to be more affected by wasting.

The crisis that has created the situation in which the availability, access and consumption of food in Venezuela has a proportionately greater effect on girls and women. This not only has severe consequences for the country as a whole but particularly on the health and prosperity of future generations.

Case study 3 which follows contains a more specific discussion of how exactly women, particularly with their individual body needs are disadvantaged with respect to food security largely because of their society's gender relations which favor men over women.

Case Study 3

The Gender Perspective in Food and Nutrition Security

Food security is a problem that affects millions of people on our continent and around the world, particularly women and girls. For several reasons, women and girls tend to consume less food than the men in the family, and in some countries it is even customary for them to eat afterwards. Statistics show that the number of women suffering from malnutrition doubles that of men, and that girls are twice as likely to die from the lack of adequate food as boys.

Several studies[22] show that there is a strong link between gender inequality and food and nutrition insecurity. This is because women and children's needs are different from those

22. ABOUD G. AND BALLARA M. (2015) "El pueblo maya ch'orti': Afrontando la inseguridad alimentaria mediante un enfoque con justicia de género". In En Breve, Bridge, United Kingdom, 2015, ISBN 978-1-78118-204-8.
BRODY A. (2015) "Género y seguridad alimentaria: panorama general". In Breve, Bridge, United Kingdom, 2015, ISBN 978-1-78118-204-8; "Género y seguridad alimentaria. Hacia una seguridad alimentaria y nutricional con justicia de género", General Report, Bridge, 2014; "Género, Seguridad Alimentaria y Nutrición", Comité de Seguridad Alimentaria Mundial (CSA), 37° period of sessions, 2011.
DAND S. AND ABOUD G. (2015) "El derecho a la alimentación en Guyarat: Organización local que está contribuyendo al cambio en el ámbito nacional". in En Breve, Bridge, United Kingdom, 2015, ISBN 978-1-78118-204-8. ONIANG'O R. AND MUKUDI E. (2002) "Nutrición y género". In Nutrición: La Base para el Desarrollo, Geneva: SCN, 2002.

of men and end up being neglected, due to the prevalence of discriminatory social and cultural norms.

Women have limited access to land, education, information, credit, technology and decision-making spheres. They are primarily responsible for raising children and rely on developed social networks that serve as an informal social safety net for the family at times of crisis. When they engage in formal employment, they typically receive lower pay than their male colleagues, despite having the same skills. Due to the triple burden of responsibilities, as a result of their productive, reproductive and social role, women also tend to have less time to attend to their own needs, whether for rest or otherwise.

At the same time, women have particular physiological needs during pregnancy and breastfeeding. During these periods, the female body becomes particularly vulnerable, and requires a good nutritional status, a balanced diet and proper health services. Good health and a balanced diet are essential for a pregnant woman to ensure the correct formation of the embryo and its subsequent survival outside the mother's body. The nutritional status of newborns is closely linked to that of their mothers, both during pregnancy and subsequently through breastfeeding. Maternal malnutrition has a direct impact on the high rates of child morbidity and mortality. Thus, cases of malnutrition during pregnancy are doubly alarming since they compromise the health of both the mother and the fetus, which will be born underweight and even less likely to survive or develop properly.

Studies show that women with less influence or power within the home and community are unable to guarantee the fair distribution of the food they provide for their families. Thus, although food and nutrition insecurity has political and economic origins, it is also a question of gender justice. Marked gender inequalities are both a cause and a result of inequity in access to food as well as its consumption and production.

Current policy concerns about increasing food availability are expressed in short-term strategies to provide food assistance and longer-term strategies designed to increase food supplies through intensive agricultural production. These policies include women, and prescribe investment in small-scale women farmers and promote rural women farmers as a previously underused resource for boosting economic growth.

Although these measures are moving in the right direction, they do not go far enough, valuing women solely as a means of achieving greater economic efficiency and food and nutritional security. However, these policies acknowledge that economic empowerment is only part of the solution. Unless the solutions envisaged address the root causes of gender inequality, there is a danger that current approaches will actually exacerbate inequalities. Cycles of gender-based discrimination are likely to continue, perpetuating gender injustice, poverty and food insecurity.

Likewise, the importance of the right to food as a founding principle of solutions for food security has been reaffirmed through its centrality in high-level documents and processes at the multilateral level. However, despite these efforts and the numerous binding frameworks, the idea of a right to food has made very little headway in transforming gender inequalities. This is partly because women's rights and the right to food have been artificially separated from each other in legally binding international documents and institutional and policy mechanisms that have not been harmonized.

It is therefore necessary for public policy strategies undertaken by states to recognize that food insecurity is a political and economic problem exacerbated by unequal power relations, reproduced over generations and present at multiple levels: global, national, social, and above all, domestic.

A food and nutrition security with gender justice perspective means a world that guarantees everyone's right to adequate food, according to their situation and nutritional needs, thereby ensuring respect for human dignity and fundamental human rights.

Conclusion

This chapter maintains that global food security and insecurity cannot be fully understood without reference to one of the major dividing social forces in society. While sex is basically a biological division based primarily on reproductive organs and functions, gender is a social classification based on personal identity, behaviour, and interactions with others. Gender is a learned behavior which humans acquire through the processes of socialization. Throughout most of human history however the male sex and its related social characteristics are prized over that of females leading to significant difference in the power dynamics of any society. Gender as viewed through the values, norms and everyday behavior often create inequality and injustice and nowhere is this more evident than in the uneven access and distribution of food and food resources. Small gains, as illustrated by the Bolivian case study above, indicate that with concerted action, women can share equally in food related processes. The case study of Venezuela, on the other hand, provides striking evidence of how political forces shape the life and destiny of women and girls in a time of food scarcity. Our final case study argues poignantly that the needs of women cannot be met without changing the larger socio-political forces which create and maintain gender inequality.

Food and Nutrition Security in Canada

Farmhouse in field of canola in Alberta, Canada © Shutterstock

Canada

[1] John Klironomos
[2] Satinder Kaur Brar
[3] Evan Fraser
[4] Krishnamoorthy Hegde
[5] Negin Kazemian
[6] Ashley McInnes
[7] Jeremy McNeil
[8] Mitra Naghdi
[9] Vinayak Pachapur
[10] Mehrdad Taheran

Canada: Rich in natural resources and a major food exporter, but **vulnerable to climate change** and the widening gap between rich and poor.

Summary

Canada is a large country with abundant natural resources, and a highly diverse agricultural sector. It is one of the largest food producers and exporters in the world. Most of its agricultural activity is located near the southern border with the U.S. Despite being a rich country, there is a widening gap between rich and poor, and a significant proportion of its population (approx. 12%) is in poverty and experiences food shortages. Northern communities are particularly vulnerable. In addition, another 20% of the population is considered obese. There is significant investment in agricultural education and research across the country. Universities across the country offer programs in agriculture and food technology. Research to improve food production using advanced technologies is conducted at universities, government labs and by industry. Many policy recommendations have been put forward to encourage farming and to promote sustainable practices. Climate change is a major risk to food and nutrition security in Canada.

1. National characteristics

Canada is the second largest country in the world, with a total surface of 9,984,670 sq. km, including 891,163 sq. km. of water. The current multicultural population of Canada is an estimated 35,362,905, 18.2% living in rural areas and the remaining 81.8% living in urban centers that are mostly within 150km of the Canada/USA border.

Due to its geographic location and the resulting climatic conditions, <7.5% of Canada's 9,093,507 sq. km. landmass is used for agricultural purposes: the majority being located within 300-400km of the border with the USA. Furthermore, the percent of total land mass dedicated to agriculture varies considerably between provinces being highest in Alberta (31.9), Saskatchewan (42.4) and Prince Edward Island (42.3) with the lowest in Newfoundland (0.1), Quebec (2.5), New Brunswick (5.3) and Ontario (5.6).

The number of active farms in Canada declined significantly between 1931 and 2006, from 728,623 to 229,373. By 2011, the number of farms had decreased an additional 10.3% while the average farm size had increased an average of 50 acres (6.9%). At the same time, the total area being farmed, 160.2 million acres, had declined by 4.1% since 2006. Overall, just under 60% of Canadian farms produce crops while the remainder are livestock based. The provinces of Ontario (51,950), Alberta (43,234), Saskatchewan (36,952) and Quebec (29,437) have the largest number of farms, while the larger sized farms are found in Saskatchewan (1,668 acres), Alberta (1168 acres) and Manitoba (1,135 acres), significantly larger than 244 and 280 acres in Ontario and Quebec, respectively.

The major agricultural crops are oilseeds (canola, flaxseed, soybeans), cereals (wheat, barley, corn, oats, rye, mixed grains), and pulses (dry peas, lentils, dry beans, chickpeas). In 2011, oilseeds were produced on 30% (19,400,000 acres) of all crop growing land in Canada, with >98% of canola produced in Saskatchewan, Alberta and Manitoba. Most of the soybeans come from Ontario, Quebec and Manitoba. Winter wheat and fodder crops are of considerable importance and each occupy 20% of all crop growing land, although fodder crops have declined (by 13.5% from 2006 to 2011) due to a decrease in beef production. There has been a significant increase in the production of pulses that now represent 6% (2.2 million acres) of all field crops grown in Canada. Many of these pulses (79.3%) are produced in Saskatchewan.

The area dedicated to the production of field vegetables is 267,665 acres, 83.2% of which is in Ontario and Quebec. Sweet corn is the number one crop (over 65,000 acres), followed by green peas, carrots, beans, tomatoes, onions, crucifers and pumpkins. There has been an increase in the greenhouse industry, now at 249.3 million sq. ft., of which 135.1 are dedicated to vegetable production and the remainder to flowers. The majority of greenhouses are found in Ontario (54.2%), British Columbia (24.5%) and Quebec (12.2%) and the most frequently produced vegetables are tomatoes, cucumbers, peppers and lettuce.

In Canada, fruit production occupies 312,041 acres, with blueberries being the most important crop with nearly 175,078,000 acres dedicated to their production in Quebec, the Maritime provinces and British Colombia. Apples are the second most important fruit crop followed by grapes, the latter associated with the expanding wine industry in British Columbia, Ontario, Quebec and Nova Scotia. Other cultivated tree fruits include peaches (3,154 hectares), pears (944 hectares), plums and prunes (684 hectares). Cranberry production has increased nationally, with Quebec and British Columbia being the major producers.

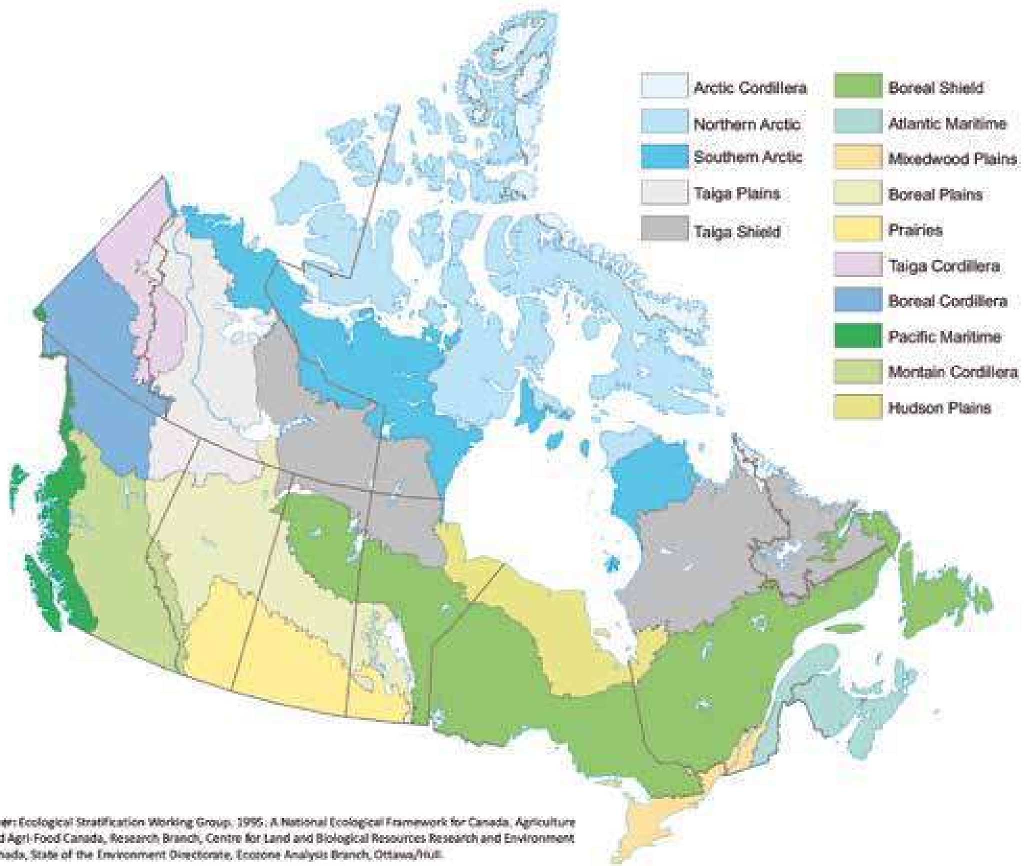
Apiculture is found across Canada though it is concentrated in the prairies. For instance, more than 70% of the 561,297 recorded honeybee colonies, as well as >98% of other bees used for pollination (i.e. leaf cutter bees) are found in Alberta, Manitoba and Saskatchewan. Maple syrup is an alternative to honey and Canada is a major source of maple syrup, with >94% being produced in the province of Quebec.

While there has been a decline in cattle production over the past 20 years, beef and dairy farms still represent the most important sectors of Canadian livestock production. Alberta has nearly 60% of the national beef herd, while Quebec (37.4%) and Ontario (33.1%) are the provinces with the most dairy herds. Quebec, Ontario and Manitoba are the major pork producers while Ontario is the biggest poultry producer in the country, having 38.2% of egg-laying chickens and producing 32.5% of birds destined for the table.

In addition to the active marine fishing industry, aquaculture is now being practiced across the country and represents about 20% of Canada's total seafood products, including various salmon species, trout and arctic char, as well as mussels, clams and oysters.

[1] John Klironomos, Chapter Coordinator. Department of Biology, University of British Columbia, Okanagan campus, BC, Canada. john.klironomos@ubc.ca **[2] Satinder Kaur Brar,** Institut National de la Recherche Scientifique, Quebec, Canada. **[3] Evan Fraser,** Arrell Food Institute and Department of Geography, University of Guelph, Ontario, Canada. **[4] Krishnamoorthy Hegde,** Institut National de la Recherche Scientifique, Quebec, Canada. **[5] Negin Kazemian,** Department of Biology, University of British Columbia, Okanagan campus, BC, Canada. **[6] Ashley McInnes,** Department of Geography, University of Guelph, Ontario, Canada. **[7] Jeremy McNeil,** Department of Biology, Western University, Ontario, Canada. **[8] Mitra Naghdi,** Institut National de la Recherche Scientifique, Quebec, Canada. **[9] Vinayak Pachapur,** Institut National de la Recherche Scientifique, Quebec, Canada. **[10] Mehrdad Taheran,** Institut National de la Recherche Scientifique, Quebec, Canada.

Map 1. Terrestrial ecozones of Canada



After: Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull.

In the last half century Canada's population has increased from just over 19.6 million to just over 36.5 million. Currently, >81% of the population reside in urban areas (73% in 1965) and >70% of all Canadians live in two provinces, Quebec and Ontario. Due to an aging population (median age in 2016 was 40.8 compared with 27 in 1965) and the decrease in average fertility (the number of children per female declining from 3.6 to 1.6) the natural increase accounts for only one third of population growth. Thus, 67% of the population growth is the result of immigration, a trend that is expected to continue in the coming years.

Currently less than 2% of the economically active population is directly engaged in farming; however, 2.2 million Canadians are working in agriculture and agri-food industry that accounts for 12.5% of the country's labor force (Statistics Canada, 2011; AAFC, 2016c). Yet the number of farmers is declining; in addition to the decrease in the number of farms, average age of farmers is increasing, which indicates an alarming failure of intergenerational transfer (Schutter, 2012). About 14% of Canadian farms are considered multigenerational and this is lowest in Alberta (12.3%) and highest in Quebec (20.3%), while just under 7% of the farming community is made up of mainly European immigrants to Canada. The National Farmers Union (NFU) of Canada complains about the role of powerful lobbies of the food manufacturing sector that keeps the price of their products at low levels while the input prices farmers pay are constantly increasing. This is known as the cost-price squeeze and has contributed to the increasing number of farmers leaving their farms, unable to maintain a living.

While precision agriculture, defined as technologies such as "smart tractors or robotic milkers" that allow farmers to tailor inputs more precisely, has improved efficiency it also requires a significant investment in machinery and subsequently is more cost-effective on larger farms. This would explain why <10% of the active farms in Canada, often family corporations, account for approximately 50% of all gross agricultural receipts. The observed increase in the average age of farmers is, at least in part, due to the high costs of establishing a successful business. However, the increase in the value of certain crops and the resulting increased profitability of farming as an enterprise is bringing younger people back into the business.

Temporary foreign workers are an important part of Canadian agriculture and there are two different government programs available. The first is the Seasonal Agricultural Workers Programme (SAWP) open to citizens of Mexico and twelve Caribbean countries. If approved, workers may spend up to 8 months in a calendar year working on Canadian farms. The second program is called the Temporary Foreign Workers Programme and allows for citizens from other countries to work in agriculture for up to two years.

Canada is a major player in the international trade of Agriculture and Agri-food Products (AAP). It was ranked fifth largest exporter in 2014 and sixth largest importer of AAP in the world. In that year, Canada export and import sales reached $51.5 billion and $39.4 billion, which accounted for 3.6% and 2.9% of the total value of world AAP exports and imports, respectively. In 2015, Canada's agri-food and seafood exports exceeded CAD$61G. The major importing countries were the USA (CAD$32.6G), China (CAD$6.3G), Japan (CAD$3.8G), Mexico (CAD$1.7G), India (CNAD$1.5G), Hong Kong (CAD$0.9G), Italy (CAD$0.8G), Bangladesh (CAD$0.8G), Indonesia (CAD$0.7G) and the United Arab Emirates (CAD$0.6G). The top export agri-food products were wheat, canola seed, dried legumes, crustacean products, pork, unmodified vegetable oils, soybeans, bread and pastry, live cattle and beef.

In the same year, agri-food imports were about CAD$47.0G, with the biggest exporters being the USA (CAD$28.0G), Mexico (CAD$2.1G), China (CAD$1.4G), Italy (CAD$1.1G), France (CAD$0.9G), Brazil (CAD$0.8G), Chile (CAD$0.8G), Thailand (CAD$0.8G), Australia (CAD$0.6G) and India (CAD$0.6G). The top imported products were wine, prepared foods, bakery products, pet food, coffee, chocolate and cocoa-containing products, bottled waters, fresh fruits, prepared fruit and nut products and crustaceans.

One of the major challenges for Canadian agriculture, as for all other countries, will be adapting to the effects of climate change. This is because climate change will not only have direct effects on crops but will also affect the impact of both beneficial organisms (e.g. pollinators, biological control agents, mycorrhizas) as well as pests (e.g. herbivores, pathogens). As the demands for agricultural products increase globally, other challenges will include the development of policies that ensure the quantity and quality of agricultural land that is available to provide the desired productivity, while limiting the negative effects that agricultural practices have on other ecosystems.

Finally, food security is a major issue for many of Canada's northern communities that do not have access to land suitable for farming and are isolated and remote. Food insecurity in northern communities is further exacerbated by climate change, as increasing temperatures are shortening the time that "ice roads" can be used to safely transport goods from South to North. Clearly, these needs must be addressed through the development of new approaches driven by social welfare programs backed by cutting-edge research and initiatives that will provide opportunities for developing certain forms of sustainable agriculture in areas where it is currently limited or inexistent.

Across the country, approximately 1 in 7 Canadians (1 in 5 children) are considered to be living in poverty, affecting their access to food, suitable housing and medical care. The incidence is higher amongst certain groups, which include single mothers, the elderly, members of first nations and Canadians with mental or physical challenges. In recent years, there has been a significant increase in the use of food banks in most parts of the country as 12% of Canadian households have difficulty putting food on the table.

Table 1. Agriculture and Agri-Food Canada research stations across the Canadian provinces (AAFC, 2017a)

Provinces of Canada	Research Stations
British Columbia	Agassiz Research and Development Centre Summerland Research and Development Centre
Alberta	Lacombe Research and Development Centre
Alberta	Lethbridge Research and Development Centre
Saskatchewan	Saskatoon Research and Development Centre Swift Current Research and Development Centre
Manitoba	Brandon Research and Development Centre Morden Research and Development Centre
Ontario	London Research and Development Centre Ottawa Research and Development Centre Guelph Research and Development Centre Harrow Research and Development Centre
Quebec	Sherbrooke Research and Development Centre Saint-Hyacinthe Research and Development Centre Quebec Research and Development Centre Saint-Jean-Sur-Richelieu Research and Development Centre
New Brunswick	Fredericton Research and Development Centre
Prince Edward Island	Charlottetown Research and Development Centre
Nova Scotia	Kentville Research and Development Centre
Newfoundland and Labrador	St. John's Research and Development Centre

2. Institutional Setting

National agricultural research systems: Canada's research capabilities and areas of local strength

Canada is one of the world leaders in agricultural research. The federal ministry of Agriculture and Agri-Food Canada (AAFC) has 20 research and developmental centers across the country (**Table 1**) (AAFC, 2017a). These research stations, along with their satellite locations and facilities, provide the country with scientific research and advancements in agriculture. Also, many of these research centers are participants in the minor use pesticide program, which was launched in 2002 by AAFC and Health Canada's Pest Management Regulatory Agency (AAFC, 2017b). This program works toward increasing grower competitiveness by providing new and effective crop protection tools and technologies (AAFC, 2017b). Each province across Canada also has distinctive areas of focus and research systems relating to the unique characteristics of the agricultural systems in that region (see Section 1). For example, one of the research centers in Saskatchewan (Swift Current Research and Development Centre) focuses on addressing severe drought, erosion, frost, pests and crop disease-related problems, as well as developing land management systems to enhance soil and water quality for the growth of wheat varieties (AAFC, 2017d). Implementation of new technologies and methods has allowed for high productivity in the agricultural sector. However, research and particularly projects that are more long-term need to be better funded. The "fast-to-market" mindset is driving research

Lake Ontario (Credit: J. deSousa).

funds to meet short-term market objectives. In addition, each province also has ministries of agriculture and often these are linked closely with specific universities. For instance, the Ontario Ministry of Agriculture, Food and Rural Affairs maintains a close connection on research and extension with the University of Guelph through a "research contract" that includes cooperating on maintaining agricultural research facilities as well as laboratories devoted to animal and food safety.

Research and development has also led Canada to become an international leader in areas such as animal genetics, the development of new cultivars, and greenhouse and climate-controlled greenhouse production (Steppler & Switzer, 2014). Canada is also internationally known for its research successes in plant and animal breeding, and disease control. Development of wheat varieties, from Red Fife (1840s) to Marquis (1907) and to rust-resistant varieties (e.g. Renown 1936, Selkirk 1953) are among the most significant achievements (AAFC, 2017d). The creation of canola as a source of vegetable oil was also an important Canadian success story during the post-war period (AAFC, 2017d). Research on this was conducted at the University of Manitoba that was largely responsible for the development of a new cereal crop, triticale, a fertile cross between wheat and rye (AAFC, 2017d). In terms of livestock genetics, Canada is also a leader. For instance, work done at the University of Guelph has used genetic breeding values for immune response to naturally breed cattle for greater disease resistance. Other important developments in improving maize (corn), soybeans, sunflowers, tobacco, and various fruits and vegetables have helped increase crop yield (AAFC, 2017d). There is also important research looking at genetic and congenital defects of animals such as poultry (for meat and egg yield), beef and dairy cattle (AAFC, 2017d).

Canada's scientific collaboration

Several programs have been developed to promote scientific collaboration and innovation. The Growing Canadian *Agri-Innovations Program* has many initiatives such as promoting agri-based investment opportunities that link potential investors and agri-entrepreneurs (AAFC, 2017b). The *Agricultural Bioproducts Innovation Program* is another program that is aimed at supporting networks of private, public and academic talent to build research capacity in specific areas of agricultural bioproducts and bioprocesses (AAFC, 2016b). International collaborations are also a major emphasis. For example, Canada is one of the founding members of the *Global Research Alliance on Agricultural Gases*, which is an international network of more than 30 countries devoted to collaborative research on greenhouse gas mitigation and beneficial management practices for farmers (AAFC, 2017a). Canada and the USA have a long history of bilateral science and technology collaboration in Agriculture, which is particularly useful as they share some similar climatic zones (albeit only with northern states). This partnership is a major economic sector for both countries and includes the AAFC and the United States Department of Agriculture (USDA) collaborating on many initiatives including PROCINORTE, the Soil Moisture Active Passive (SMAP) and the Wheat Initiative that helps advance the agriculture sector (AAFC, 2017a). Canada and China also have a strong and well-established relationship in agricultural research in genetics and genomics, crop pests and diseases, agri-food, and sustainable production systems (Government of Canada, 2016). The Canada-China Agriculture Science Network was recently launched in 2014 to bring together Canadian and Chinese agricultural scientists and collaborators (Government of Canada, 2016).

Canada's agricultural databases

Agricultural databases are critical in scientific research and can reduce duplication and provide a snapshot of the current state of work. Databases, such as the *Grower Priority database* provides an information source for growers, registrants, and regulatory officials (Health Canada, 2014). The *National Soil database* also contains important information relating to soil, landscape and climate data for all of Canada (AAFC, 2017c). The national archives contents were collected by federal and provincial field surveys, or created using information from land data analysis projects. Other collections such as the *Glomeromycetes* In Vitro *Collection (GINCO)*, are also essential for scientific research. For example, GINCO, the first international collection of Glomeromycete (Mycorrhizal) fungi propagated under monoxenic culture conditions on excised roots is a valuable source of material for crop plant-microbe interactions research (AAFC, 2017a). The *Plant Gene Resource of Canada* contains a clonal genebank and helps conserve, characterize, index and distribute crop plants (AAFC, 2017a). Other collections such as the Canadian National Mycological Herbarium (DAOM) holds over 350,000 fungal and fungal plant disease specimens, which makes it the largest fungarium of non-lichenized fungi in Canada (AAFC, 2017a). The AAFC also contains collections of vascular plants and includes 1.5 million irreplaceable specimens protected in a climate-controlled environment at AAFC's Central Experimental Farm (AAFC, 2017a). Although databases and collections require a long-term commitment for development and ongoing maintenance to stay current, they are essential to Canada's ongoing research in agriculture and need to be improved.

Universities and research institutes Scientific development and infrastructure

There is significant agriculture expertise across the country, although cuts in federal spending in recent years have resulted in the closure of some agricultural research centers and fewer research positions. At universities, there has been an increased reliance on the support of the federal "tri-council" research agencies for agriculture-related research, specifically grants from the Natural Sciences and Engineering Research

Council of Canada that often requires industry-matched funding. That said, there are some grower groups that provide small funding. Also in 2015 and 2016, several large federal research programs on agriculture commenced thanks to investment through the Canada First Research Excellence Fund. These include initiatives relating to cereal genetics and water conservation led by the University of Saskatoon and a $76.6M program called "Food from Thought: Agricultural Systems for a Healthy Planet" that focuses on applying Big Data to food production at the University of Guelph. Additionally, there are many universities, colleges, and institutes across Canada that provide training in agriculture-related fields (**Table 2**). These programs range from undergraduate and graduate programs to more specialized certificates in specific areas.

Table 2. Institutions that offer training programs in agriculture

Provinces of Canada	Research Stations
British Columbia	University of British Columbia University of Fraser Valley Organic Farming Institute of BC Kwantlen Polytechnic University Vancouver Island University College of the Rockies Camosun College Malaspina University College Kootenay Permaculture Institute
Alberta	University of Alberta University of Lethbridge Lethbridge College Red Deer College Olds College Grand Prairie Regional College Lakeland College
Saskatchewan	University of Saskatchewan University of Regina Saskatchewan Polytechnic Parkland College
Manitoba	University of Manitoba Red River College Assiniboine College
Ontario	Brock University University of Guelph Mohawk College Algonquin College Fleming College Trent University Seneca College Durham College Conestoga College St. Lawrence College
Quebec	McGill University (McDonald College) Université Laval
Nova Scotia	Nova Scotia Agricultural College (NSAC)
Yukon	Yukon College

Inter- and transdisciplinary research, modeling and assimilating technological innovations

Technological innovations pertaining to food and farming systems in Canada are stimulated and strengthened by inter- and transdisciplinary research across the country. The *Enabling Research for Competitive Agriculture* initiative has programs such as the *Canadian Agricultural Innovation and Regulation Network*, which brings researchers together to study the processes of agricultural innovation and proactively engaging government, industry, academia and the public to improve the agricultural innovation system in Canada (CAIRN, 2011). This network is composed of 37 members representing academic, government and private institutions from British Columbia to Nova Scotia as well as the USA and Europe (CAIRN, 2011). There are many successful projects across the country. For example, researchers from Carleton University and Agriculture and Agri-food Canada are collaborating on projects applying nanotechnology methods to create "intelligent" fertilizers that while meeting specific nutrient needs, reduce leaching into watersheds (Steppler & Switzer, 2014). Farmers are also using location technologies based on GPS tracking systems to ensure that the right seed variety is planted in the right location within a field depending on the nutrient and water content of the soil (Steppler & Switzer, 2014). New approaches based on "4R" nutrient stewardship, defined as Right fertilizer at the Right rate at the Right time and in the Right place) have also been popularized

Iceberg from nearby (J. McNeal).

by the *Canadian Fertilizer Institute*, which allows farmers to apply fertilizer in variable doses to avoid losses into the water or atmosphere, and at the right time by taking weather conditions into account (Steppler & Switzer, 2014). Crop rotation practices are also allowing farmers to improve fertilizer management and soil conservation, while breaking pest, disease and weed cycles (Steppler & Switzer, 2014). Farmers have used dynamic greenhouse climate control to conserve energy and improve crop quality, while reducing energy consumption in winter (Steppler & Switzer, 2014). Finally, there are many examples of new varietal strains being developed, such as a new variety of cherry, the "Sweetheart", that has the characteristics of self-fertilization and late ripening that can extend the growing season and the fruit harvest. This cultivar has helped increase British Columbia's cherry exports from $500,000 a year in the 1990s to almost $40 million in 2011 (Steppler & Switzer, 2014).

It is also important to note that these innovations invariably require interdisciplinary and intersectoral partnerships and that such partnerships require appropriate financial support and must contain well-developed administration to support extra administrative and collaborative costs associated with collaboration (CFA, 2016). Innovation is not limited to research activities; thus, it is imperative that this continuum develops further in order to thrive in the agricultural sector.

Skilled work force development and Canada's national education system

Canada's system of agricultural education began in New France in 1670 at the Petit Seminaire at St. Joachim (Johnson, 2015; CAHRC, 2016). A program begun by Bishop Laval provided some training in agriculture directed to practical experience on the school farm (Johnson, 2015). By 1874, the first English-language agricultural school was established at Guelph, Ontario (Johnson, 2015). Today, Canada's agricultural education system has expanded to 18 post-secondary institutions, 5 of which offer programs in French (one in New Brunswick, 3 in Quebec, and 1 in Ontario) and the remaining 13 offer programs in English (Johnson, 2015). In addition, there are many courses offered at additional institutions that would serve those that are working in agriculture (for example, plant pathology, entomology). Over time, subjects deemed appropriate to agriculture have also changed significantly. Early schools offered courses in crop and animal production, as well as soil science agricultural engineering and agricultural economics (Johnson, 2015). Presently, more faculties now address the processing of agricultural products as well as primary production. Some include wildlife and forestry as a part of natural resource management training as well as environmental studies (Johnson, 2015). Although Canada's education system has developed over the years, the challenge of spreading agricultural knowledge to the public still remains a problem. Many of today's consumers have little idea as to where their food comes from or how the agricultural sector operates. Therefore, educating people about agri-food systems is imperative. Organizations such as Agriculture in the Classroom, available in seven provinces across the country, help integrate agricultural education into Canada's curriculum. These organizations may also help to encourage students to join the agricultural sector, to offset the shortage of Canadians working in agriculture. The gap between labor demand and the domestic workforce in agriculture has also doubled, from 30,000 to 59,000 in the past ten years and projections indicate that by 2025 the Canadian agriculture workforce will need 114,000 additional workers (FSC, 2011a). Offering farmer-training programs in rural and urban communities along with financial assistance, such as partial student-loan forgiveness, for those going into farming can help decrease this gap.

Funding

In Canada, agriculture falls within a shared federal–provincial jurisdiction and is strengthened by the private sector. Responsibilities mainly rest with federal authorities, while provinces have jurisdiction over agricultural teaching and extension since agricultural research activities vary from province to province and are unique to their region. Federal departments include: Agriculture and Agri-Food Canada; Canadian Food Inspection Agency (CFIA); Health Canada, Environment Canada; Federal Research and Innovations Agency, and National Research Council Canada. The three federal research granting councils (Natural Science and Engineering Research Council of Canada; Canadian Institutes of Health Research; Social Sciences and Humanities Research Council) provide funding to university researchers, some of whom work on subjects related to agriculture, fisheries and forestry (Steppler & Switzer, 2014). The federal government also uses a science-based legislative and regulatory framework to guide the introduction of new products into the market or the development of new methods (Steppler & Switzer, 2014). The federal government participates in and funds research and innovation activities undertaken within the government itself or in partnership with industry and academia (Steppler & Switzer, 2014). The federal government supports stakeholders to facilitate the transfer and adoption of new processes or technologies. The Canadian Agricultural Services Co-ordinating Committee, for example, coordinates research, extension and education services, and is responsible for assessing immediate and future research needs and developing appropriate proposals (Steppler & Switzer, 2014). Provincial and regional committees, and also grower groups, also assess and make recommendations regarding agricultural research and education within provinces. Thus, the research function is shared among Agriculture Canada and other federal agencies, provincial departments of agriculture, provincial research councils, university faculties of agriculture and veterinary medicine and private industry.

Many key policies have helped shape Canada's public science and technology policy. For instance, in 1999, the Council of Science and Technology Advisors released the *Science Advice for Government Effectiveness* report, which confirmed the federal role in performing public-good research (AAFC, 2017a). The provincial governments have also implemented an innovative *Community Economic Development Investment Fund,* which are funded by individual investors but supported by the provincial government through tax incentives. One project funded in 2011, for example, has led to over $1 million being invested in new or expanding farm and food businesses in Nova Scotia.

Growing Forward 2, a 5 year (2013-2018) policy framework for Canada's agricultural and agri-food sector, is a $3B investment by federal, provincial, and territorial governments and is the foundation for government agricultural programs and services (AAFC, 2017d). Growing Forward 2 focuses on innovation, competitiveness and market development to support Canadian producers and processors with the tools and resources they need to continue to innovate and capitalize on emerging market opportunities (AAFC, 2017d). In terms of government investment in agriculture, however, the trend is toward lower levels of agricultural subsidies, which makes it difficult for individual farmers. More generally, the Canadian government has been focusing less on supporting basic research and production subsidies and more on promoting commercialization and end-product innovation (CFA, 2016). Public and private partnerships also leverage funds and resources and encourage collaboration among government, universities, and industry (CFA, 2016).

3. Resource and Ecosystem Characteristics

Water resources and challenges in Canada

Safe, reliable water supplies are necessary for irrigation, livestock watering and cleaning and processing operations, as well as domestic and potable uses on farms. Although Canada is currently a nation with vast amounts of water resources, there are many challenges. Ponds and dugouts, for example, are reservoirs that are common all over Canada and represent an important water source for rural residents including household use, livestock watering, crop spraying and agriculture (AAFC, 2017a). However, as a result of decomposition, oxygen levels are low in many such bodies, so anaerobic decomposition may lead to changes in the water's color, odor and taste (AAFC, 2017a). Furthermore, some of the water collected comes from surface runoff, which may contain unwanted materials, including pathogens, plant nutrients, pesticides, decomposed plant material, suspended sediment and contaminants such as fuels and solvents (AAFC, 2017a). Water erosion is another challenge that may lead to the accumulation of sediments, which can cause turbidity in streams and lakes and reduce volumes of lakes and reservoirs (AAFC, 2017a). Another major challenge is water pollution of local and regional water sources due to the transport of phosphorus and other nutrients from croplands (Natural Resources Canada, 2017). For example, 70% of phosphorous input into the Great Lakes has been attributed to agricultural sources (Bickis, 2016). The rapid expansion of oil sand projects in Canada is also causing strains on freshwater sources and can lead to many ecological and environmental issues.

Soil resources and challenges in Canada

Canada's land provides many different types of soils suitable for agriculture. Soil degradation, however, remains a challenge, due to excessive rates of soil erosion and other forms of soil degradation such as salinization, acidification, compaction and depletion of organic matter (AAFC, 2017a). Topsoil is most susceptible to

Yukon (Credit: B. Spragg).

erosion and its loss can lead to soil productivity loss and impact crop yields (Natural Resources Canada, 2017). Previous studies have found that removal of topsoil reduced unfertilized crop yields by 50% for four of six soils in Alberta (AAFC, 2017a). The loss of soils and associated chemicals from cropland can also affect water supplies and can result in increased eutrophication, damaged fish habitats, and reduce water holding capacity and lower crop yields (Bickis, 2016). Erosion also results in patchy crops which are difficult to manage and generally have reduced yield (AAFC, 2017a). Many of these soil problems have also been linked to practices associated with conventional agriculture such as excessive tillage, monoculture row cropping and the declining number of farms with livestock (hence less forage in rotation) (Bickis, 2016).

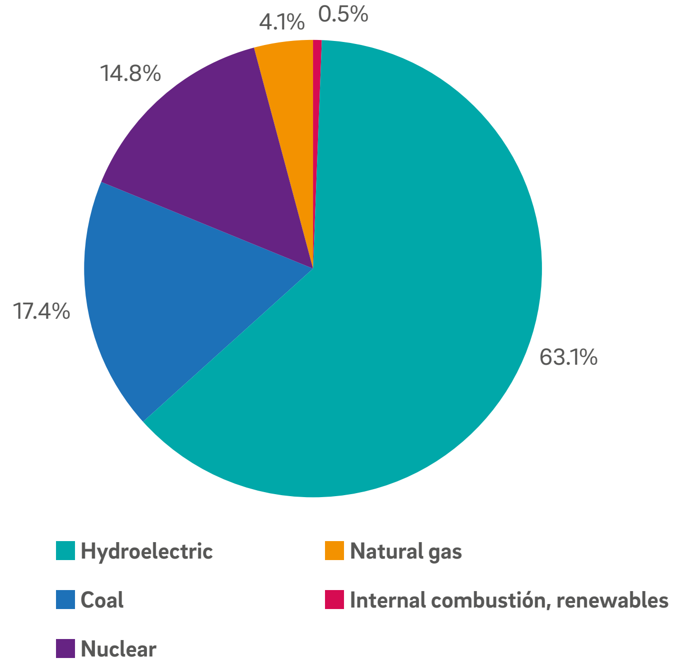
Energy challenges

Canada has large quantities of diverse sources of energy (**Figure 1**), including hydro, wind, solar, oceans (tidal and wave), biomass, uranium, oil, natural gas, nuclear, coal, oil sands-bitumen and coal bed methane (Environment Canada, 1995). Canada generates an immense amount of hydroelectric power and uranium (accounting for 21% of global production), ranks second in natural gas exports and is the 7th largest oil producer in the world (Environment Canada, 1995; Natural Resources Canada, 2016). Canada also has some of the largest and safest nuclear generating stations in the world and several important nuclear research facilities that contribute to research and development in other sectors such as aerospace, automotive, manufacturing and engineering (Environment Canada, 1995). Despite these large energy sources, energy consumption is a problem. For example, Canadians spent nearly $135 billion in 2004 on energy to heat and cool their homes and to operate their appliances, cars and industrial processes (Canadian Biodiversity, 2016). Canada adds significantly to global energy consumption, which remains problematic and is projected to increase by 49% over the next quarter century, from 522 EJ in 2007 to 779 EJ in 2035 (Environment Canada, 1995). In Canada, the agri-food sector accounts for approximately eleven per cent of total energy consumption (Environment Canada, 1995). Mechanization of agriculture, the commercial production of synthetic fertilizers and pesticides and the transportation and handling of agricultural commodities for trade lead to high levels of energy use (Environment Canada, 1995). The use of fossil fuels as an energy source to increase agricultural productivity also poses significant challenges with contributions to several environmental problems (Environment Canada, 1995). Therefore, although non-renewable energy sources are becoming difficult to find and extract, new sources of sustainable energy for the future should be a fundamental priority for the country (Canadian Biodiversity, 2016). Continuing research on alternative forms of fuel such as ethanol, biodiesel, natural gases and electricity for transportation can help with energy challenges in Canada (Canadian Biodiversity, 2016).

Biodiversity conflicts and challenges

The human footprint continues to increase globally, as a result of our increasing population, urbanization and development, and consumption habits. Canada is home to over 70,000 known species and many others that remain to be discovered (Canadian Biodiversity, 2016). Degradation of ecosystems and habitats due to pollution, climate change, wildlife disease and the introduction of alien species have endangered many species and affected the biodiversity in Canada (Canadian Biodiversity, 2016). Agriculture is one sector that requires significant space, which thus reduces space for wildlife. For example, the agricultural sector has led to decreased intact prairies (13% of the shortgrass prairie, 19% of the mixed grass prairie communities remain, and almost none of the tallgrass prairie community remains) (Natural Resources Canada, 2017). This reduction in available land threatens many prairie species and can lead to the depletion of genetic diversity.

Figure 1. Canada's energy resources (Natural Resources Canada, 2016)



Agriculture in Canada is very important for the country's economy, can provide many jobs and even has a beneficial role by protecting habitats from urbanization and conserving plant species. Although there are many advantages and contributions from this division, overharvesting and overexploitation in the agricultural sector has had the greatest effect on biodiversity (Canadian Biodiversity, 2016). Humans have been exploiting species in order to maximize short-term profit, which affects the sustainability of many species and leads to the depletion of resources. Other agricultural effects and management practices including habitat alteration, soil erosion, exotic pest introduction and pollution from pesticides and fertilizers have also greatly impacted the ecosystem (Canadian Biodiversity, 2016).

In addition, the need to conserve the genetic diversity of microbes and mycorrhizal fungi is being increasingly recognized in Canada, since they play a major role in the diversity of life. Therefore, agricultural applications of fertilizers and pesticides need to be further tested for their effects on biodiversity.

With the loss of biodiversity in Canada, advances in ecological management practices are imperative. Restoration and rehabilitation of species and ecosystems can be extremely expensive and not always successful, but are critical for preventing ecosystem degradation. The AAFC for example has established the *Canadian Animal Genetic Resources Program* in collaboration with *Rare Breeds Canada*, which aims to conserve, preserve and increase the utilization of the genetic diversity of plants, animals, microbes and plant viruses of economic importance to Canada (AAFC, 2017b). Canada has also been involved in vast research across the country on this topic and has produced a variety of strategies which include protecting ecologically important natural areas, conserving private land, connecting conservation and resource management strategies through integrated planning and management, reducing human impacts on working landscapes and restoring damaged ecosystems.

Forestry trends and implications

Much of Canada is covered by forests, and much of this land is managed for human use, including for agriculture. Forestry has a major impact on Canada's economy. In 2013, for example, forestry exports contributed $19.3 billion to the net balance of trade (Natural Resources Canada, 2017). Although forestry can have many advantages, forestry practices such as clear cutting can significantly impact the forestry sector that provides resources such as food, fuel and medicine, and that are used for hunting, trapping and gathering. In 2010, for example, an estimated 45,900 hectares were deforested in Canada (Natural Resources Canada, 2017). Deforestation rates for Canada, however, have been declining and are among the world's lowest. In 2010 for example the rate was less than 0.02% of the forests (Natural Resources Canada, 2017). The healthy, productive and thriving forests in this region highlight Canada as a world leader in sustainable forest management.

Deforestation for pastures and agriculture may be beneficial for the agricultural sector, but it can also be costly to the environment and destroy habitats, affect soil and water quality, influence climatic conditions and decrease biological diversity. Deforestation can also cause the nutrient-rich topsoil to be swept away by rain and wind, which can lead to eutrophication and decrease productivity. This process can affect biodiversity, and reduce carbon storage of forests which can result in net carbon dioxide emissions. Re-growth and tree planting can also often lead to uniformity in density and types of trees, which differ from the original environment. However, a variety of plans have been implemented to continue establishing protected areas in support of conservation of forest biodiversity. The government also has rigorous laws for protecting forests and carefully monitors and regularly publishes reports on deforestation to help manage the health of Canadian forests.

Climate change

Climate change and its impacts are of major concern for Canada, since Canada's rate of warming is approximately twice the global rate. Global warming computer simulation models have predicted different effects for different vegetation zones in Canada, from the shrinking of the tundra zone with increasing temperatures and expansion of the hardwood forest zone in the South. Climate change can also affect Canada's forests and water temperatures and alter the ecosystems. The alteration in temperature, salinity and the availability of nutrients can also affect biodiversity (Steppler & Switzer, 2014). Other ecological changes such as reduction in snow-cover duration, earlier spring thaws and the melting glaciers and ice caps can lead to extreme weather events such as torrential rains and prolonged drought. There are many effects of droughts and floods, including the reduction of crop yields and pasture productivity, an increase in the growth of unwanted weeds, an increase in the prevalence of pests and pathogens and an increase in energy demands (associated with the manufacture, transport and application of pesticides, for example) (Steppler & Switzer, 2014).

Although many are concerned about the negative impacts of climate change on Canadian agriculture, it is also possible that this sector could benefit from the higher temperatures accompanying climate change. For example, land that is currently not suitable for cultivation may become amenable to crop growth as the growing season lengthens. In addition, the growing season for crops and other horticultural products might be longer and this may increase yields (Steppler & Switzer, 2014). Benefits to livestock production may also be observed in the form of lower feed requirements, increased survival rates of the young and lower energy costs. However, higher temperatures may also result in heat stress for crops (for example, canola). Overall, any benefits in terms of a longer growing season and warming temperatures may be offset if climate change also results in new hydrological and pest patterns, so much remains unknown about how climate change may affect the Canadian farming sector.

In terms of emission, Canada contributes about 2% of the total Global Greenhouse Gas (GHG) emissions, which puts Canada among the highest per-capita emitters (AAFC, 2017a). Many sectors contribute to GHG emissions in Canada, with the energy sectors (consisting of stationary combustion, transport and fugitive emission sources) producing the majority of Canada's total GHG emissions in 2013, at 81% (AAFC, 2017a). Other sectors also contributed, such as agriculture, industrial processes and product use, and minor contributions from the waste sector. Although agriculture will be greatly impacted by climate change, there is feedback where weather and climate may be influenced by agricultural practices, as the agriculture sector produces high greenhouse emissions. Nonetheless, GHG emissions from the agricultural sector have declined since 2008 and accounted for approximately 10% of total emissions in 2011 (AAFC, 2017a). New management techniques, however, are needed that result in higher carbon sequestration on agricultural lands. Implementing solutions and action toward reducing greenhouse gases is essential and can decrease the impact on the country.

Building resilience

Ecological agriculture in Canada is very important to produce foods that respect nature and biodiversity. The partnership and alliance between scientists and farmers is allowing for observations of the landscapes, weather patterns and natural resources to help with broadening diversity of plant genetic resources. Farmers are building production systems that are highly resistant to variability and changing climates. The USC Canada *Seed of Survival* program launched in 2013, for example, is an initiative for Canadian seed security that works with farmers and researchers to build a more secure and diverse seed supply in Canada (USC Canada, 2016). With proper training, plant selections and conservation, seed security and diversity can be protected and ensure the survival of plants and the planet's biodiversity.

New techniques and management practices are critical for conserving biodiversity and achieving a resilient and sustainable environment. Agroecological integrity can allow for ecosystems that have high functional diversity and are biologically resilient and capable of adaptation in case of disturbances. Farmers play a major role in adaptive capacity by experimenting with new approaches and techniques in order to diversify cropping systems. The implementation of variety selection and cultivar rotation (which is a traditional move back to past practices) is a simple method to increase overall yield, produce lower levels of GHG emissions and increase genetic diversity in prairie cropping systems in Canada. Using self-regenerating cover crops, crops for weed suppression, grain intercropping, adding woody plants, using green manure and decreasing tillage can also increase resilience and

Rural Alberta (Credit: B. Spragg).

biodiversity. Farming practices that are more resilient to climate change for example are important to consider and allow for crops that are drought-resistant, less affected by flooding and more resistant to frosts and extreme temperature changes. Dependency on non-renewable resources must also be reduced to increase resilience. By using new approaches and continuing research in this field, Canada is capable of building resilience and increasing food security.

Future outlook

Although natural resources are vast in Canada, there are many challenges. Emphasis must be placed on conservation of resources, such as water and soil, and on developing new sources of energy. With new innovative technologies presently available, and collaborations among different government departments, Canada has the potential to use energy more effectively and efficiently. Energy conservation can ensure Canada's energy security and reduce negative impacts on the environment. There is still much uncertainty on the impact of climate change on agriculture. This uncertainty needs to be embraced and more research is needed.

4. Technology and Innovation

Role of Biotechnology

Agricultural biotechnology is a collection of tools and scientific methods, including traditional breeding techniques, but also including gene editing and genetic modification, all of which are used to alter and improve the genomics of agricultural plants, animals and microorganisms. In general, therefore, agricultural biotechnology refers to a suite of methods that enable genetic improvements, which are not possible by traditional techniques alone such as breeding, and provides an opportunity to make production more manageable and less expensive. Agriculture products are regulated by different agencies in Canada. The main regulatory bodies are the Canadian Food Inspection Agency, Health Canada and Environment Canada (CFIA, 2016). The inputs of biotechnology are used in the agri-food sector in a variety of ways to produce superior agricultural inputs and food products. The broad areas of biotechnological applications related to food and nutrition sector include (CFIA, 2016):

1. Veterinary drugs and biologics
2. Bio pesticides
3. Novel bio-fertilizers or fertilizer supplements to improve plant growth
4. Livestock feed and feed additives
5. Novel foods
6. New seed varieties

In the past decade, biotechnology has substantially reshaped the Canadian agriculture and food sector, providing new ways to improve Canadian agriculture and food products with higher yields, superior resistance to pests, insects and adverse environmental conditions and sustainable management practices (see **Table 3** for list of genetically modified crops) (AAFC, 2017d; Sparling, 2010). The newer and advanced practices have increased profits, reduced production cost and in some cases, enhanced carbon sequestration and the potential for tradable carbon credits (CFIA, 2016). Genomic technologies applied to the livestock sector have resulted in management practices that reduce inputs, including antibiotics, while maintaining herd health and animal welfare along with productivity.

In addition to genetically modified crops, several other methods are being practiced in Canada. For example, researchers from the Kentville Research and Development Centre have developed a technology called HarvestWatch™ that monitors the chlorophyll fluorescence in stored fruits to calibrate temperature and other environmental factors, such as oxygen and carbon dioxide levels to ensure longer shelf life and product freshness (DeLong et al., 2007). There have been several improvements in mustard varieties in Canada, such as improved yellow and brown mustard with reduced oil content and increased protein content (AAFC, 2017d). Modern technological approaches have been used to improve AC Gehl, a premium variety of oat being widely cultivated in Canada so that it has twice the protein and high antioxidant content, as well as low glycemic index, making it ideal for people with diabetes (CFIA, 2016).

Other innovative approaches have been initiated in the animal agriculture, dairy and fishery sectors. Some of the examples are listed in Table. 1 In addition, novel research initiatives include essential oil-based formulations to help control detrimental gut bacteria, such as *Salmonella* and *Clostridium* perfringens in poultry, innovative milk separation techniques for more nutritional dairy products, research and innovation in genetics, nutrition, reproduction and herd management in the beef sector to produce 15 % less greenhouse gas emissions compared to emissions three decades ago (AAFC, 2017d).

The intensity of the research commitments and achievements of Canada are evident from several technologies and intellectual properties available for commercialization from Agriculture and Agri-Food Canada (AAFC, 2017a). These include:

1. Altering Carotenoid Profiles in Plants: Method of enhancing carotenoid levels in seeds of plants by altering the expression of the lycopene epsilon cyclase enzyme.
2. Anti-leukemia Plant Extract: Anti-monocytic-leukemia extract that can be produced from vegetables.
3. Altering Seed Oil Content and Oil Quality: Novel clone with the DiacylGlycerol

Table 3. Genetically modified crops and meat products approved and used in Canada in the past 10 years (CFIA, 2016; Health Canada, 2015)

Genetically modified ag-food product	Type of Genetic Modification	Developer	Canadian Food Inspection Agency approval year
Corn	Insect resistance and herbicide tolerance	Syngenta Canada Inc.	Applied for approval in 2016
Alfalfa	Reduced lignin	Monsanto Canada Inc. and Forage Genetics International LLC	2013
Apple	Engineered to be non-browning	Okanagan Specialty Fruits Inc.	2012
Canola	Glyphosate tolerance	Monsanto Canada Inc.	2011
Corn	Glyphosate herbicide tolerance	Monsanto Canada Inc.	2011
Cotton	Dicamba and glufosinate tolerance	Monsanto Canada Inc.	2012
Maize	Herbicide tolerance	Monsanto Canada Inc.	2015
Maize	Increased ear biomass	Monsanto Canada Inc.	2014
Maize	Insect resistance and herbicide tolerance	Monsanto Canada Inc.	2014
Maize	Resist Northern and Western Corn Rootworms	Syngenta Seeds Canada Inc.	2011
Mustard (*Brassica juncea*)	Herbicide tolerance using conventional methods (mutagenesis and breeding)	BASF Canada Inc.	2007
potato (Innate™ potatoes)	Low Acrylamide Potential and Reduced Black Spotw	J.R. Simplot Company	2015
Rapeseed (*Brassica napus*)	Herbicide tolerance using conventional methods (mutagenesis and breeding)	BASF Canada Inc.	2011
Rice	Glufosinate tolerant	Bayer CropScience Canada Co.	
Rice	ACCase inhibitor herbicide tolerance	BASF Plant Science	2016
Soybean	Dicamba herbicide tolerance	Monsanto Canada Inc.	2011
Soybean	Insect resistance	Monsanto Canada Inc.	2014
Soybean	Insect resistance	Dow AgroSciences Canada Inc.	2014
Soybean	Herbicide resistance	Syngenta Canada Inc. and Bayer CropSciences Inc.	2014
Soybean	Herbicide resistance	Dow AgroSciences Canada Inc.	2012
Soybean	Increased yield for commercial planting purposes and livestock feed and food use	Monsanto Canada Inc.	2011
Sunflower (*Helianthus annuus*)	Herbicide tolerance using mutagenesis and conventional breeding	BASF Canada Inc.	2009
Tomato (Flavr Savr™)	Engineered to slow the rate of ripening	Calgene, Inc.	2013
Wheat	Bred for herbicide tolerance	BASF Canada Inc.	2006
Wheat (Durum)	Bred for herbicide tolerance	BASF Canada Inc.	2006
Eggs	Chicken Eggs Enriched by Dietary Means in Lutein	Maple Leaf Foods Agresearch, SHUR-GAIN	2007
Eggs	Lutein and Zeaxanthin enhanced Eggs	L.H. Gray & Son Limited	2007
Eggs	Omega Pro shell eggs containing Lutein	Burnbrae Farms Ltd.	2008
Salmon (AquAdvantage Salmon)	Genetically modified to grow faster	Aqua Bounty Canada Inc.	2016

O-AcylTransferase (DGAT) enzyme in Canola for altering seed oil content and oil quality.
4. Modulation of Plant Cyclin-Dependent Kinase Inhibitor Activity: A method for controlling plant growth and morphology.

Prospects for novel high value agricultural products

Adoption of innovation and technologies are routine for agriculture businesses. Canadian agriculture produces commodity products for highly competitive markets, including high-value compounds such as proteins, and other foods such as mushrooms and truffles (Duckett Truffieres, 2013). Health Canada conducts safety assessments for well-characterized organisms before their release to the market (Health Canada, 2015). The enzyme market in North America was worth approximately $5 billion in 2015, with a projected 8% annual growth (see **Table 4** for a list of enzymes that are available) (Global Market Insights, 2016).

5. Increasing efficiency of food systems

Prospects for technology based increases in agricultural production Canada's status in world agriculture

Canada has maintained a strong role in international trade of AAP over the past decade. During 1994-2004 and 2004-2014, export sales of AAP from Canada experienced 76% and 96% growth, respectively. Likewise, import sales of AAP experienced 66% and 90% growth, respectively (AAFC, 2016a; Mathews, 2015).

Table 4. The list of permitted food enzymes published by Health Canada

Additive	Permitted Source	Permitted in or upon	Maximum Level of Use and Other Conditions
Amylase	*Aspergillus niger* var.; *Aspergillus oryzae* var.; *Bacillus amyloliquefaciens* var.; *Bacillus subtilis* var.; *Rhizopus oryzae* var.	Ale; Beer; Light beer; Malt liquor; Porter; Stout, Bread; Flour; Whole wheat flour; Cider; Wine,;Chocolate syrups; Plant-based beverages; Infant cereal products	Good Manufacturing Practice
Cellulase	*Aspergillus niger* var.; *Rasamsonia emersonii*; *Trichoderma longibrachiatum*	Distillers' Mash; Liquid coffee concentrate; Natural flavor and color extractives; Spice extracts; Single-strength fruit juices; Tea leaves for the production of tea solids: Bread; Flour; Whole wheat flour, and fruit juices	Good Manufacturing Practice
Protease	*Geobacillus stearothermophilus* TP7, *Bacillus licheniformis; Bacillus subtilis Aspergillus oryzae* var.	Hydrolyzed animal, milk and vegetable protein; Dairy-based flavoring preparations; Hydrolyzed animal, milk and vegetable protein; Industrial spray-dried cheese powder; Meat tenderizing preparations; Plant-based beverages	Good Manufacturing Practice
Papain	Fruit of the papaya *Carica papaya* L. (Fam. *Caricaceae*)	Ale; Beer; Light beer; Malt liquor; Porter; Stout, Pumping pickle for the curing of beef cuts	Good Manufacturing Practice
Trypsin	Pancreas of the hog (*Sus scrofa*)	Hydrolyzed animal, milk and vegetable proteins	Good Manufacturing Practice
Lipase	Animal pancreatic tissue; *Aspergillus niger* var.; *Aspergillus oryzae* var.; Edible forestomach tissue of calves, lambs; *Rhizopus oryzae* var.	Dairy-based flavoring preparations; Cheddar cheese; (naming the variety) Cheese; Processed cheddar cheese; Hydrolyzed animal, milk and vegetable protein; Hydrolyzed animal, milk and vegetable protein	Good Manufacturing Practice
Lipoxidase	Soybean whey or meal	Bread; Flour; Whole wheat flour	Good Manufacturing Practice

Interestingly, the trade balance of AAP in the primary agricultural products sector (i.e. exports directly from the farm sector) increased from less than $4 billion in 2004 to more than $16 billion in 2014, while the trade balance in the processed agri-food products sector decreased continuously from $2.5G in 2004 to -$4G in 2014 (AAFC, 2016a). Technologies increasing agricultural production could be used to take advantage of the growth in this sector. Considering the growing global demand for AAP (mostly due to population growth) and also Canada's natural capabilities (as a result of climate and water sources), Canada can be a leading producer and exporter in this sector. Attention is needed to diversify the AAP portfolio (e.g., varieties of value-added crops for domestic demands and also foreign markets in the mid-term and long term). However, the declining trend of trade balance in the processed agri-food products sector is worrying and indicates that Canada needs to invest in this sector since the value addition and job creation of processed products is generally higher than raw products. Acquiring technologies for efficient production of processed products at competitive prices should be considered in the short term and mid-term.

Agricultural land use

As noted earlier, the total land used for agriculture in Canada decreased from 67.5 million hectares in 2004 to 64.8 million hectares in 2014, which accounts for 7% of Canada's total land area. Despite this slight decrease in land use, an 80% increase was observed in the volume index of AAP during 1997-2014, largely due to the implementation of new technologies and methods. These new technologies have improved the production efficiency and have counterbalanced the need for more lands, but may also decrease the required labor.

For expanding AAP production, the most important infrastructure currently is the availability of appropriate land. Canada's lands are divided into 7 classes, with class 1 being the best land without limitations for crop production, while class 7 has no capacity for permanent pasture or arable cultivation. The majority of class 1 and 2 lands are already used for agriculture. There are still lands in class 3 which are covered by forest or shrubs and using them for agriculture needs to be thoroughly studied to address environmental impacts. Much of lands with class 4 to 6 are far from existing agricultural infrastructure, such as transportation and processing plants (AAFC, 2016a; CFA, 2016). That said, as new technologies such as vertical farming and other approaches linked with indoor food production become mature, the primacy of land as the main driver of agricultural production may decline in relative importance. Some of these have infrastructure requirements (see list below).

Postharvest Losses

Postharvest treatment is important since product deterioration begins after harvesting, and how this is handled determines whether the product can be sold fresh or in processed form (Fan et al., 2014). Storage in an appropriate place that is preceded by cleaning, sorting and packing is an important stage of postharvest treatment processes in Canada due to the long distances between production and consumption points. In addition to distance, there are also constraints of sub-freezing temperatures and high humidity. Many foods can be frozen, but others such as fruits need to be kept in a cold but not freezing atmosphere.

In 2014, Canadians wasted around $31G worth of food: over 30% of fruits and vegetables were rejected by stores due to their less-than-perfect cosmetic appearance, and an additional 47% occurred once they were bought by consumers. This food waste is a dilemma as many Canadians use a food bank to get adequate nutrition (Second Harvest, 2016). In addition to educating the public about such food losses, scientific and technological measures are also needed. For fresh products, techniques for preserving product appearance and increasing shelf life seem to be the straightforward solution in the short term. In addition, genomic manipulations can be used to prevent shape defects and vulnerability to fungi, bacteria, scratches and bruising. For rejected fresh

Farming infrastructure requirements

- **Transportation:** Farm operators should have access to different means of transportation including railways, road, ports in waterways and airports at competitive price.
- **Telecommunications:** Farm operators need landline/cellular phone, fax and internet to communicate with different sectors.
- **Weather networking:** Weather networking stations in remote area are necessary for farm activities.
- **Energy:** Most forms of energy, such as electricity, natural gas, etc., must be available for new agricultural areas.
- **Education and Training:** The education system must have a commitment to develop programs to address the needs of agriculture to instrumental and management skills.
- **Machinery:** New farm operators should be supported to acquire their needed machinery through lease, rental or purchase programs.
- **Technology development:** Due to undeniable role of technology in improving efficiency, troubleshooting and increasing profitability, farm operators need to take advantage of new advances in agricultural technologies.
- **Insurance:** Agricultural industry also has inherent specific risks; therefore, insurance companies should recognize risk management programs developed by the agriculture sector.

foods from supermarkets, fast mechanisms to distribute them among needy people or transport them to processing need to be developed.

Considering the environmental costs of fossil fuels, there is a push to develop cleaner and more renewable sources of energy, such as wind, solar and biofuels. However, the use of these alternative sources also has potentially negative consequences. Biofuel crops, such as wheat, corn and soybeans, are also key sources of food for millions of people, and their use for bio-energy production may decrease their availability as food (Helston, 2012). Furthermore, the land used for this purpose may displace other food-related crops (Helston, 2012). A plant capable of producing 100,000 m^3/year of wheat-based ethanol needs approximately 300,000 tons of grain annually, which requires 101,000 hectares of land (ECCC, 2017b). In Canada, corn and wheat are the main crops used for production of bioethanol. In 2006, 7% of the corn and 1% of the wheat produced were used for ethanol production in Canada (Helston, 2012). In 2014, around 6% of the total primary agricultural crop production was consumed for non-food purposes (AAFC, 2016a). To address this conflict, advances in the next generation of fuels, i.e. non-food feedstock such as algae, and cellulosic fuel crops such as switchgrass, may be developed further. Currently, there are many ongoing research projects for production of bio-hydrogen, bio-methanol and bio-diesel from biomass, however, they are not yet comparable with first-generation bio-fuels in terms of production cost (Helston, 2012; Wilt, 2015).

Agri-food systems in most countries have integrated and competitive supply chains that are resilient enough to adapt to varying consumer demands and advances in related technologies. These supply chains include input and service suppliers to farms, primary producers, storage, transportation, food and beverage processing plants, wholesalers and retailers of food and foodservice providers. In Canada, one in eight jobs comes from this supply chain and they account for 6.6% of Gross Domestic Product (GDP) (CFIA, 2016).

The National Farmers Union of Canada worries about the effect of powerful lobbies in the food manufacturing sector that keep the price of their products at low levels while input prices at the farm level are constantly increasing.

They are also concerned about the decreasing number of farms and the increasing average age of farmers (see section 1) which indicates an alarming failure of intergenerational transfer (Schutter, 2012).

6. Health Considerations

There are several important health considerations related to agriculture and food security in Canada. First, is the problem caused by foodborne ailments. Annually, more than 4 million Canadians are affected by food poisoning, resulting in 11,600 being hospitalized and 238 deaths. Of the annual total, 2.4 million are due to unknown causes and 1.6 are associated with known bacteria, viruses and parasites. Where the causal agent of food poisoning has been identified, 1 million cases are due to noroviruses, resulting in just under 1,200 individuals being hospitalized and 21 deaths.

The most frequently encountered bacterial agents are *Escherichia coli, Campylobacteria jejuni, Clostridium botulinum, Listeria* spp., *Salmonella* spp., *Shigella* spp., and *Vibrio* spp. However, the health impacts following food poisoning vary depending on the causal agent. Annually, there are about 88,000 cases of *Salmonella*, (25% of all cases of food poisoning in Canada) yet only 925 result in hospitalization and 17 in death. In contrast, of the 178 cases of Listeria-associated food poisoning, 150 individuals were hospitalized and 35 died.

The causes of infection are similar in all cases: (i) the consumption of contaminated food/water, often resulting from poor hygiene at processing plants or in the service industry, or

Cattle in Blackfoot, Alberta (Credit: Wapiti8).

(ii) direct contact with infected humans or other animals. As evidenced by the small number of persons who end up in the hospital/or die, in the vast majority of cases in Canada the infected individuals express flu-like symptoms that, while disagreeable, are generally short lived.

There are few parasites directly associated with food production in Canada. Consequently, most reported cases have been contracted during international trips or, on rare occasions, associated with the consumption of contaminated imported goods.

The second major food-related public health problem are the chronic diseases associated with diet. Since the 1980s, there has been a more than two-fold increase in the proportion of Canadians who are overweight or obese: today 36% of adults and 20% of children are overweight, with an additional 25.4% of adults and 13% of children classified as obese (2016 Senate report). In addition to differences among ethnic groups there are regional differences in proportion of the population classified as obese, with British Columbia being significantly lower than the national average, while Newfoundland, Nova Scotia, New Brunswick, Manitoba, Saskatchewan and the Northwest Territories were higher.

The increase in obesity has been associated with significant increases in the incidence of diabetes, stokes, heart disease and certain types of cancer. For example, from 2008 to 2015 the proportion of the Canadian population diagnosed with diabetes rose from 6.8% to 9.3% and in 2008, 19.1% of 45-65-years-of age individuals without diabetes were obese, compared with 47.5% of diabetics in the same age group. Mozaffarian et al. (2015) examined the factors influencing heart disease and strokes in the USA and found that poor diet was a major factor and it is quite reasonable to assume that the same holds for Canada. Thus, the rise in obesity observed will certainly result in a similar increase in cardiovascular diseases and strokes.

In response to the significant increase in obesity, as well as the associated direct and indirect costs to the health system (estimated at CND $4.3 billion in 2008), a 2016 Senate report made a series of recommendation to address this issue including: (i) fiscal changes that would insure those of lower socioeconomic status are able to afford a healthy lifestyle; (ii) taxing sugar sweetened beverages; (iii) minimizing the use of trans-fats; (iv) updating the national food guide, based on the latest scientific evidence relating to the relative benefits of fresh versus processed foods and noting that in general the healthier foods do not require labelling; (v) prohibiting food advertising aimed at children; (vi) nutritional labeling on menus, and (vii) actions at different levels of government to promote physical activity as part of a healthy lifestyle. As a result, in 2016 the federal government announced that it would be revising "Canada's Food Guide" and public consultations are scheduled for 2017. As noted previously, "evidenced-based" is being emphasized when developing this national food guide. This process would have to include an impartial examination of the validity of studies funded by different marketing boards relating to the positive/negative health benefits of certain food products. For example, Kearns et al. (2016) examined the sugar industry's role in the preparation of scientific publications, propagating the idea that it was dietary fat not sugar that was the major cause of coronary disease.

7. Policy Considerations

Though early Canadian agriculture policy supported farmers through subsidy programs, by 1996, these were reduced in accordance with new World Trade Organization rules that prohibit subsidies giving producers a competitive advantage in global markets (Wipf, 2013). Following a decade of subsidy reduction, expanding farmer debt and ensuing pressure on increase farm subsidies, Canada adopted a single national agricultural policy framework called Growing Forward (GF) that saw significant expansion of farm subsidies (Wipf, 2013). These programs were designed to adhere to World Trade Organization (WTO) trade rules,

Goat in Sherbrooke, Quebec (Credit: A. Chivinski).

aiming to support farmers during periods of low margins without giving producers a competitive advantage in global markets. These programs focused on Business Risk Management (BRM; i.e., safety nets) such as insurance programs covering margin declines or disaster support, and aimed at supporting declining farmer incomes while adhering to trade rules (Wipf, 2013). In many ways, GF represented a return to farm subsidy programming and institutionalized federal disaster assistance for farmers (Wipf, 2013). Since then, the original framework was succeeded by Growing Forward II (GF2) in 2013, and currently, a new framework is being discussed by the federal ministry of Agriculture and Agri-Food Canada (AAFC).

Growing Forward II

GF2, Canada's current agriculture and agri-food policy framework, is a three billion dollar investment by federal, provincial and territorial governments that provides the basis for government agricultural programs and services over the five-year period from 2013-2018. The programs focus on economic competitiveness, market opportunities, product and technology innovation and risk management. GF2 includes Business Risk Management (BRM) programs, though with reduced spending compared with the first GF framework and shifted emphasis from BRM farm subsidies to strategic initiatives in the form of Non-Business Risk Management (NBRM) (Wipf, 2013). The NBRM programs include 2 components: one administered by the provincial governments and the other by the federal government. The provincial component, guided by bilateral agreements, includes a $2 billion cost-shared funding commitment (60:40 federal/provincial ratio). It allows the provinces to tailor the programs to local needs within three priority areas: Innovation; Competitiveness and Market Development, and Adaptability and Industry Capacity (AAFC, 2017d). The $1 billion federal component includes 3 programs: AgriInnovation; AgriCompetitiveness, and AgriMarketing. These programs emphasize technological development, profitability and market development, respectively, and do little to directly address the needs of Canadian farmers and consumers. Indeed, while recognizing the growing consumer interest in the food system as it relates to issues of health, the environment and animal welfare, GF2 makes no effort to address these issues and instead focuses on addressing public perceptions of industry practices (NFU, 2013).

Critics of the Growing Forward policy frameworks argue that the policy aims to address industry as a whole, rather than the farm sector specifically. Furthermore, they believe that GF focuses almost exclusively on agriculture, rather than a broader suite of issues pertaining to food security, nutrition, equity and access. As a result, GF and GF2 do little to curb what some perceive as anti-competitive actions by agribusinesses. such as corporate consolidation (Winson, 2013; Wipf, 2013). By investing federal dollars in areas favored by agribusiness corporations, the federal government demonstrates a broader commitment to agribusiness (NFU, 2013), but shows little interest in other social or environmental problems linked with agriculture, such as food security. In effect, through GF2 the government invested in (or subsidized) technology developments of agribusinesses including biotechnology and chemical inputs, and this may have further exacerbated the cost-price squeeze as farmers have to pay the increased costs of these new technologies (Qualman, 2011), resulting in fewer, larger farms as farmers seek economies of scale (Magnan, 2011). Farm subsidy programs that emphasize emergency assistance can support farmers through one, or even a few, bad years, but do little to keep farms operating over the prolonged periods of debt resulting from the increasing cost-price squeeze (Wipf, 2013). As a result, Wipf (2013) argues that the policy marks the further neoliberalization of Canadian agriculture by emphasizing market competitiveness, and provides little assurance that farm incomes will recover or improve in the context of the diseases, pests, climate change and trade issues that continue to plague farmers. Further, the framework does not address food security in Canada, despite the nearly 2.5 million food-insecure Canadians and increasing dependence on nongovernmental food-access programs such as food banks (Wiebe & Wipf, 2011). Indigenous peoples are particularly affected by food insecurity, with as much as 75% of the population of some Indigenous communities considered food-insecure, and a loss of access to traditional territories where hunting, gathering, cultivation, fishing and trading provided food prior to colonization (Desmarais & Wittman, 2014).

Ultimately, GF2 does little to address the broad needs of farmers (being limited to safety nets), let alone all actors in the broader food system. In response, a movement to embrace a national food policy that better addresses the needs of Canadians is gaining ground across Canada.

The Need for a National Food Policy

Given the focus of GF2 on the agricultural market, rather than the food system as a whole, scholars and activists agree that there is a need for policy reform (e.g., Blay-Palmer, 2012; Boehm et al., 2011; CAPI, 2009). In particular, arguments for an integrated food policy that reflects the diversity of interests and domains pertinent to the food system (agriculture, health, environment, social and cultural values, and economic development) are gaining ground (e.g., FSC, 2015; Kneen, 2011; MacRae, 2011). There are numerous federal departments involved in the Canadian food system, including Agriculture and Agri-Food Canada, Fisheries and Oceans Canada, Environment Canada, Foreign Affairs and International Trade Canada, Health Canada, Industry Canada, and Transport Canada, (CAPI, 2009). The lack of clear communication pathways among these jurisdictional divisions, or one particular institutional place to work, create barriers for proactive policy and program solutions addressing the complex and multifaceted issues facing the Canadian food system (MacRae, 2011). For instance, many believe that Canada's Action Plan for Food Security (CAPFS), developed in response to the 1996 World Food Summit, was a failure in part due to the lack of interdepartmental coordination (Koc & Bas, 2012).

The complexity of Canadian food policy means that actors seeking to broaden the national policy debate about food are usually most effective when they seek specific policy changes as attempts to create a holistic policy framework for "the food system", which would include issues ranging from sustainable agriculture through to the need for low-income consumers to obtain healthy nutritious food, have generally failed (Eaton, 2013). The need to be highly knowledgeable about the inner workings of pertinent government departments and programs, and closely communicative with the staff and elected officials in working in them, meaning that any organization working on policy change – generally on shoestring budgets – must focus their goals (MacRae & Winfield, 2016).

Thus far, attempts to create a national food strategy have generally fallen to non-state actors. For instance, the Conference Board of Canada established a national food strategy in 2014 (Conference Board of Canada, 2014). Similarly, Canada has several provincial and federal networks that facilitate collective impact for systemic change. Food Secure Canada (FSC) is one such network operating at the national level, providing both communication opportunities and an institutional setting to engage in broad food-systems work. Since its formation in 2005, FSC has led several campaigns for a national food policy, such as coordinating the development of a national food policy, the People's Food Policy Project, that was released during the 2011 federal election campaign (FSC, 2011b). The policy is based on a food sovereignty platform, emphasizes community engagement in policy development and provides a holistic perspective on the food system. FSC carried their goals forward during the 2015 federal election, FSC launching Eat Think Vote, a national campaign aiming to bring attention to the need for a national food policy. The campaign garnered support for a national food policy from four of the five main political parties, including the elected Liberal Party. In particular, the Liberal Party promised to develop and fund a national strategy aimed at reducing food insecurity in Canada, in addition to promising support for new farmers and a strong voice for civil society in the development of food policy (FSC, 2015). Developing this policy fell to the Minister of Agriculture, and public consultations are set to begin in 2017 on this important topic.

Upcoming Trends in Canadian Food Policy

Since coming into power in 2015, the Liberal Party has taken a number of new initiatives that suggest the federal government is now taking steps to establish a holistic national food strategy that includes food security as a priority in Canada. For instance, and as noted earlier, Canada's next agriculture and agri-food policy framework will be launched in 2018. This policy will be based on the Calgary Statement, which highlights key priority areas including: Markets and Trade; Science, Research and Innovation; Risk Management; Environmental Sustainability and Climate Change; Value-Added Agriculture and Agri-Food Processing, and Public Trust (AAFC, 2017d). The Calgary Statement indicates that the next federal agricultural policy framework may proceed with business as usual, but the priority area Environmental Sustainability and Climate Change emphasizes a strong focus on risk management and economic growth, and much like GF2, focuses on addressing public trust in industry practices rather than supporting practices sought by many Canadians (AAFC, 2017d). Concurrently, the Minister for Agriculture has also been tasked with establishing a national food strategy that explicitly includes food security as one of its four pillars.

While the AAFC may continue to maintain its focus on economic growth, Environment and Climate Change Canada (ECCC) has included food in their recent sustainable development strategy, and may provide food policy that addresses the needs of all Canadians. In particular, ECCC launched a Federal Sustainable Development Strategy (FSDS) that was revamped to include a section on food and agriculture following public consultation (ECCC, 2017a). The long-term goal is similar to the GF frameworks, namely that "innovation and ingenuity contribute to a world-leading economy for the benefit of all Canadians" (ECCC, 2017a, p. 60). Additionally, the short-term milestones emphasize continuing or ensuring compliance with existing programs and regulations, and the highlighted partner is Agrium, a fertilizer corporation. Nonetheless, many of the 'contributing actions' include research on environmental challenges pertinent to agriculture, and encouraging sustainable agriculture practices. Further, while the action plan includes $30 million for biotechnology research, it also includes $197.1 million for freshwater and ocean science. An additional short-term goal includes expanding the number of communities eligible for Nutrition North, a subsidy program intended to support food security for Indigenous communities in Canada's North, (N.B., Nutrition North itself is highly controversial with some experts calling for its complete overhaul (Splawinski, 2015)). Overall, the inclusion of sustainable food in the FSDS provides a hopeful starting point for the development of sustainable food policy in Canada, but some are still worried that it risks being reduced to yet another program that maintains the status quo and continues to prioritize the economy over social and environmental concerns, subsidize agribusiness and does little to alleviate the cost-price squeeze faced by farmers or reduce food insecurity in Canada.

While ECCC provides a more holistic picture of food policy than AAFC to date, it is too early to tell exactly which direction the federal government is going to take with regard to food security. It may be an essential part of the upcoming national food policy, led by AAFC, and provide a strong defining policy framework through which to address the problems of food security in Canada. However this plays out, without a federal department dedicated exclusively to food policy, Canada's food system risks being regulated by a series of separate policy programs rather than cohesive, integrated programming. Given the interrelated nature of challenges and solutions within food systems, Canada's federal government must commit to a national food policy that highlights interdepartmental communication and integrates the multifaceted issues relevant to food in Canada.

8. Conclusions

Canada is a vast nation and a major world leader in the agricultural sector and is ranked among the largest agricultural producers and exporters in the world. Due to its geographical location and climate, however, less than 7.5% of Canada's landmass is used for agriculture. The need to encourage farming is also more important than ever, with less than 2% of the population directly engaged in farming. Therefore, developing policies for growth in farming is a priority.

Canada is also a world leader in agricultural research and has many research and developmental centers across the country. With the unique characteristics of each province in Canada, there are various distinctive areas of focus and research systems. Agricultural education and training in Canada is easily accessible and has evolved and improved over time. Inter- and transdisciplinary research has also increased and led to many programs which aim to proactively engage the government, industry, and the public. Many programs are also available that promote scientific collaboration and innovation in Canada and abroad. Although there are many ongoing research projects and success stories, many challenges remain, such as adequate federal funding for scientific development. Fostering and prioritizing investments and research projects that are more long-term require more funding to sustain a strong Canadian agricultural sector that is internationally competitive. Educating the public and spreading agricultural knowledge is also imperative.

With the increased population growth, urbanization and economic development in Canada, many environmental issues have developed. Canada is a nation with vast amounts of resources, such as water, varieties of soil, forests and diverse sources and large quantities of energy available for agriculture, and yet future challenges still remain and pose a threat to the agricultural sector. Policies are required that enforce sound farming practices, including the use of pesticides and fertilizers, in order to protect water and soil quality and eliminate sources of contamination. Although Canada is an "energy superpower", energy consumption also needs to be reduced. Additional research on alternative, cleaner forms of fuel is a fundamental priority for the country. Canada is also a world leader in sustainable forest management and has declining deforestation rates, but environmental impacts due to forestry are still affecting soil and water quality, influencing climate change and decreasing biological diversity. Although management plans have been established to protect areas and conserve forests, new policies need to be implemented to increase awareness of the ecological impact due to deforestation and to heighten our resource management capabilities as a whole.

In addition to these obstacles, climate change and associated impacts are major concerns for Canada, especially with a rate of warming that is about twice the global average. Northern communities are particularly vulnerable. Efforts to reduce GHG emissions are a priority, and so is research on climate-change adaptation. Also of concern are impacts of agriculture on natural ecosystems, including inputs of pollutants, introduction of invasive species, habitat fragmentation and spread of pathogens. Research is needed on improved ecological management practices, restoration and the rehabilitation of species and ecosystems. Also, improved public awareness and education of these environmental issues is needed.

Canada is continuously improving its agricultural sector with new technological advancements and novel innovative approaches. There are many genetically modified organisms that have been developed and used. However, the link between scientific discovery and technological development can be more efficient. Other needs for improvement include reduction in food waste, developing an evidence-based national food guide and various health considerations. In particular, the convenience and affordability of high-sugar, low-nutrient processed foods are highly problematic. Policies are continually being modified, although it is not clear whether these policy changes lead to significant improvements on the ground.

Several policy recommendations have been put forward to address food security in Canada. Gaining ground are the need for a living wage to ensure all Canadians can access adequate food (United Nations General Assembly, 2012) and development of social assistance programs that emphasize food access. In addition, urban zoning laws that support gardening on unused land, animal agriculture within city limits and improve access to fresh fruits and vegetables by streamlining approvals for temporary fresh markets in urban spaces can improve access to fresh food for urban Canadians. Given the high rates of food insecurity in Indigenous communities, coupled with historical and ongoing economic and political marginalization of Indigenous communities in Canada, it is particularly important to develop policy that supports Indigenous food sovereignty (United Nations General Assembly, 2012).

Policy recommendations that support farmer incomes include: adjusting policy and zoning to allow value-added businesses such as on-farm processing (Friedmann, 2011); more flexible health and safety regulations that can be met by small- and mid-sized farms (Carter-Whitney, 2008), and ensuring fair returns to farmers through traditional farmer-led marketing boards and policies prohibiting corporate capture of profits through high input costs and low commodity prices (Qualman, 2011). In addition, conserving farmland and improving farmer access to farmland provides a key strategic policy point to reduce the loss of farmers in Canada. Currently, most opportunities for farmers to purchase farmland depend on personal income and financing, while the Canadian government has supported investor buying of farmland, both through marketing to international investors and through the federal crown agency Farm Credit Canada, which has provided multimillion dollar loans to Assiniboia Capital, a company

Farmland in Alberta (Credit: N. Stanley).

that purchases farmland on behalf of investors (Qualman, 2011). A number of programs in Ontario may provide starting points for improving farmer access to land, including cooperative ownership, Community Land Trusts and Farmland Conservation Agreements (Learmonth et al.). Further, more financial support for farmers seeking to retire may improve intergenerational transfer of farmland and/or farmland prices at more affordable rates for new farmers, as currently many farmers depend on selling their land to retire, an issue exacerbated by increasing farmer debt and an aging farmer population (Friedmann, 2011).

Policy recommendations to support environmental sustainability of farming emphasize agroecological and organic farming practices. Examples include designing policy tools that recognize the value of ecosystem services provided by agroecological farms and support expansion of on-farm ecosystem services (Power, 2010), setting up of research institutions and farmer-academic partnerships to determine the full costs and benefits of conventional, organic and agroecological farms, and allocate federal funding accordingly (Wittman, Desmarais, & Wiebe, 2011), and increasing funding for organic farms, which would ultimately decrease funding needed for business-risk management programs as organic farmers are able to receive higher returns on their products and may be at lower risk for disaster-induced margin declines when paired with agroecological farming techniques (MacRae, Martin, Juhasz, & Langer, 2009).

Overall, an integrated food policy that considers and integrates all of the issues pertinent to food in Canada is needed to overcome food-related challenges in Canada. To be effective, such a policy must be developed in consultation with all groups affected by food issues in Canada (Wiebe & Wipf, 2001). The Peoples Food Policy Project provides one starting point for such a policy: developed in consultation with organizations and individuals involved in the food movement across Canada, its holistic framework provides policy suggestions around Indigenous food sovereignty, food sovereignty in rural and remote communities, urban food access, agriculture and livelihoods, sustainable fisheries, environmental health, science and technology, trade and aid, health and safety, and food democracy and governance (People's Food Policy Project, 2011)

References

AAFC, Agriculture and Agri-Food Canada (2016a) An Overview of the Canadian Agriculture and Agri-Food System 2016. Available at: https://caes.usask.ca/members/_pdf/Overview%20 2016-Final_eng.pdf

AAFC, Agriculture and Agri-Food Canada (2016b) Innovation From the Agricultural Bioproducts Innovation Program. Avaiable at: http://www5.agr.gc.ca/resources/prod/doc/pdf/2010_08_ABIP_EN.pdf

AAFC, Agriculture and Agri-Food Canada (2017a) Science and Innovation. Available at: http://www.agr.gc.ca/eng/science-and-innovation/?id=1360882179814

AAFC, Agriculture and Agri-Food Canada (2017b) Programs and Services. Available at: http://www.agr.gc.ca/eng/programs-and-services/?id=1362675650980

AAFC, Agriculture and Agri-Food Canada (2017c) Canadian Soil Information Service. Available at: http://sis.agr.gc.ca/cansis/nsdb/index.html

AAFC, Agriculture and Agri-Food Canada (2017d) About Us. Available at: http://www.agr.gc.ca/eng/about-us/?id=1360699683758

Bickis, I. (2016) Agricultural Industry Betting the Farm on Innovation to Boost Yields, Profits. Available at: http://www.cbc.ca/news/technology/farming-technology-1.3442023

Blay-Palmer, A. (2012) Alternative Land Use Services and the Case for Multifunctional Policy in Canada. In: R. MacRae & E. Abergel (Eds.), *Health and Sustainability in the Canadian Food System: Advocacy and Opportunity for Civil Society* (pp. 39-69). Vancouver, BC: UBC Press.

Boehm, T., Moore, H., & Beingessner, N. (2011) Getting to Food Sovereignty: Grassroots Perspectives From the National Farmers Union. In: H. Wittman, A. A. Desmarais, & N. Wiebe (Eds.), *Food Sovereignty in Canada: Creating Just and Sustainable Food Systems* (pp. 43-58). Black Point, Nova Scotia: Fernwood Publishing.

CAHRC, Human Agricultural Human Resource Council (2016) Shortages of Canadians Working in Agriculture to Double by 2025. Available at: http://www.cahrc-ccrha.ca/news-events/shortage-canadians-working-agriculture-double-2025

CAIRN, Canadian Agricultural Innovation and Regulation Network (2011) An Enabling Research For Competitive Agriculture Network. Available at: http://www.ag-innovation.usask.ca/

Canadian Biodiversity (2016) Conservation Issues: Human Activities and their Impacts. Available at: http://canadianbiodiversity.mcgill.ca/english/conservation/activities.htm

CAPI, Canadian Agri-Food Policy Institute (2009) Regulatory Reform in Canada's Agri-Food Sector. Available at: http://capi-icpa.ca/pdfs/CAPI-Regulatory-Framework-4March2009.pdf

Carter-Whitney, M. (2008) Bringing Local Food Home: Legal, Regulatory and Institutional Barriers to Local Food. Canadian Institute for Environmental Law and Policy.

CFA, Canadian Federation of Agriculture (2016). Available at: http://www.cfa-fca.ca/

CFIA, Canadian Food Inspection Agency (2016) Plants. Available at: http://www.inspection.gc.ca/eng/1297964599443/1297965645317

Conference Board of Canada (2014) From Opportunity to Achievement: Canadian Food Strategy. Available at: http://www.conferenceboard.ca/e-library/abstract.aspx?did=6091

DeLong, J. M., Prange, R. K., & Harrison, P. A. (2007) Chlorophyll Fluorescence-Based Low-O2 CA Storage of Organic 'Cortland' and 'Delicious' Apples. *Acta Horticulturae*, 737, 31–37.

Desmarais, A. A., & Wittman, H. (2014) Farmers, Foodies and First Nations: Getting to Food Sovereignty in Canada. J Peasant Stud, 41(6), 1153-1173.

Duckett Truffieres (2013) *The Economics of Growing Truffles* [Online]. Available at: www.ducketttruffieres.com/index.htm

Eaton, E. (2013) *Growing Resistance: Canadian Farmers and the Politics of Genetically Modified Wheat,* Winnipeg: University of Manitoba Press.

ECCC, Environment and Climate Change Canada (2017) Sustainable Development. Available at: https://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=C2844D2D-1

ECCC, Environment and Climate Change Canada (2017b) Environmental Indicators. Available at: https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En

Environment Canada (1995) Canadian Biodiversity Strategy: Canada's Response to the Convention on Biological Diversity. Available at: http://www.biodivcanada.ca/560ED58E-0A7A-43D8-8754-C7DD12761EFA/CBS_e.pdf

Fan, D., Kandasamy, S., Hodges, D. M., Critchley, A. T., & Prithiviraj, B. (2014) Pre-harvest Treatment of Spinach with *Ascophyllum nodosum* Extract Improves Post-Harvest Storage and Quality. Scientia Horticulturae, 170, 70-74.

Friedmann, H. (2011) Food Soveriegnty in the Golden Horseshoe Region of Ontario. In: H. Wittman, A. A. Desmarais, & N. Wiebe (Eds.), *Food Sovereignty in Canada: Creating Just and Sustainable Food Systems* (pp. 169-189). Black Point, Nova Scotia: Fernwood Publishing.

FSC, Food Secure Canada (2011a) Discussion Paper 4-Agriculture, Infrastructure, and Livelihoods. Available at: https://foodsecurecanada.org/sites/foodsecurecanada.org/files/DP4_Agriculture,_Infrastructure_and_Livelihoods.pdf

FSC, Food Secure Canada (2011b). Resetting the Table: A People's Food Policy for Canada. Available at: https://interpares.ca/sites/default/files/resources/2011-04ResettingTheTableAPeoplesFoodPolicyForCanada.pdf

FSC, Food Secure Canada (2015) Federal Elections: 4 Parties are in Favour of a National Food Policy. Available at: https://foodsecurecanada.org/

Global Market Insights (2016) *Enzyme Market* [Online]. Available at: https://www.gminsights.com/segmentation/detail/enzymes-market

Government of Canada (2016) Bilateral Relations. Available at: http://www.canadainternational.gc.ca/china-chine/bilateral_relations_bilaterales/index.aspx?lang=eng&_ga=1.129542927.246945411.1485999937

Health Canada (2014) Consumer Product Service. Available at: http://www.hc-sc.gc.ca/cps-spc/pest/agri-commerce/usa-can-gpd-eng.php

Health Canada (2015) Food and Nutrition. Available at: http://www.hc-sc.gc.ca/fn-an/index-eng.php

Helston, C. (2012) *Biofuels* [Online]. Available at: http://www.energybc.ca/profiles/biofuels.html#references

Johnson, K. (2015) Agriculture Losing its Spot in Canada's Education System. The Western Producer. Available at: http://www.producer.com/2015/07/agriculture-losing-its-spot-in-canadas-education-system/

Kearns, C. E., Schmidt, L. A., & Glantz, S. A. (2016) Sugar Industry and Coronary Heart Disease

Research: A Historical Analysis of Internal Industry Documents. *JAMA Internal Medicine,* 176(11), 1680-1685.

Kneen, C. (2011) Food Secure Canada: Where Agriculture, Environment, Health, Food and Justice Intersect. In: H. Wittman, A. A. Desmarais, & N. Wiebe (Eds.), *Food Sovereignty in Canada: Creating Just and Sustainable Food Systems* (pp. 80-96). Black Point, Nova Scotia: Fernwood Publishing.

Koc, M., Bas, J. A. (2012) Canada's Action Plan for Food Security: The Interactions Between Civil Society and the State to Advance Food Security in Canada. In: R. MacRae & E. Abergel (Eds.), *Health and Sustainability in the Canadian Food System* (pp. 173-203). Vancouver, BC: UBC Press.

Learmonth, P., Darrell, A., English, A., Thomas, L., Watkins, M., & Young, T. Accessing Land for Farming in Ontario. Available at: http://www.farmstart.ca/wp-content/uploads/Accessing-Land-for-Farming-in-ON-Guidebook-REV4.pdf

MacRae, R. (2011) A Joined-Up Food Policy for Canada. *Journal of Hunger & Environmental Nutrition,* 6(4), 424-457.

MacRae, R., Martin, R. C., Juhasz, M., & Langer, J. (2009) Ten Percent Organic Within 15 years: Policy and Program Initiatives to Advance Organic Food and Farming in Ontario, Canada. *Renewable Agriculture and Food Systems,* 24(02), 120.

MacRae, R., & Winfield, M. (2016) A Little Regulatory Pluralism with Your Counter-Hegemonic Advocacy? Blending Analytical Frames to Construct Joined-up Food Policy in Canada. *Canadian Food Studies*, 3(1), 140-194.

Magnan, A. (2011) The Limits of Farmer Control: Food Sovereignty and Conflicts Over the Canadian Wheat Board. In: H. Wittman, A. A. Desmarais, & N. Wiebe (Eds.), *Food Sovereignty in Canada: Creating Just and Sustainable Food Systems* (pp. 114-133). Black Point, Nova Scotia: Fernwood Publishing.

Mathews, J. (2015) *The Fact Sheet: Prepare To Be Amazed By Canada's Agricultural Industry* [Online]. Available at: http://talentegg.ca/incubator/2015/02/16/fact-sheet-canadas-agriculture-industry/

Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., . . . On Behalf of the American Heart Association Statistics Committtee and Stroke Statistics Subcommittee. (2015) Heart Disease and Stroke Statistics-2015 Update: A Report From the American Heart Assciation. *Circulation*, 131(14), e29-e322.

Natural Resources Canada (2016) Energy. Available at: http://www.nrcan.gc.ca/energy

Natural Resources Canada (2017) Forests. Available: at http://www.nrcan.gc.ca/forests

NFU, National Farmers Union (2013) Growing Forward 2 – Accelerating Globalization, Stalling Food Sovereignty: Implications of the GF2 Strategic Initiatives Suite. Available at: http://www.nfu.ca/

People's Food Policy Project. (2011) *Resetting the Table: A People's Food Policy for Canada.* Available at: https://foodsecurecanada.org/people-food-policy

Power, A. G. (2010) Ecosystem Services and Agriculture: Tradeoffs and Synergies. *Philos Trans R Soc Lond B Biol Sci*, 365(1554), 2959-2971.

Qualman, D. (2011) Advancing Agriculture by Destroying Farms? The State of Agriculture in Canada. In: H. Wittman, A. A. Desmarais, & N. Wiebe (Eds.), *Food Sovereignty in Canada: Creating Just and Sustainable Food Systems* (pp. 20-42). Black Point, Nova Scotia: Fernwood Publishing.

Second Harvest (2016) Hunger Facts [Online]. Available at: http://www.secondharvest.ca/hunger-facts

Schutter, O. D. (2012) *Farmers, the Food Chain and Agriculture Policies in Canada in Relation to the Right to Food* [Online]. Available at: http://www.nfu.ca/story/farmers-food-chain-and-agriculture-policies-canada-relation-right-food

Sparling, D. (2010) Innovation and Agricultural Biotechnology – Where's Canada's Future? Available at: http://sites.ivey.ca/agri-food/files/2010/07/Innovation-and-Agricultural-Biotechnology-June-2010.pdf

Splawinski, A. (2015) The Failure That is Food Policy in Nunavut. Rabble. Available at: http://rabble.ca/news/2015/02/failure-food-policy-nunavut

Statistics Canada (2011) *Canada Year Book* [Online]. Available at: http://www.statcan.gc.ca/pub/11-402-x/2011000/chap/ag/ag-eng.htm

Steppler, H. A., Switzer, C. (2014) Agricultural Education. In the *Canadian Encyclopedia of Agriculture*. Available at: http://www.thecanadianencyclopedia.ca/en/article/agricultural-education/

United Nations General Assembly. (2012) Report of the Special Rapporteur on the Right to Food, Olivier De Schutter. Mission to Canada. UN Doc A/HRC/22/50/Add.1.

USC Canada, Unitarian Service Committee (2016) Building Resilience Through Ecological Agriculture. Available at: http://www.usc-canada.org/

Wiebe, N., & Wipf, K. (2011) Nurturing Food Sovereignty in Canada. In: H. Wittman, A. A. Desmarais, & N. Wiebe (Eds.), *Food Sovereignty in Canada* (pp. 1-19). Black Point, Nova Scotia: Fernwood Publishing

Wilt, J. (2015) *Agriculture, Not Energy, Will Fuel Canada's Economy in Coming Decades: Experts* [Online]. Available at: https://www.desmog.ca/2015/07/29/agriculture-not-energy-will-fuel-canada-s-economy-coming-decades-experts

Winson, A. (2013) *The Industrial Diet: The Degradation of Food and the Struggle for Healthy Eating*. Vancouver: UBC Press. Available at: http://www.ubcpress.ca/books/pdf/chapters/2013/TheIndustrialDiet.pdf

Wipf, K. (2013) *From Farm Crisis to Food Crisis: Neoliberal Reform in Canadian Agriculture and the Future of Agri-Food Policy* (PhD Dissertation), University of Alberta, Edmonton, Alberta

Wittman, H., Desmarais, A. A., & Wiebe, N. (Eds.). (2011) *Food Sovereignty in Canada: Creating Just and Sustainable Food Systems.* Black Point, Nova Scotia: Fernwood Publishing.

Challenges of Food and Nutrition Security in the Caribbean

Fairtrade Banana Farmer in St. Vincent and the Grenadines (Photo by Terry Sampson, UWI, Trinidad)

Caribbean

[1] Mark N. Wuddivira
[2] Vidya de Gannes
[3] Gerrit Meerdink
[4] Nequesha Dalrymple
[5] Shantelle Henry

Coordinated production of **value-added products** using local commodities can sustain the future by minimizing food import bill, establishing the **Caribbean** common market and fostering food and nutrition security

Abstract

The Caribbean region with a population of 43.5 million extends from Bahamas in the North, to Guyana and Suriname in the South-American continent, including Belize in Central America. The availability, accessibility, utilization and stability of foods to meet food and nutrition demands are critical for the sustainable development of the Caribbean population. The status of Food and Nutrition Security (FNS) in the Caribbean, however, has been challenged by natural disasters, overexploitation of natural resources, volatility in food production and prices, barriers to trade, outdated technologies, high incidence of pests and diseases, climate change, and lack of an enabling environment to foster innovation. Additionally, the small undiversified Caribbean economies have been experiencing slow trading activity coupled with slow growth in exports. Consequently, the food import bill has increased significantly from US$2.08 billion in 2000 and exceeded the US$4.25 billion mark in 2011. Food policies are weak and driven by socioeconomic and political forces. Although the Caribbean has met the 2015 United Nations (UN) millennium hunger targets, easy access to unhealthy sugary, ultra-processed and fatty foods has exacerbated the incidences of obesity, and Chronic Non-communicable Diseases (CND), which are now the leading cause of premature mortality and a major burden to individual and national budgets. This chapter elaborates on the major challenges of FNS in the Caribbean. Recommendations and polices are proffered and, if implemented, they are envisaged to improve the FNS situation of the region.

1. Introduction

The root of the Caribbean population emanates from many areas of the world; hence, it can be considered as a very diverse region. This diversity results in a variety of languages, foods, traditional crops, cultures and farming systems. While there are more than twenty five island states in the Caribbean (Figure 1), there are many regional groupings and the largest is the Caribbean Community (CARICOM), which includes fifteen countries with twelve other countries that are associate members (www.caricom.org). The population of the region is about 43.5 million with a land area of approximately 239,681 km^2 where approximately 25% is under agricultural production and 11% is arable. Up until the early 1960s, agriculture was the primary economic driver in the Caribbean. In the last five decades, however, the growth of different economic sectors, primarily tourism and services, has led to a shift from agrarian to more diverse and thriving economies with strong competing uses emerging, leading to a decline in the agricultural sector and increasing food import bills in excess of US$4 billion per annum. Consequently, as a result of the decrease of agriculture, the other main contributors to GDP include mining, tourism and commercial services. For example, for Jamaica and Suriname, their economies are driven by the mineral sectors while Trinidad and Tobago's economy is driven by oil and gas. The tourism sector is dominant in the Organization of Eastern Caribbean States (OECS) (www.oecs.org).

In previous years, agriculture in many of the Caribbean countries was controlled mainly by plantation sectors (sugar cane, bananas, cocoa and coffee). However, these sectors have dwindled, which led to the migration of labor out of agriculture. The status of FNS in the Caribbean region can therefore be considered as precarious, because of the region's increasing vulnerability to high incidence of pests and diseases, poor human resource capacity, limited land resources, reliance on inefficient and outdated technologies in food production and processing, low investments in research, the lack of an enabling environment to foster innovation and entrepreneurship, and high occurrence of tropical storms, hurricanes, floods, droughts and earthquakes. Additionally, volatility of food production and food prices including high import bills, unsustainable high energy prices, some barriers to trade and the continuation of climate change and its impacts undoubtedly add to these risks. Reports have shown that almost all CARICOM countries import more than 60% of the food they consume. Among the top five food import categories in the region are: processed foods, grains (wheat and corn), and livestock products (meat and dairy), which account for over US$ 1 billion or approximately 25% of annual food imports regionally (FAO, 2015). Food imports are expected to increase to US $8-10 billion by 2020 if efforts are not successful in addressing this problem of a high level of imports (FAO, 2015).

Advances in biotechnology and technology are providing powerful tools to alleviate problems associated with FNS. These tools include the following: mass propagation of plants through plant tissue culture; plant breeding; quick and efficient diagnosis of plant pests and diseases; transgenic crops (Genetically Modified Crops, GMC), Artificial Insemination (AI), molecular cloning of genes, gene transfer, genetic manipulation of animal and plant embryo transfer, chemical and biological treatment of low-quality animal feeds for improved nutritive value, genetically engineered immunodiagnostic and immunoprophylactic agents, as well as veterinary vaccines. However, the Caribbean has yet to harness the full benefits from these powerful tools (de Gannes and Borrotto, 2016). Moreover, the adoption of technologies such as precision agriculture that efficiently manage spatially variable fields to optimize limited resources in a cost- and time-efficient manner, while maintaining an environmentally-friendly ecosystem in these islands, is inadequate (De Caires et al., 2015).

This chapter focuses on the major challenges and opportunities associated with FNS in the Caribbean as it provides details on: national characteristics, resource and ecosystem characteristics, technology and innovation, efficiency of food systems, and health considerations and policy considerations. In this regard, it is envisaged that the information, recommendations and policies presented could be used to support developmental policies to address the challenges of FNS in the Caribbean region.

[1] **Mark N. Wuddivira,** Field of Specialization: Agricultural and Environmental Soil Physics, Soil & Water Management, Precision Agriculture; The University of the West Indies, St Augustine, Trinidad and Tobago; mark.wuddivira@sta.uwi.edu
[2] **Vidya de Gannes,** Field of Specialization: Biotechnology, Microbial Ecology and Soil Microbiology; The University of the West Indies, St Augustine, Trinidad and Tobago; vidyadegannes@gmail.com [3] **Gerrit Meerdink,** Field of Specialization: Chemical Technology, Food Science and Technology; The University of the West Indies, St Augustine, Trinidad and Tobago; gerrit.meerdink@sta.uwi.edu [4] **Nequesha Dalrymple,** Field of Specialization: Human Nutrition & Dietetics and Nutritional Sciences; The University of the West Indies, St Augustine, Trinidad and Tobago; nequesha.dalrympe@sta.uwi.edu
[5] **Shantelle Henry,** Field of Specialization: Food Safety and Quality Assurance; The University of the West Indies, St Augustine, Trinidad and Tobago; henryshantelle@live.com

Figure 1. Location, ecological and biodiverse areas of the Caribbean

2. Caribbean Physical and Demographic Characteristics

2.1 Physical size

The Caribbean archipelago is made up of a chain of islands characterized by limited land resources. The Caribbean is Southeast of the Gulf of Mexico and the North-American mainland, East of Central America and North of South America (**Figure 1**). The Caribbean occupies an area of 2,754,000 km² with land area totaling 239,681 km². The population currently stands at 43,489,000. CARICOM countries with a population of 17,674,000 make up 41% of the population of the Caribbean (**Table 1**). The land area in the Caribbean is divided into three groups:

- The mainland comprises Guyana, Belize and Suriname.
- The Greater Antilles consist of Jamaica, Hispaniola, Cuba, Puerto Rico and the Bahamas.
- The Lesser Antilles are smaller islands extending from Anguilla in the North to Trinidad and Tobago in the South. The Lesser Antilles are divided into two groups: Leeward (St. Kitts and Nevis, Antigua and Barbuda), and Windward Islands (Dominica, St. Lucia, Grenada, and St. Vincent and the Grenadines). The older islands are located in the Northeast (Antigua, Barbuda, Anguilla and Guadeloupe); they are low, rising between 100 ft. and 1,400 ft. The others are younger islands of the arc separating the Atlantic Ocean from the Caribbean Sea (Williams-Bailey and Pemberton, 1980).

2.2 Arable land inventory

The Caribbean region is comprised of a heterogeneous mix of islands with limited land resources. These limited land resources are subjected to immense strain from high population density, industrialization, tourism and urbanization. Arable land for agriculture has been on the decline over the years (**Table 2**) due to the aforementioned strong competing uses. Arable land use ranges from as low as 0.2% and 0.4% in Suriname to 37.2% and 25.6% in

Barbados in 1961 and 2013, respectively. Antigua and Barbuda, Grenada, St. Lucia, and Trinidad and Tobago all showed a two-fold decrease in arable land mass from 1961 to 2013. The forest in the Caribbean has remained somewhat pristine, thus has been unchanged over the period from 1990 to 2015, although small land holdings by farmers on mountain ranges and incessant forest fires have had a detrimental impact on forested land.

Table 1. Population and size of Caribbean Community (CARICOM) countries

CARICOM States	Pop. ('000) (2014-16)	Area (km²) (2014)
Larger island States		
Haiti	10,533	27,750
Jamaica	2,806	10,830
Trinidad and Tobago	1,346	5,130
Smaller island States		
Antigua and Barbuda	92	440
The Bahamas	386	13,900
Barbados	286	430
Dominica	73	750
Grenada	107	340
St Kitts and Nevis	55	260
St. Lucia	185	610
St. Vincent and the Grenadines	109	390
Mainland States		
Belize	344	22.810
Guyana	806	196,850
Suriname	546	156,000

Source: Extracts 1 & 2 from (www.worldbank.com).

Table 2. Arable land inventory in Caribbean Community (CARICOM) states

CARICOM member states	Arable Land (% of Land Area)		Forest Area (% of Land Area)		Permanent Cropland (% of Land Area)	
	1961	2013	1990	2015	1961	2013
Antigua and Barbuda	18.2	9.1	23.4	22.3	-	2.3
Bahamas	0.7	0.8	51.4	51.4	0.2	0.4
Barbados	37.2	25.6	14.7	14.7	2.3	2.3
Belize	1.6	3.4	70.8	59.9	0.3	1.4
Dominica	9.3	8.0	66.7	57.8	10.7	22.7
Grenada	14.7	8.8	50.0	50.0	41.2	20.6
Guyana	1.8	2.7	84.6	84.0	0.1	0.1
Jamaica	15.3	11.1	31.8	31.0	10.2	8.8
Saint Kitts and Nevis	28.6	19.2	42.3	42.3	17.1	0.4
Saint Lucia	8.2	4.9	35.7	33.3	14.8	11.5
Saint Vincent and the Grenadines	15.4	12.8	64.1	69.2	7.7	7.7
Suriname	0.2	0.4	98.9	98.3	0.0	0.0
Trinidad and Tobago	11.1	4.9	46.9	45.7	6.8	4.3

Source: World Bank 2016.

Table 3. Demographic indicators for various Caribbean Community (CARICOM) member states

CARICOM member states	Total Population		Population growth (annual %)		Population ages 0-14 (% of total)		Population ages 15-64 (% of total)	
	1960	2015	1961	2015	1960	2015	1960	2015
Antigua and Barbuda	54,980	91,820	1.3	1.0	43	24	53	69
Bahamas	109,530	388,020	5.0	1.3	42	21	54	71
Barbados	230,930	284,210	0.3	0.3	38	19	55	66
Belize	92,070	359,290	2.8	2.1	45	32	51	64
Dominica	60,020	72,680	1.7	0.5	-	-	-	-
Grenada	89,860	106,830	1.5	0.4	49	26	46	66
Guyana	564,220	767,090	3.1	0.4	46	29	50	66
Jamaica	1,629,000	2,725,940	1.4	0.2	42	24	54	67
Saint Kitts and Nevis	51,200	55,570	-0.0	1.1	-	-	-	-
Saint Lucia	89,900	185,000	1.1	0.7	45	23	51	68
Saint Vincent and the Grenadines	80,950	109,460	1.5	0.1	50	25	46	68
Suriname	289,970	542,980	2.8	0.9	48	27	48	66
Trinidad and Tobago	848,480	1,360,090	2.0	0.4	43	21	54	70

CARICOM member states	Population ages 65+ (% of total)		Fertility rate, total (births per woman)		Mortality rate, infant (per 1000 live births)		Life expectancy at birth, total (years)	
	1960	2015	1960	2014	1960	2015	1960	2014
Antigua and Barbuda	4	7	4.4	2.1	-	6	62	76
Bahamas	4	8	4.5	1.9	-	10	63	75
Barbados	7	14	4.3	1.8	70	12	61	75
Belize	4	4	6.5	2.6	-	14	60	70
Dominica	-	-	-	-	85	20	-	-
Grenada	5	7	6.7	2.1	-	11	60	73
Guyana	3	5	5.8	2.6	68	32	60	66
Jamaica	4	9	5.4	2.0	62	14	64	76
Saint Kitts and Nevis	-	-	-	-	-	8	-	-
Saint Lucia	4	9	7.0	1.9	-	13	57	75
Saint Vincent and the Grenadines	4	7	7.2	2.0	-	17	58	73
Suriname	4	7	6.6	2.4	-	19	60	71
Trinidad and Tobago	4	9	5.3	1.8	57	18	63	70

Source: World Bank 2016.

2.3 Landscape and environmental heterogeneity

The Caribbean has one of the most diverse combinations of landscapes in the world. This region encompasses a terrain that is situated above the Caribbean Plate with approximately 7,000 islands, islets, reefs and caves. The landscape varies from volcanic mountains, lakes and limestone cliffs to lush green hills, mangrove swamps and forests. In fact, 40 percent of the Caribbean terrain is covered by tropical forests. The topography is generally mountainous with several mountainous peaks and limited flat lands that are mostly coastal. In terms of steepness of slopes, the Caribbean territories can be grouped as follows (Wuddivira and Atwell, 2012):

- Antigua and Barbuda, and Barbados, which are flat with little or no steep slopes;
- Dominica, Grenada and Cariacou, Monsterrat, St. Kitts and Nevis, St. Lucia, St. Vincent and Tobago, which are dominated by steep slopes;
- Trinidad and Jamaica that are larger and contain a high percentage of flat land, undulating land and steep slopes; and
- The mainland territories of Guyana and Belize, with 70% and 50% of sloping land, respectively.

Many slopes in this region are greater than 30° (58%) and widespread unsustainable farming practices are carried out on these steeply sloped hillsides. The Caribbean region has a wide diversity of ecosystems. The Windward Islands receive a greater amount of rainfall compared to the Leeward Islands; the difference in rainfall and the topography contributes to the forest types in the various islands. Climatic conditions in the Caribbean are dependent on elevation.

2.4 Demographic characteristics and future trends

It is evident from **Table 3** that population growth is low in the Caribbean. The highest population growth rate in 2015 was recorded in Belize (2.1%) followed by the Bahamas (1.3%). The lowest population growth rate during the same period was recorded in St. Vincent and the Grenadines (0.1%) followed by Jamaica (0.2%). Many countries recorded a consistent fertility rate in 2014. Mortality rates have been declining drastically in the region. The highest change occurred in Dominica, where the mortality rate declined from 85 per 1,000 live births in 1960 to 20 per 1,000 live births in 2015. The highest life expectancy at birth for both males and females (2014) was recorded in Jamaica (76 years) while Guyana recorded comparatively low life expectancy at birth (66 years).

The data presented by the UN population division on future trends (**Table 4**) showed that by the year 2050, the majority of the islands in

Table 4. Demographic indicators (future trends) for various Caribbean Community (CARICOM) member states

CARICOM member states	Total population		Total fertility (Average number of children per woman)		Mortality rate, infant (per 1000 live births)		Life expectancy at birth (years)	
	2030	2050	2025 – 2030	2045 – 2050	2025 – 2030	2045 – 2050	2025 – 2030	2045 – 2050
Antigua and Barbuda	105,000	114,000	2.03	1.94	6.0	3.7	78.3	81.6
Bahamas	446,000	489,000	1.77	1.75	6.1	4.4	77.6	80.8
Barbados	290,000	282,000	1.82	1.84	6.0	3.9	77.8	81.0
Belize	472,000	588,000	2.19	1.89	9.9	6.6	71.7	74.3
Dominica	76,000	74,000	-	-	-	-	-	-
Grenada	112,000	110,000	1.90	1.76	6.7	4.2	75.3	78.3
Guyana	821,000	806,000	2.27	2.00	27.4	20.4	67.8	69.8
Jamaica	2,867,000	2,710,000	1.86	1.77	10.7	7.4	77.5	80.3
Saint Kitts and Nevis	63,000	68,000	-	-	-	-	-	-
Saint Lucia	202,000	207,000	1.69	1.66	7.5	5.7	77.0	80.0
Saint Vincent and the Grenadines	112,000	109,000	1.75	1.69	12.8	8.8	74.4	76.7
Suriname	599,000	624,000	2.08	1.86	12.1	7.9	72.9	75.6
Trinidad and Tobago	1,372,000	1,291,000	1.68	1.70	18.9	13.0	71.8	74.0

Source: United Nations, Department of Economic and Social Affairs, Population Division (2015).

the Caribbean will experience an increase in their total population while islands such as Jamaica, Trinidad and Tobago and Barbados will have a decline in their population growth. Also, in 2050 there will be no significant decline in the fertility rate. However, individual islands will experience a drastic decline in their infant mortality rate and an increase in their life expectancy.

2.5 Food and nutrition insecurity

2.5.1 Fraction of population suffering from food and nutrition insecurity

Hunger is associated with food and nutrition insecurity while undernourishment is a reflection of chronic food insecurity (Martínez et al., 2009). In the Caribbean, from 2011 to 2016, 19.8% of the population, equivalent to 7.5 million, is estimated to be undernourished (**Figure 2**). Some progress has been made to reduce the prevalence of undernourishment in the region. The percentage of the undernourished has declined; from 1990 to 1992, 8.1 million people (27%) were undernourished. The Millennium Development Goal targets which ended in 2015 showed that the Caribbean observed a 7.2% reduction in the undernourished population. Although the reduction occurred at a very slow pace, the target was achieved.

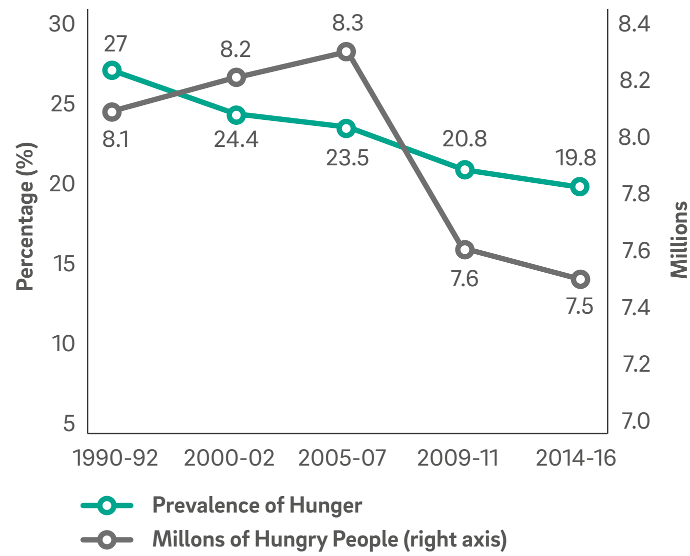
2.5.2 Food and nutrition insecurity trajectory

The prevalence of food inadequacy is an indicator used by the FAO to determine the percentage of persons in the population whose food access is deemed to be insufficient. For the 1990 – 2013 period, there was a general decrease in the prevalence of food inadequacy in the Caribbean (**Table 5**). The CARICOM islands have made progress over the past 25 years in reducing undernourishment as most have met the global hunger targets and the United Nations Millennium Development Goals (FAO, 2015).

2.6 Agricultural modes

Agriculture played a dominant role in the Caribbean economy. Agriculture in the Caribbean changed from plantation monocropping of sugar cane in the 17th century to a diversified

Figure 2. Number (millions) and prevalence (%) of undernourished people in the Caribbean



Source: The State of Food Insecurity (SOFI) in the World, 2015 (FAO, 2015).
Note: Millennium Summit and World Food Summit hunger targets for the Caribbean are 13.5 percent and 4.1 million, respectively by 2015.

production which includes banana, citrus, coffee and cocoa. Two main agricultural systems used in the Caribbean are subsistence and commercial farming. The two agricultural systems vary considerably. Subsistence farming is mainly practiced by resource-poor peasant farmers on small land holdings while commercial farming is carried out on a larger scale. Both small and large commercial farms exist; the smaller farms supply the local market while produce from the larger farms is exported. Large commercial farms have a well-established marketing system.

2.6.1 Important plant crops

Post-plantation agriculture in the Caribbean saw a shift from sugar cane monocultures to a more diversified system that included fruits (mangos, oranges, pineapples), vegetables (tomatoes, cucumber), and root and tubers (cassava, sweet potato, yam), which are considered the most important staple crops. Traditional crops such as sugar cane, banana and rice are grown mainly for export. According to the FAO Statistical Yearbook 2014, Latin America and the Caribbean account for 8% of the global production of fruits, 13% of global roots and tubers and 7% of global cereal production. However, vegetable output in the region accounted for a small percentage of the global output (Yearbook, 2014).

2.6.2 Animal agriculture

Ruminant production in the Caribbean is a low-input and low-output system. Due to inadequate access to lands, animals are placed in rough pastures to graze. Meat from these animals is mainly sold on the local market. The Caribbean accounts for 0.1% of total world meat production, where poultry is the most important meat in the Caribbean, followed by beef then pork (America, 2007). Latin America and the Caribbean recorded the highest density of buffaloes and cattle in the world, while the density of goats and sheep is comparatively low (Yearbook, 2014). Moreover, Latin America and the Caribbean contributed to >12% of global fish production (Yearbook, 2014). In 2010, St. Kitts and Nevis recorded the largest capture and fisheries output in the Caribbean (37.4%).

2.7 The state of agro-food systems in the Caribbean

The contribution of agriculture to the national GDP is relatively small (<6%) in most Caribbean countries, with the exception of St. Vincent and Grenadines (8%) and Dominica (15%). The contribution in Trinidad and Tobago is even less than 1%. The relative importance of agriculture has decreased during the last decade in all Caribbean countries particularly in St. Lucia, Trinidad and Tobago and St. Kitts and Nevis. These countries saw an increase of over 74% in the past 15 years. The contribution of agriculture in most countries is now much smaller than that of tourism. However, for many rural communities, agriculture remains the main economic activity and provider of employment. An important and defining characteristic of the agro-food system in the Caribbean is the high import of consumer food products as well as raw materials which require further processing.

In the Caribbean, the average total percentage of food imported increased from 64% in 1995 to 80% in 2011 (**Table 6**). The value of the total import was 4.3 billion US$ in 2011. It is expected, that the value of imports will rise further. Local agriculture is clearly insufficient

Table 5. The prevalence of food inadequacy in the Caribbean

CARICOM member states	Prevalence of Food Inadequacy (%)	
	1990 – 1992	2011 – 2013
Antigua and Barbuda	26.2	24.4
Bahamas	18.1	13.0
Barbados	6.8	8.6
Belize	15.4	11.6
Dominica	9.5	5.2
Grenada	25.9	28.9
Guyana	32.5	9.4
Jamaica	17.7	16.3
Saint Kitts and Nevis	23.2	17.9
Saint Lucia	20.7	21.3
Saint Vincent and the Grenadines	30.6	11.3
Suriname	28.0	18.8
Trinidad and Tobago	20.0	14.4
CARIBBEAN	**36.7**	**26.4**

Source: FAO statistical yearbook 2014.

Table 6. Size and importance of food imports in the Caribbean

Country	Imports as % of total consumption in 1995	Imports as % of total consumption in 2011	Food imports in million US$ in 2011
Antigua and Barbuda	79	92	113
The Bahamas	91	92	570
Barbados	72	87	312
Dominica	50	55	52
Grenada	65	81	60
Jamaica	39	63	991
Saint Kitts and Nevis	74	95	39
Saint Lucia	53	83	104
Saint Vincent and the Grenadines	54	68	77
Trinidad and Tobago	66	85	909

Source: FAO, State of Food Insecurity in CARICOM Caribbean, 2015.

to feed the regional population. The Caribbean faces considerable food supply, quality and safety issues. Most famers in the region are small holders of hillside farms, resource-poor and unable to supply sufficient quality and safe foods to meet the demand of the population. The quality and safety of foods are challenged due to the high incidence of pests and diseases and high usage of pesticides. In all countries, agricultural production has declined considerably during the last decade with the exception of poultry production, which has increased significantly.

In the Caribbean, the local and regional food manufacturing industry is not very well developed. Moreover, the food industry often processes imported raw materials instead of using local produce. The food industry consists mostly of Small and Medium Enterprises and micro-companies. There are only a few larger (>500 staff) food processors, including a few international companies. It is usually the larger companies which have the capacity for Research and Development. Among the countries in the region, Trinidad and Tobago is one of the biggest contributors to the food industry, where the contribution to the Gross Domestic Product (GDP) is approximately 4.5%.

Only a few companies export outside the region. The export of Banana, nutmeg and sugar exports have significantly declined recently. The size of the interregional agricultural and food trade is small. The region has a number of medium-sized retail chains, together with a large number of small local shops, street vendors and food markets. About two thirds of grocery sales are conducted in the retail sector. A number of international and regional fast food chains are present. However, an in-depth and comprehensive assessment of the overall agro-food system in the Caribbean is hindered by the lack of up-to date and reliable data.

2.8 Major export/import crops and markets

Agricultural crops in the Caribbean mainly comprise on sugar cane, bananas, coffee, tobacco, root crops (cassava, sweet potato and yams), some citrus fruits and cacao (**Figure 3**). Other commercial crops grown in the region include vegetables and fruits (Figure 3). Most of the crops from plantation farming are used for export. Bananas are significant exports in the English-speaking Caribbean countries of Jamaica, Grenada, St. Lucia and St. Vincent. Coffee is an important export crop in Jamaica, which is famous for its Jamaican Blue Mountain coffee, which is mainly exported to European, Japanese and U.S. markets.

A recent report showed the combined food import bill for the CARICOM countries that increased significantly from US$2.08 billion in 2000 to US$4 billion in 2008, and surpassed the US$4.25 billion mark in 2011 (FAOSTAT, 2013). Additionally, the main CARICOM agricultural crops related import items in 2011 were wheat

Figure 3. Caribbean food and export crops

(US$248.8 million), rice (US$240 million), maize (US$145.5 million) and soybean oil (US$131.9 million). Between 2000 and 2011, the prices of the main imported commodities (wheat, maize, rice and soybean oil) increased by 137%, 274%, 92% and 159%, respectively. Wheat imports in 2011 for Jamaica (29%), Trinidad and Tobago (20%) and Guyana (10%), were approximately US$73 million, US$49 million, and US$24 million, respectively (FAO, 2013). An econometric analysis of Caribbean food import demand reported that an increase in prices of imported food will not result in an equivalent decrease in the quantity of imported food demanded, mainly comprising oils, staples and other food products (Walters & Jones, 2016).

It should be noted that this high level of food imports has negatively impacted the development of domestic agriculture products and agroprocessing industries due to the inability of domestic sectors to compete against imports (Silva et al., 2011). The agricultural producers of the Caribbean region experience many challenges throughout the food value chain. Some of these include: insufficient processing capability, high freight costs, small markets, tariff policies and lack of mechanisms for health/food safety and production certification.

In order to reduce this high food import bill in the region, a shift is needed to one that can replace a high proportion of food imports. For example, root crops such as cassava and sweet potato are important commodities grown in the Caribbean region and can be used to replace some of the wheat flour in the Caribbean diet.

2.9 Potential sources of FNS instability/ Major agricultural challenges

2.9.1 Trade

In the Caribbean region, trade and food security are connected via various links to the importance of exports and imports to their economies. The Caribbean has experienced slow trading activity and growth in export goods as a result of various economic issues with several of its international trading partners in North America and Europe. The report of the Caribbean Trade and Adjustment Group (CTA) revealed considerable decreases in major agricultural exports. Standardized data on trade is only available for certain countries in the region. Such data demonstrated that for Antigua and St. Kitts, the ratio of imports to exports was approximately 20:1; for Barbados, Dominica, Jamaica, St. Lucia, St Vincent, Suriname and Trinidad, the 2008 level of imports was over twice that of exports (CTA, 2011). The aforementioned data reflect a high dependence on imports, thus indicating potential susceptibility to food insecurity. Currently, the Agricultural sector depends on the international market for raw materials and final consumer food products, but Non-Tariff Measures (NTM) have hampered this type of agriculture trade. There are also several non-tariff barriers to trade, which affects compliance with international and industry-driven Agricultural Health and Food Safety (AHFS) measures which in turn, creates challenges for food and agricultural exports to enter the markets.

However, recently, there have been efforts to liberalize global trade such as the World Trade Organization (WTO), Caribbean Economic Partnerships Negotiations with the European Union (EU) and regional trade agreements. However, while all these efforts are important, it is even more imperative to identify and establish the necessary trade policies to promote agricultural development and food security in the region. Policies must effectively address the various facets and cross-sectoral nature of FNS. The Caribbean Agricultural Health and Food Safety Agency (CAHSFA) and firm linkages to the Caribbean Public Health Agency (CARPHA) are important regional institutions for new directions.

2.9.2 Volatility in food production and food prices

Instability and vulnerability in food production and food prices caused by natural and economic tremors constantly threaten efforts to advance food production and sustain food prices in the Caribbean. The domestic food price volatility index measures variability in the relative price of food in a country. According to FAO reports, the index for the 2000-2014 periods showed that the lowest levels of domestic price volatility occurred in 2000 and 2002 in CARICOM countries, while the highest volatility in domestic food prices occurred in 2001, 2004 and, to a lesser extent in 2005 and 2009. In 2014, the domestic food price volatility index was double the level recorded in 2000. The report also revealed that variation in food production per capita across the region has been declining since the mid-1990s.

2.9.3 Natural disasters

Caribbean countries are vulnerable to natural disasters, which cause widespread damage to agriculture, thus challenging efforts to enhance food security. Because of the small size of these countries, their coastal nature and their close proximity to each other, the damage per unit area and cost per capita is usually high. For the 1990-2014 period, 182 major natural disasters occurred in the region, affecting 11.5 million persons, and causing US$ 16.6 billion in damage to immovable assets and stock. These included landslides (1%), earthquakes (3%), droughts (7%), floods (30%) and storms/hurricanes (59%) (Guha-Sapir, 2015). It has also been reported that damage and losses due to natural disasters has been increasing for the past 15 years. In 2004 alone, hurricane Ivan caused devastating damage to the tune of US$815 million in Grenada, US$40 million in St. Vincent and the Grenadines and US$2.6 million in St. Lucia. The disruption in food production systems caused by natural disasters is due to the interlude in the production and flow of goods and services which affects FNS.

2.9.4 Pest and diseases

The Caribbean region is beset with plant pests and diseases which are a serious constraint on FNS. Furthermore, movement of pests and diseases among these small islands constitutes a severe quarantine problem. Root crops provide a major source of food in this region and they alone are affected by a myriad of diseases caused by species of *Macrophombia, Rhizoctonia* and *Sclerotium*, bacterial diseases caused by species of *Xanthomonas* and a number of virus disease problems, such as cowpea mosaic virus. A number of vegetables are also widely produced in the region but they are also significantly affected by pests such as aphids, mites, nematodes and white flies. The Caribbean region has yet to achieve sustainable means of managing pests and diseases which is important for food security in the region. Moreover, there has been indiscriminate use of pesticides in the region and inadequate knowledge about pests and diseases, which often lead to misdiagnosis and incorrect management. Sustainable means of managing and controlling pests and diseases in the region rely on biotechnology tools and integrated pest and disease management approaches. There are too many potential pest and disease agents that overwhelm the re-sources of the countries of the Americas. This, coupled with the high mobility of humans through the Americas and between the Caribbean Islands and the mainland countries poses a daunting issue for managing and controlling of pests and diseases. Therefore, integrated research among all the countries of the Americas and developing diagnostic strategies and integrated control mechanisms could be a critical way forward to alleviate the detrimental impact of pests and diseases on FNS (Gómez-Pompa, 2004).

3. Institutional Setting

In the face of heightened vulnerability to the impacts of world trade markets, natural hazards and climate change, generating new knowledge through research is paramount to increase the competitiveness and adaptation of the Caribbean to these impacts. At presen, the institutional settings are such that resources, equipment and funding are not strong enough for research and development in local agricultural commodity development in order to increase comparative advantage. This is coupled with the general apathy and lack of interest by the governments in the Caribbean to plow resources into agricultural research. As a result, the agricultural research system is still largely drawing on agricultural research utilizing outdated green revolution technologies. This has compounded the inability of the research systems to attract innovative research technologies that will advance the realization of FNS in the region.

Despite these constraints, however, agricultural research is slowly emerging. Regional institutions such as CARICOM, OECS, the Ministries of Agriculture and Caribbean Agricultural Research and Development Institute (CARDI) collaborate in the implementation of agricultural research projects with the EU, FAO, and the Inter-American Institute for Cooperation on Agriculture (IICA) among other institutions. This has slowly built linkages and networking, which has been building institutional capacity and resources to execute innovative research projects. Databases emanating from these research collaborations allow stakeholders to view trends in agricultural production/consumption across the Caribbean. However, there is still limited access to databases across the Caribbean and where they exist, the information is either outdated or inaccessible.

While research conducted in the region through these linkages has made some contribution in the area of FNS, there is still a need for more access to a wide range of scientific infrastructure such as modernized facilities in order to compete with universities/institutions in developed countries. Adequate funding is required for these facilities to be maintained or kept up-to-date. The regional University with the mandate for training, research and development in agriculture is the University of the West Indies St. Augustine (UWI-STA). The UWI-STA has maintained close relationships with universities in developed countries, mainly to strengthen research programs and engage in collaborative works. Funding programs have promoted these collaborations by encouraging students and scientists' liaisons, thus bringing innovative research teams together. Europe is the major donor for research and development in the Caribbean. There are many scientific organizations and networks in the region including The UWI, IICA, CARDI, PROCICARIBE, The Caribbean Agricultural Science and Technology Networking System, The Caribbean Biotechnology Network, Plant Biotechnology in Latin America and the Caribbean: REDBIO/FAO, the United Nations University BIOLAC or Biotechnology for Latin America and the Caribbean. From all of these webs a connectivity of scientists and agricultural-related research is slowly emerging.

Since the 1960s, the Faculty of Food and Agriculture at the UWI (FFA, UWI) has trained a pool of graduates at the undergraduate and postgraduate level who were/are employed in the Ministries of Agriculture and other regional agricultural institutions. However, the number of enrolments and graduates in agriculture has dwindled over the years due to the shift in focus of regional governments to tourism, engineering, medicine and so on.

4. Resource and Ecosystem Characteristics

4.1 Water resources in the Caribbean

Water is as fundamental to human life as it is vital to human FNS. Water is required for crop and livestock production to meet the food and nutrition needs of humans. It is implicated in important biogeochemical, ecohydrological and physiological processes that determine the function of ecosystems (forests, lakes and wetlands) on which the FNS of the present and future generation depend (Robinson et al., 2008; FAO 2015). Hence, for good nutrition in the Caribbean, water must be available in sufficient quantity and quality for safe drinking, agricultural production and for the preparation and processing of food.

In the Caribbean, the abundance of water resources is such that the region should not be constrained by fresh water availability except in the low-lying more arid islands of Barbados, Antigua & Barbuda, the Bahamas and the Virgin Islands with scarce surface free-flowing water (**Table 7**). Rainfall arising from maritime tropical climate mostly dictates the water resources of the Caribbean (Eudoxie and Wuddivira, 2014). The Caribbean is characterized by two distinct seasons; the dry season from January to May and the rainy season coinciding with the hurricane season from June to December (Cashman et al. 2009; Eudoxie and Wuddivira, 2014). The large variability in rainfall amount, intensity and water yields from island to island (from 1,127mm in Antigua and Barbuda to 4,500mm in Dominica) is influenced among other climatic features by topography, size, geology and proximity to mainland continents.

A 10%-30% decrease in wet season rainfall across most of the Caribbean countries as a result of climate change impact by 2080 has been projected (Hall et al., 2012). The already experienced bouts of droughts and dry spells undermine FNS as rainfed production, freshwater flows and groundwater recharge is reduced (Cashman, 2014). Additionally, inadequate infrastructures or institutional frameworks to manage excess water for supply during the off-season are major threats. The urbanization, deforestation and degradation of upper watershed areas have resulted in higher peak flows, downstream flooding, an overall decrease in base flows (Edwards, 2011) and higher sediment loads. The denuding of hillsides has resulted in slope instability, mud flows and catastrophic flooding. These affect food production and the supply of good-quality water for FNS. Sea-level rise has caused saline intrusion salinizing coastal aquifers and migration of the fresh-saline water interface further inland. Some of the main water quality issues affecting FNS are saline intrusion, pollution from bauxite mining, high nitrate levels and improper sewerage disposal in Jamaica; agricultural pollution and inappropriate sewage disposal raising nitrate levels to approximately 8 mg/L in Barbados; high iron concentrations in groundwater, high chloride levels in coastal aquifers and pollution in Trinidad.

4.2 Soil resources in the Caribbean

The Caribbean region, although limited in land resources, has tremendous variability in soil resources emanating from diverse historical geological formation and parent material (Ahmad, 2011). There are six major pedological soil

Table 7. Water resources in selected Caribbean countries and water supply situation

Country	Brief Description of the Water Supply Situation
1. Bahamas	In New Providence Island (with 67% of the population), water supply is from local groundwater and 30% from water barged from Andros Island, 75 km to the West. All water is from groundwater except small supplies from roof catchments and desalination of seawater. New Providence alone has a projected demand of 64,500 m^3/d in 2000 but only has a safe yield of 9100 m^3/d from its water sources, a depressingly serious shortage of water. There are no major surface water sources because of the porous nature of the soil and rock. No major irrigation is carried out.
2. Barbados	Public water supply is from groundwater reservoirs. Water from well sources is either pumped directly to transmission and distribution mains or otherwise into 24 service reservoirs varying in capacity from 900 m^3 to 6,800 m^3. Irrigation water is provided in the public water supply system (23%). Shortage of water is envisaged in the near future, but measures are in place to prevent this.
3. Belize	Public water supply is obtained from nine rivers, springs and wells. Surface water requires the removal of turbidity, tastes and odors through sedimentation, filtration and chlorination. Department of Agriculture drills wells for agricultural use in farming communities, separate from the public water system. Enough water is available for the near future for irrigation and other purposes.
4. Dominica	Abundant rainfall, coupled with steep relief and valleys lead to abundant surface water for domestic, industrial and hydroelectricity. Surface water is collected in five new reservoirs constructed of welded steel. The capacity of developed water sources estimated at 45,500 m^3/d, greatly exceeds the forecasted demand of water up to the year 2005. Not enough water for irrigation.
5. Guyana	Public water supply is obtained from groundwater (84%) and surface water (16%). Quality of groundwater is good except for the relatively high iron content of 1.5 to 2.5 mg/L in sand aquifers. Treatment of surface water is necessary because of the high turbidity, color, odors and tastes caused by decaying organic matter. Only 40% of produced water is treated. Supply is unreliable; 98% of water is used for irrigation.
6. Jamaica	Public water is from surface (8%) and groundwater (92%) scattered in different Parishes. An estimated 2,542,465 m^3/d is drawn from developed sources. About 11.2 x 106 m^3/d of water is still available for further development. The quality of groundwater is good, requiring only chlorination. Surface water is conventionally treated to remove turbidity, tastes, odors and hardness. No problem of water scarcity is envisaged in the near future; 74% of water use is for irrigation.
7. St. Kitts	Both surface water tapped from high elevations and ground aquifers (which occur in formations of volcanic origin) are used. There are 16 distribution reservoirs. Raw water quality of surface and groundwater is good. One third of water supply sources are treated by sedimentation, rapid sand filtration and chlorination. Developed water supply sources with a safe yield of 27,100 m^3/d can meet local needs for the next 10 to 15 years. Not enough water for irrigation.
8. St. Lucia	Water supply is drawn from 33 surface water sources, the most recent being the Roseau River, on which a dam and a storage reservoir have been constructed to augment supplies to the Castries area. All supplies are disinfected but some require additional treatment through coagulation, sedimentation and sand filtration. Turbidity levels of water rise because of increased erosion in catchments as a result of removal of forest cover. Present water sources are enough for the future demand forecast, but not for irrigation.
9. Suriname	Public water supply is from groundwater extracted from 10 well fields in three major aquifers. Water is stored in reservoirs. Presence of carbon dioxide, iron, ammonia and chlorides from sand aquifers require treatment. Principal treatment methods are aeration, sand filtration and chlorination. Water is abundant for irrigation and other purposes.
10. Trinidad and Tobago	Water is supplied from surface sources (79%) and groundwater (21%). A total of 97 sources are involved. Caroni-Arena, Navet, Hollis and Oroupouche resources supply 64% of total production. The first three have earth dams and impounding reservoirs. There are 76 distribution reservoirs ranging in size from 45,500 m^3/d to less than 45 m^3/d. The Desalination Company of Trinidad and Tobago supplies 109,589 m^3/d. The present safe yield of identified water supply sources will take care of the projected water demand. More land could be brought into irrigation if more water can be exploited.

Source: Ekwue, E.I. 2010. Management of Water Demand in the Caribbean Region: Current Practices and Future Needs. West Indian Journal of Engineering, 32:28-35.

groupings encompassing hundreds of individual series.

1. Soils derived from recent marine and freshwater sediments. These comprise alluvial, naturally fertile, heavy textured expanding clay soils found in the low-lying flood plains of Caribbean countries. The soils have impeded drainage, are prone to waterlogging, flooding and are physically difficult to manipulate. Sea-level rise, frequent and longer drought and higher intensity rainfall portentously lowered the productivity of these soils.
2. Soils derived from pre-Quatenary marine and freshwater sediments. These inland alluvial-deposit soils have a wider textural range, moderate-to-high natural fertility, good physical properties, high capacity for agricultural productivity and the best and most resilient soils of the Caribbean. They are, however, structurally unstable, prone to degradation and less prone to sea-level rise. With urbanization, tourism and industrialization, the arable areas dominated by these soils have decreased significantly and may vanish in the next 50 years.
3. Soils derived from older freshwater sediments. These soils occur on flat topography elevated on a plateau above the former groups and subjected to higher precipitation. Although these soils have a naturally low capability for agriculture, appropriate management can make them productive. The low inherent fertility is mainly due to a surface dominated by fine sand and silt and a densipan subsurface with impeded water movement.
4. Soils derived from calcareous material. These soils are formed from calcium carbonate (limestone) parent material. They comprise: (i) soils derived from soft, impure calcareous claystone, siltstone, sandstone, shale, chalk and marl, located on gently to steeply sloping terrain, clay textured, desirable soil pH, adequate nutrient availability and uptake efficiency. The soils are susceptibility to erosion as large expanses have been converted from monoculture (sugar cane, bananas) to short-term vegetable and food crops with less soil cover and protection (Eudoxie and Wuddivira, 2014); (ii) Soils derived from indurated calcareous rocks. These soils have shallow profile depth deterring good root volume and water-holding capacity. The soils are naturally infertile, poor in structural stability and are prone to water-induced erosion with low resilience to climatic variability.
5. Soils derived from volcanic materials. These are soils found mainly in the volcanic Windward Islands of Grenada, St. Vincent and the Grenadines, St. Lucia and Dominica. The Andisols subgroup formed from volcanic ash has outstanding physical condition and resilience to water-induced erosion. But agglomerate and lava subgroup is low in fertility as a consequence of high rainfall and topography, with erosion being the main degradation hazard.
6. Residual soils derived from sedimentary, igneous and metamorphic basic to acidic rocks. These are the most prevalent soils in the Caribbean, dominant on various mountain ranges and steep topographies. The depth of the profiles varies as a function of slope and the magnitude of erosion. The soils are normally under primary forest vegetation and well protected from climatic and erosional elements. Application of other land uses that remove vegetation exposes the soils to the high energetic rainfall of the Caribbean leading to extreme erosion and soil degradation.

The Caribbean region is endowed with unique interspersed soil types that truly exist nowhere else. This presents an exceptional opportunity to develop a sustainable approach, integrating modern agriculture with traditional approaches to facilitate FNS in the region. However, soil areas coupled with the major threats of urbanization, deforestation, land use, cultivation practices, pollution, saline intrusion, erosion hazards and climate-change impact are rapidly degrading and decreasing the arable areas of Caribbean soils.

4.3 Energy challenges

A major constraint on Caribbean growth, development and competitiveness is high energy costs (McIntyre et al., 2016). This has increased the vulnerability of Caribbean economies to external forces, which in turn leads to high food prices, undermining FNS. Despite high electricity access, Caribbean countries utilize expensive off-grid supply in many sectors, including the food industry, to compensate for utility deficiencies such as frequent power outages. High energy costs are caused by limited generation capacity, outdated power systems, isolated grids, lack of technical expertise and volatility in oil prices (McIntyre et al., 2016). Electricity tariffs in the Caribbean increased by almost 80% during 2002-2012, exceeding 0.30 US$/kWh for most countries in 2012 (McIntyre et al., 2016). This has contributed to high food prices affecting food access in the Caribbean. There is heavy reliance on expensive, imported fossil fuels for electricity generation in the Caribbean. Caribbean countries other than Trinidad and Tobago import 87% of petroleum products for electricity generation, transportation and cooking gas in households.

Bioenergy as a sustainable alternative has been considered for the survival of the Caribbean states (Evanson, 2009). Even though biomass represents only 11% of the Caribbean energy supply, it is mostly concentrated in Jamaica. Furthermore, the selection of bioenergy crops is affected by factors such as (i) agroindustrial productivity (liters of fuel per hectare), power generation efficiency (kWh/tons), technological availability (access and affordability), energy balance (energy contained/delivered: energy used in production), environmental impact of production; competition with food production, and incentives and barriers (Evanson, 2009).

Renewable resources such as solar, wind and geothermal are in abundance in the Caribbean and can be viable energy options. Caribbean wind resources, which measure an average 7.5–9.0 meters per second throughout the year, far exceed the wind resources of the wind energy leaders Denmark and Europe (Haraksingh, 2001). Solar radiation in the Caribbean with insolation of 15-20 MJ m^{-2} day^{-1} supersedes summer insolation in Europe (Haraksingh, 2001). However, most Caribbean countries still rely on expensive imported fossil fuel to generate >90% of their energy. This has been attributed to the lack of economic infrastructure to undertake renewable energy projects and weak policies on grid interconnection.

4.4 Biodiversity conflicts and challenges

The Caribbean region supports diverse ecosystems characterized by a high proportion of endemic plants and animal species. The exceptionally high diversity of plants includes more than 13,000 species, species, including 6,500 which can be considered single-island endemics. More than 600 bird species are found in the region and approximately 90 species of mammals. Notably, the region includes 160 freshwater species of fish. In addition, the coastal ecosystem includes coral reefs, mangroves, seagrass beds, salt marshes, wetlands, estuaries, bays, beaches and rocky shores; all of which provide important ecosystem services. There are 26,000km of coral reefs representing 7% of total world coral-reef ecosystems. The shallow marine environment also includes 117 sponge, 633 mollusk, 45 shrimp, over 1,400 fish and 23 seabird species (CEPF, 2010). Caribbean forests also add to the rich biodiversity of the region and are classified as Tropical and Subtropical Moist Broadleaf Forests, Tropical and Subtropical Dry Broadleaf Forests or Tropical and Subtropical Coniferous Forests.

The Caribbean is a rich biodiversity region but it faces challenges such as habitat destruction and fragmentation due to agricultural, urban, tourism and commercial development; overexploitation of natural resources and pollution of the marine environment (Maunder et al. 2008). There are high rates of deforestation of the tropical forests. Reports have also shown that the West Indian manatee (*Trichechus manatus*) is increasingly threatened by commercial fishing and fatal collisions with boats (Conservation

International, 2007). In order to protect and preserve the unique biodiversity of the Caribbean region, policies that involve the promotion and sustainability of the forest, marine and all other terrestrial ecosystems should be enforced.

4.5 Forestry Trends

The Caribbean islands are small and densely populated with steep topographic and climatic gradients which support a large variety of forest types. Species composition is very diverse and ranges from only one or a few dominant tree species (e.g., mangrove forests) to at least 170 in rainforests (Lugo et al. 1981). Researchers reported 2,000 species of flowering plants, 243 tree species and 13 different forest formations in the Windward and Leeward Islands (Lugo et al. 1981; Beard 1949). The various forest types include pine forests, palm forests, savannas, coastal and freshwater marshlands, montane forests, mangrove forests, lowland evergreen and semi-evergreen forests, dry evergreen coppice forests, flooded forests, dry deciduous forests, inland forests, and bamboo forests, and introduced plantation species such as Caribbean pine and teak. These forests provide vital ecosystem services and a source of livelihood that is important for FNS. Forests in most of the islands exceed 30% cover of land area. Nevertheless, there have been reports of decreasing trends in forest cover from 1990-2010 in Dominica, Jamaica, St. Lucia and Trinidad and Tobago (**Table 8**; FAO, 2010).

Forests in the Caribbean have been continuously cleared and degraded due to increasing population pressure and negative anthropogenic activities such as deforestation, uncontrolled and malicious fires, logging and climate change. These activities modify vegetation cover, thus creating new ecosystems with significant soil degradation and substantially altered carbon budgets, nutrient cycling, fuel and habitat characteristics (Robbins et al. 2008; Aide et al., 2012), energy and hydrological balance. Studies have shown extensive deforestation in some islands, but forest recovery has also been reported. Trinidad and Tobago and Jamaica saw the greatest area of woody vegetation loss to deforestation between 2001 and 2010 (Aide et al., 2012). However, there is limited knowledge in the Caribbean on the impact of these anthropogenic activities and climate change on forest structure, ecosystem function and livelihoods. Furthermore, the forests' resilience is compromised by continuous loss and degradation undermining climate change mitigation and adaptation of the Caribbean region that has hitherto been considered one of the world's most vulnerable region to climate-change impacts.

Sustainable forest management is of paramount importance for FNS and sustainability of the Caribbean in the next 50 years. This is important given the unabated deforestation, urban sprawling, forest fires and small holder farming on steep slopes, which continue to fragment and reduce forest areas and their

Table 8: Percentage change reported in the extent of forest 2005–2010 for selected Caribbean countries

Country/Area	Extent of forest cover (% of land area)	1990-2000	2000-2005	2005-2010
Dominica	60	-0.55	-0.57	-0.59
Grenada	50	0	0	0
Jamaica	31	-0.11	-0.10	-0.12
St. Lucia	77	0.64	0.13	0
St. Vincent & the Grenadines	68	0.27	0.23	0.30
Trinidad and Tobago	44	-0.30	0.31	-0.32

Source: FAO (2010). Global Forest Resources Assessment 2010 Country Report: St. Vincent and the Grenadines. Rome, Italy: FAO.

resilience to natural hazards and climate change. It is worth mentioning that the great diversity of forest types in the Caribbean makes it difficult for effective management of forests over wide areas. Therefore, there is a need for: the incorporation of effective adaptation and mitigation strategies into forest management and practice; enhancement of information on forests and the impact of climate change; updating and strengthening the weak and outdated legal, legislative and policy framework for forest management; clear land-use guidelines and policies to reduce uncoordinated encroachment onto protected forests areas; education on the importance of forests for services such as slope stabilization and soil protection by hillside forests and coastal protection by mangroves.

4.5 Potential impacts of climate change

The impacts of world trade markets, natural hazards and vulnerability to climate change are major factors undermining food access in the Caribbean. This is due to unforeseen sudden shocks from economic or climatic crisis and cyclical events such as seasonal food insecurity. These negative effects have been accentuated by several devastating events of hurricanes, floods, volcanic eruptions and earthquakes that have caused monumental damage to infrastructure including agricultural farms, affecting food availability, access and stability.

Climate change must be addressed because of the potentially harmful impact it has on the resources upon which the FNS depends. In general, sea-level rise is expected to pose a greater threat to lives and livelihoods in the predominantly coastal communities of the Caribbean through saline intrusion, coastal flooding and infrastructural damage caused by storm surges and erosion. The warming of the seas is already causing coral bleaching and dying, water resources are already affected by changing weather patterns and invasive and non-endemic species are already creating serious public health concerns on the islands. Saline-water intrusion is projected to have more impact on agricultural water resources in coastal plains than elevated temperature through salinization of coastal and groundwater aquifers, leading to reduction in availability and quality of freshwater. This will also alter the dynamics of other coastal water resources such as wetlands, swamps and mangroves that provide important ecosystem services (Eudoxie and Wuddivira, 2014).

In addition to the effects of sea-level rise, Arnell (2004) concluded that increased variability in rainfall amount, intensity and frequency will likely make Caribbean Islands become water-stressed. Intense rainfall events would also result in less water infiltration, increased runoff and lower water quality of inland surface sources. Increased evapotranspiration associated with elevated temperature adds further problems to inland water supply. This will also adversely affect groundwater recharge. The predicted increased frequency of high energetic rainfall events increases the vulnerability of the fragile soil resources in the Caribbean to degradation. Moreover, when coupled with urbanization and agricultural production pressures on marginal lands, accelerated degradation of regional soil resources will increase. The main soil degradation issues in the Caribbean are accelerated soil loss, declining soil fertility, the increased incidence of flooding and soil and water pollution and contamination (Wuddivira et al. 2010). These issues are all related to the process of soil erosion.

Consequently, it has been forecast that climate change will aggravate vulnerability to hunger and poverty, and more environmental degradation in the poorest and most vulnerable countries that contribute the lowest levels of emissions (Evanson, 2009). It has been projected that losses due to hurricane damage, infrastructure damage due to sea-level rise and losses in the tourism industry on average will be $10.7 billion by 2025, up to $46.2 billion by 2100. These losses will represent more than 75% of GDP in St. Kitts, Dominica, Grenada, and Turks and Caicos by the end of the century (Bueno et al. 2008). Therefore, small and vulnerable economies of the Caribbean are prone to the highest economic vulnerability to natural hazards, and low resilience and high exposure to climate-change impacts.

5. Technology and Innovation

5.1 Role of biotechnology

In spite of the abundance of natural resources, poverty and food insecurity affect more than 55% of the rural population in Caribbean countries (Izquierdo and de la Riva, 2000). Hence, it is imperative to explore the ways in which the increasing demands for nutritious foods and food security can be met. One such way is through the application of biotechnology.

5.1.1 Plant Agriculture

Plant biotechnology offers several possibilities for increasing productivity, diversification and production, while developing a more sustainable agriculture (Izquierdo and de la Riva, 2000). The food sector in the Caribbean is characterized (among other factors) by the growing dependence on food imports, predominantly cereals, and the decelerated growth of agricultural production and poverty affecting wide sectors especially the rural population (Beckford, 2011). The planting material available to small-scale farmers in the Caribbean is often of insufficient quantity and of poor quality, which challenges food security (Ogero et al., 2012). Crops such as yam, cassava and sweet potato are important staple foods and while being minor crops at the global level, these contribute significantly to the food security of rural populations in this region.

Sweet potato became increasingly important in the current agricultural development plans of CARICOM countries with respect to food security. However, constraints to its development included poor yields associated with poor agronomic practices, inconsistent quality, high incidence of pests and diseases and inappropriate postharvest handling. Cassava is mainly cultivated by subsistence farmers on marginal land. A major challenge for improving the supply of this commodity has been due to access to insufficient quantities of disease-free planting material. In order to ensure a sufficient regional supply of cassava, it is necessary to increase productivity (for example by adopting improved varieties resistant to pests and diseases), improve physical and marketing infrastructure and adopt appropriate processing technologies. Yam is also considered an important crop for achieving food security; this is attributed to its excellent storage properties and its revenue-generating capacity.

The lack of high-quality planting material for these domestic food crops was recognized a few years ago and in an effort to enhance Food Security in this regard, a project was coordinated by FAO in collaboration with CARDI for the establishment and reinforcement of tissue-culture laboratories and training for the *in vitro* propagation of disease-free roots and tubers such as cassava and sweet potato during 2010-2013 (Roberts and Georges 2013). Also, through tissue culture, an *in vitro* breeding method for Fusarium resistance in banana was developed as well as an *in vitro* hardening method for banana (Roberts and Georges 2013). More recently, tissue culture has been used as an economical tool for the micropropagation of many food crops, and examples in the Caribbean agricultural sector (ECLAC, 2008a; 2008b) include support for bulk production of citrus fruits and root crops, and conservation of the White Lisbon cultivar of yam *Discorea alata* has been improved by eliminating the internal brown spot viral disease. Distribution of improved plants led to a 40% yield increase.

5.1.2 Animal Agriculture

Livestock contribute 40% of the global value of agricultural output and this is expected to increase with growing population (FAO, 2009). Technologies and biotechnologies applied in animal agriculture have contributed enormously to increasing productivity, predominantly in developed countries, and can help to alleviate poverty and hunger, reduce the threats of diseases and ensure FNS in the Caribbean. Some of the most successful and popular reports on animal breeding noted for in this region have been on the Barbados Blackbelly sheep and the Buffalypso. This cross has been a wellspring from which many important breeds of sheep have evolved. In the 1940s, a breeding program initiated the development of the water buffalo (Bubalus bubalis) as a beef producer called buffalypso (Bennett et al. 2007). This superior herd of beef producer has been exported to many countries in North and South America. Today in the Caribbean, there has been a significant reduction in the number of buffaloes particularly the Buffalypso type due to the erosion of the livestock biodiversity (Steinfeld et al. 2006). At present there is no effort to ensure the survival of this germplasm in the Caribbean (Steinfeld et al. 2006).

Embryo transfer technology and molecular genetic analysis was applied to the cattle industry in Jamaica and in early 2016, native tropical cattle breeds were developed from Jamaica Hope, Jamaica Black & Jamaica Red, using biotechnology addressed to the growing challenges associated with the live export of cattle. Additionally, embryo transfer technology could allow for genetic conservation of these important breeds and secure rapid improvement of these breeds which, no doubt, is important for food security. Also, many sheep and goat farmers in the Caribbean experienced difficulty in obtaining high-quality breeding animals for their herds and had to continuously rely on the importation and utilization of frozen semen to improve genetic stock. CARICOM countries consume over 11 million kilograms of goat and sheep meat annually but only 30% of this amount is produced locally (FAO, 2015). Through breeding technologies with a focus on AI, in 2015, FAO began lending support to alleviate this challenge by playing an integral role in providing training for farmers and livestock technicians in Guyana, Jamaica and Barbados in the AI of goat and sheep (FAO, 2009)

While there has been some successful application of biotechnology to animal agriculture, not much work in this area has been achieved. The Caribbean is still far from having the capability to engage in specific animal biotechnology projects and even in some instances where significant developments have been reported, the region failed to sustain them. Thus, through the development of suitable livestock policies and the establishment of appropriate breeding programs sustainability can be achieved.

5.1.3 Pest and Diseases

In the Caribbean region, problems associated with plant pests and diseases are a serious constraint, and especially so, since agriculture is mainly conducted on small farm holdings, which are in close proximity, hence farmers' struggle to find quick and efficient solutions for management. Early means of accurate disease diagnosis and management are imperative for food security in the region. Traditionally, microorganisms have been identified through visual means, isolation methods and morphology. These methods have provided some insights into microorganism identification but comprise a relatively slow process and only a few microorganisms are cultivable (de Gannes et al. 2013a; 2013b). Additionally, most frequently, identification of pathogens is only achieved after a significant amount of damage was already done to the crops. Biotechnology provides tools to identify pathogens rapidly. Some of these include Nested PCR, Multiplex PCR, Multiplex nested PCR, Amplified Fragment Length Polymorphism (AFLP), Real Time PCR (RT-PCR) and DNA sequencing.

In some of our neighboring tropical countries (Colombia, Costa Rica, Peru and Brazil), the cassava Frog Skin Disease has caused up to as much as 90% in yield loss and attempts made to determine the causal agent of this disease through conventional means were futile. However, through AFLP the causal agent was identified (Cockcroft et al. 2003). This is just one example of how the application of biotechnology has contributed to food security in our neighboring tropical countries. Thus, the Caribbean region can use this model as a springboard to increase the application of biotechnology in this region.

In Caribbean countries such as Trinidad and Jamaica, major diseases have challenged the papaya industry and accurate identification of the pathogens responsible for this disease is important to developing disease management strategies. Anthracnose of papaya is a major postharvest disease. To address unsuccessful identification of the pathogen, PCR was applied and results were able to provide phenotypic characterization of *Colletotrichum* species associated with anthracnose disease of the two main papaya cultivars in Trinidad (Rampersad, 2011). In Jamaica, through a plant breeding program, transgenic Papaya with Resistance to Papaya ringspot Virus (PRSV) diseases was developed (Tennant et al. 2002). Unfortunately, the legislative and regulatory mechanisms needed to facilitate the field testing of subsequent generations of PRSV-resistant transgenic papaya in farmers' orchards and to build seed supply and later stages of commercialization were not established (Tennant, 2002).

While molecular laboratories have been developed in some emerging economies, they still lag behind in the Caribbean countries. There is a need for more funding, substantial growth in human skills, technological and infrastructure capacity and enhancement of delivery of diagnostic services to reap the benefits of molecular diagnostic techniques in plant pathology (de Gannes and Borroto 2016). Governments have a crucial role to play in supporting diagnostic capacity, but most importantly, molecular diagnostic systems and networks in the Caribbean must be sustained (de Gannes and Borroto, 2016).

5.2 Prospects for novel agricultural products

The modernization of the food manufacturing industry should mainly focus on the implementation of 'best practices' in the areas of: food safety and quality management, postharvest technologies, logistics and infrastructure, hygienic design of food premises and manufacturing equipment, lean manufacturing, automation and ICT systems, packaging materials and systems and staff training on all levels. Most of these systems can be bought off-the-shelf and do not need new R&D. Policies should be in place so that companies can commercially make the required technology jumps. Areas for specific R&D are the market-lead development of specific added-value 'Caribbean' food products and beverages (fresh, chilled, ready-to-eat, culinary, non-alcoholic), including the use of novel processing and packaging technologies which can give these products a competitive edge and are appropriate for the scale-of-operation in the Caribbean.

5.3. Precision Agriculture Technology in the Caribbean

Ending hunger and achieving FNS can be attained by promoting sustainable agriculture using relevant technologies. Technology has been shown to progressively increase food availability in the Caribbean during the last decades (FAO, 2016). However, the limited land resources in its chain of islands are characterized by a wide diversity of soils that vary in major soil properties within short distances. This intra-field variability in space and time can lower crop productivity and impacts environmental quality negatively, as field management and application of inputs are often done uniformly without taking the field variability into account. For a food-secure region, the agricultural system must be engineered for efficiency and a lower cost of production by employing Precision Agriculture (PA) technologies that optimize the limited and variable resources to realize high agricultural productivity.

PA can invigorate the deteriorated agricultural industry in the Caribbean by modernizing existing and future farms. PA improves farm management by aiding timely site-specific applications of the required amount of input; thus, productivity, profitability and sustainability are optimized and harmful impacts on the environment are minimized. In the Caribbean, spatial and temporal variability of soil properties and other edaphic factors are known to impact crop productivity (De Caires et al. 2015; Stocking 2003). Thus, identifying major agronomic variability using PA for the judicious application of inputs can potentially increase farm profitability and progress toward FNS. PA adoption in the Caribbean has, however, been hampered by the following factors: the agricultural sector has been out-competed for land by other emerging uses (tourism, housing and industry); the agricultural sector is dominated by older generations who are not techno-savvy; the initial investment cost of PA technologies is too high for most farmers, and the general mountainous topographies coupled with the hillside small-holder farming present some difficulties in the application of PA technologies.

5.4 Development of aquaculture/marine resources

Even though the Caribbean aquaculture industry is considered small-scale in comparison to fishing nations such as Japan, Iceland and Spain, the region is highly dependent on its resources for food and nutrition and employment opportunities. Fisheries provide approximately US $400M of revenues across the region and are essential for food security (Caribbean's Marine Environment, 2016). Many species such as tilapia, freshwater prawn and penaeid shrimp were introduced into the region in the early fifties. Some species which are indigenous to Trinidad and Suriname are cascadura (*Hoplosternum littorale*), *Epinephelus striatus, Lutjanus* spp. and *Mithrax spinosissimus*).

The region also has valuable species such as swordfish and tuna which helps fuel the massive demand for seafood locally and internationally. For islands such as Trinidad and Tobago, Bahamas and Grenada, export of fish is important. The islands also play a pivotal role in areas such as spawning and nursery even for North Atlantic fish stocks and important transshipping areas such as the port in Port of Spain, Trinidad for species including swordfish, tuna and billfish (http://www.worldfishing.net/news101/regional-focus/the-caribbean).

Governments have developed several programs for the improvement of fishing vessels and use of more effective gears and to encourage fishermen to shift from heavily fished inshore fisheries to offshore pelagic fisheries. **Table 9** depicts the additional developmental process for the aquaculture/marine industry in the Caribbean based on a status report on Caribbean aquaculture by FAO in 1993 (FAO, 1993). Three stages have been conceived where the pre-requirements and expected results are demarcated, the nation-

Table 9. A developmental process for the aquaculture/marine industry in the Caribbean

Prerequisites	National Input	External Cooperation
	Experimental	
• Political willingness • Favorable physical condition • Market prospective	• Availability of basic infrastructure (e.g. land) • National counterpart	• Participation in toward the construction of infrastructures (also 100%) • Technical assistance for technology transfer and evaluation
	Developing	
• Functional infrastructure • Technology experimented • Core of technology-competent persons • An idea of developmental potential • Political awareness	• Flexible and willing public structure • Resources of infrastructures and support services • Availability of investments in pilot projects	• Assistance: technical, management & institutional • Assistance toward investment opportunities & external funding sources
	Commercial	
• Sector policy • Budget for supporting actions • Institutional framework • Specific credit lines	• Private investments • Regulatory and legislative nature of the public sector • Availability of support services	• Marketing information • Scientific information

Source: Status Report on Caribbean Aquaculture, FAO 1993.
http://www.fao.org/3/contents/26d9132a-cf8b-5bc6-86fe-00d2ed61f902/AB490E01.htm#chl

al input each country should undertake to attain expected results and possible activities by external assistance for national actions (FAO, 1993). Despite these efforts by the governments, many of the islands are still faced with challenges such as limited administrative resources and implementation capabilities. Reports have shown that all major important fishery species are fully developed or overexploited and 70% of the coral reefs are threatened with overfishing (CARSEA, 2007). Additionally, ocean acidification has been on the rise and this threatens aquaculture and fisheries as a source of food. Coral reefs provide economic and environmental services including food security, shoreline protection from strong waves and revenue from tourism, and decreases in coral calcification due to ocean acidification would reduce the invaluable benefits these reefs provide in the region (Friedrich et al. 2012). Hence, integrating corals into some more managed aquaculture and fisheries resources could be an important future direction and opportunity for the region.

6. Increasing the efficiency of food systems in the Caribbean

The efficiency of the food system in the Caribbean is difficult to assess because of a lack of comprehensive and reliable data and benchmarks that cover the whole food-supply chain. National and regional policies, regulations and enforcement agencies on food safety and quality, waste and environmental management and supply-chain organization strongly influence the efficiency of the agri-food system. However, in the Caribbean these elements are mostly outdated, and/or absent and/or inadequately enforced. In many instances the whole system is disjointed and lacks coordination. Recently, CARICOM as well as national governments have announced and published initiatives to improve this situation, but implementation will be challenging given the present difficult economic situation in many Caribbean countries. An efficient working agri-food system is in the interest of all stakeholders from farmers to consumers, and is an essential element to achieve food security in the region.

To date, only few agri-food waste case studies as well an estimate of total agro-food waste in the Caribbean have been published. The results indicate that most of agri-food waste occurs in the production phase and that the overall waste percentage is lower than average. However, more detailed studies are necessary to detail the situation in the Caribbean. In the Caribbean, appropriate postharvest practices and facilities (refrigerated transportation and storage) are mostly absent, and there are also logistical (roads, port infrastructure) issues. It can be expected that the waste problem is compounded by the lack of proper food-safety and food-quality systems, regulations, standards and enforcement which inevitably lead to consumer food products (including some imported food products) which are not fit for human consumption. Most of the solid waste in the Caribbean goes into landfill. The amount of waste that is recycled or put to other uses is very limited, although new initiatives have been planned. In most of the Caribbean countries, landfill consists of organic waste, while the percentage of plastic materials (bottles/packaging) materials is also considerable. At present, no national and regional programs are implemented to reduce the amount of agri-food waste and packaging materials. Improvements in postharvest handling and further processing of local produce can lead to an increase in water and energy use in the Caribbean agri-food industry, offsetting potential gains by implementing more efficient methods and systems in the existing industries.

Other factors which impede the efficiency of the agri-food system in the Caribbean are:

- The apparent disconnection between consumer and (retail) market demands and the local agricultural production.
- Many food-manufacturing facilities are not properly designed, do not use inadequate processing equipment and lack up-to-date food safety and quality-management systems.

- The lack of cooperation and coordination along the food-supply chain among farmers, traders, manufacturers and national and international retailers.
- The lack of sufficient and adequately skilled production and technical staff, which is an issue in all stages along the production chain.
- An underdeveloped system of service providers: testing and R&D, extension services, engineering companies, equipment and packaging suppliers.
- Relatively high crime levels in most Caribbean countries. Predial larceny is prevalent in most farmer communities and almost all famers lose produce to theft, which can be estimated at about 18% of all produce. Predial larceny deters investments in farming. At presently there are no effective policies in place to combat this crime.

7. Health Considerations

7.1 Foodborne diseases

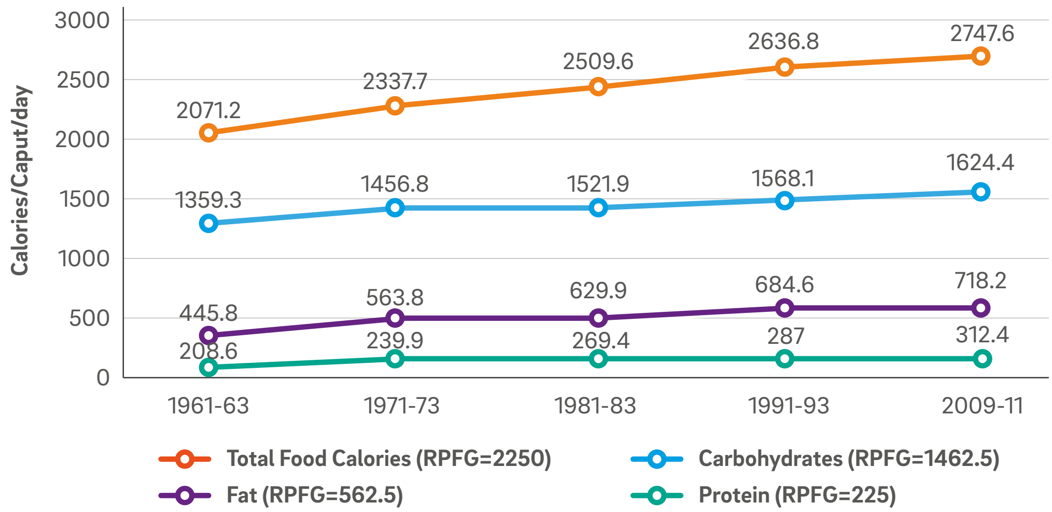
Foodborne Diseases (FBD) continue to be a serious global health problem. According to estimates from the World Health Organization (WHO 2015) on the global burden of FBD, each year as many as 600 million people in the world fall ill after consuming some sort of contaminated food. During 1990-2006, over 90 outbreaks from 16 Caribbean countries were reported, in which 40% were viral and 50% bacterial (GFN UPDATE Global Foodborne Infections Network May 2011, Vol IV). A 2008-2009 study conducted by the Caribbean Public Health Agency (CARPHA), the Pan American Health Organization (PAHO) and the UWI in collaboration with the Ministry of Health found that each year approximately 135,000 Trinidad and Tobago residents (about 1 in every 104 persons) would experience diarrhea due to possible consumption of a contaminated food or beverage (CARPHA 2015). Regional surveillance data from 2005 to 2014 showed that FBD is a public health concern of increasing importance and remains a high economic burden in the Caribbean (Indar et al. 2015a; Guerra et al. 2016).

The bacterial causative agents *Salmonella*, *Shigella*, and *Campylobacter* prevail and contribute to the overall annual economic costs of syndromic Acute GastroEnteritis (AGE) and FBD, with an estimated burden of $US2.2 M and 40.4 M, respectively (Indar et al. 2015a; 2015b). Data regarding FBD and Salmonella infections in the Caribbean revealed that the number of cases of reported human FBD increased by 26% (Indar et al. 2015a). The most common pathogen causing FBD was non-typhoidal *Salmonella* (47%), followed by ciguatera poisoning (24%), *Salmonella typhi* (9.8%), *Shigella* (8%), *Campylobacter* (6%), and norovirus (3.9%). There was an increase in non-typhoidal *Salmonella* (51%), norovirus (26%) and *Campylobacter* (25%) from 2005 to 2014, while *Salmonella typhi, Shigella*, and ciguatera decreased by 99%, 54%, and 18% respectively, during the same time period. Enteritidis was the most commonly isolated in Trinidad and Tobago, Jamaica, and Suriname. Typhimurium was dominant in Barbados and Mississippi in Bermuda (Indar et al. 2015a).

7.2 Overconsumption

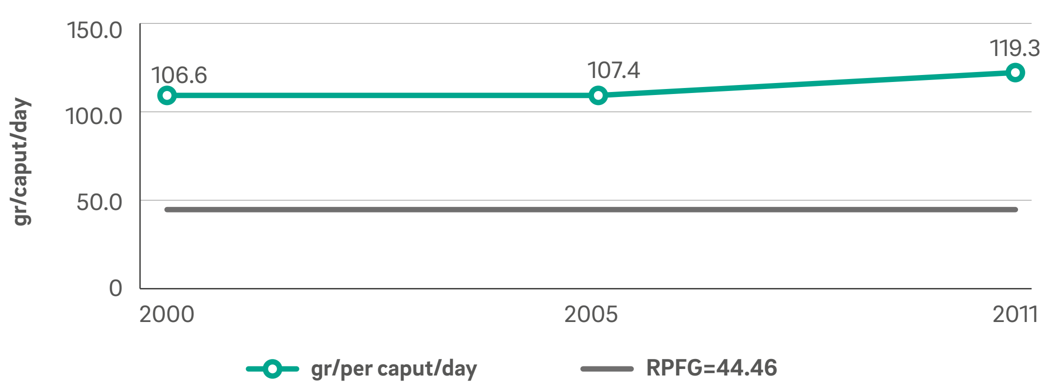
Food balance sheet data showed that for CARICOM countries, the availability of total food energy and macronutrients (carbohydrates, protein, and fats energy) has exceeded recommended population food goals from as early as the 1960s and has increased consistently over the years (**Figure 4**). It also showed that the availability of sugars and sweeteners exceeds recommended population goals and have been increasing over the years (**Figure 5**). Fat consumption and daily intake of large quantities of sugar are the main underlying causes of obesity and death in the Caribbean. The recommended daily target for sugar per day in children is approximately 25g (5 teaspoons) and for adults is approximately 50g (10 teaspoons). In comparison with global figures, the Caribbean, particularly Jamaica and Barbados, are joint leaders with Kuwait in the list of children between 13 and 15 years old who consume more than one bottle of soda daily (Caribbean Medical News, 2017).

Figure 4. Food Energy, Protein, and Fat Availability in CARICOM Countries (RPFG=Recommended Population Food Goals)



Source: Food Security and Health in the Caribbean Imperatives for Policy Implementation Ballayram, Beverly Lawrence, Fitzroy Henry Journal of Food Security. 2015, 3(6), 137-144

Figure 5. Sugars/Sweeteners Availability in CARICOM Countries (Gr/Caput/Day) (RPFG=Recommended Population Food Goal)



Source: Food Security and Health in the Caribbean Imperatives for Policy Implementation Ballayram, Beverly Lawrence, Fitzroy Henry Journal of Food Security. 2015, 3(6), 137-144

As a result, obesity rates have increased astronomically in the Caribbean with a greater impact on women and an upward trend in children (FAO, 2016). For example, in Jamaica obesity rates have increased by 1% each year since 2002, from 45% in 2002 to 54% in 2008, and 60% in 2016 increasing the risk of cardiovascular diseases (diabetes and hypertension) resulting in two out of every three deaths (Henry, 2011; Caribbean Medical News, 2017).

7.3 Expected changes in consumption patterns (and implications for food importation)

Caribbean countries are very food import-dependent. The Caribbean region has been a net food importer since 1971, and currently spends well over $US 4.5 billion annually on food imports in order to minimize the gap (**Figure 6**) between food consumption and domestic food production (FAO 2015). The following figure illustrates that CARICOM countries, with the exception of Guyana and Belize, import in excess of 50% of their food and seven of the countries import over 80% of the food they consume. The majority of the food is high in fats and oils, calorie-dense and loaded with sweeteners and sodium. All of these factors are directly linked to the overweight/obesity epidemic and the increasing prevalence of NCD in the region (Ballayram et al. 2015).

7.4 Understanding and incentivizing behavioral change, emerging personalized nutrition

Based on the collective model of household behavior, household members have different preferences for food intake (Alderman et al. 1995). Research has revealed that there are effects of intra-household bias on food distribution at the household level (Haddad et al. 1994) and pro-male and pro-adult biases have been found to affect food intake (Senauer et al. 1988; Quisumbing and Maluccio 2003). Consequently, the nutrient requirement for different groups (e.g., children and women of reproductive age require more nutrients per calories consumed) may not be met and this has led to a higher prevalence of micronutrient deficiency among women and children in the Caribbean. Based on this, it is imperative that nutrition information/education be more and more personalized. It is well understood that health behavior change works best when it is tailored, customized and personalized to respect individual choices, chances and circumstances.

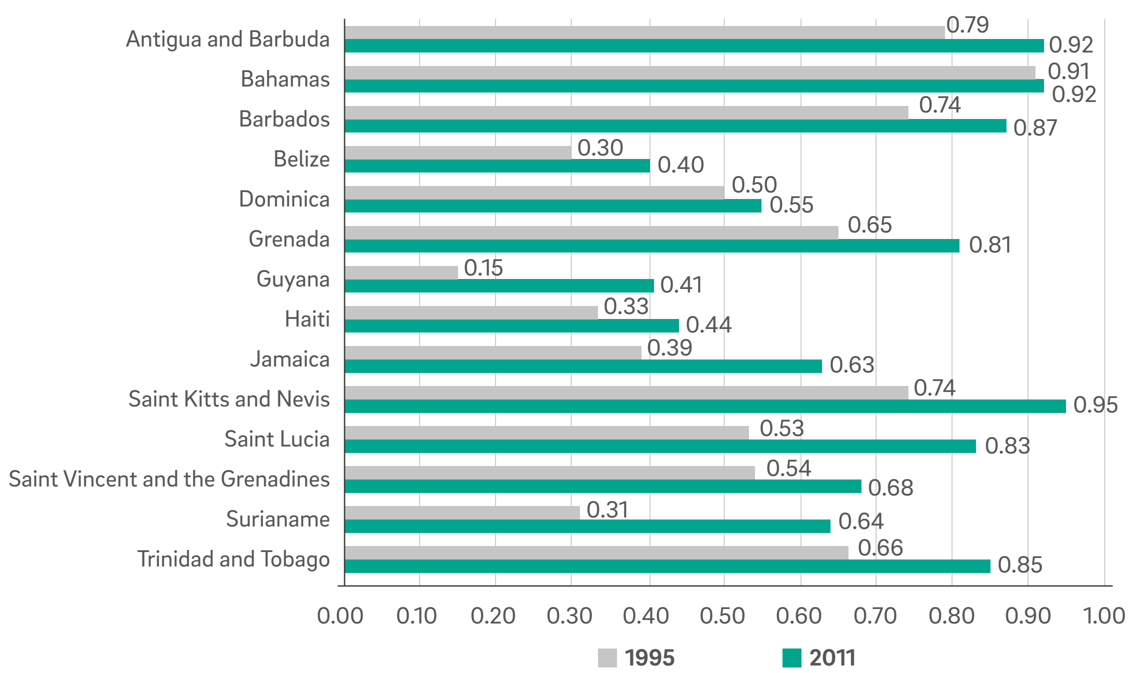
8. Policy Considerations

Policies for FNS should ensure that all Caribbean citizens throughout their lifetime enjoy at all times safe food in sufficient quantity and quality to satisfy their nutritional needs for optimal health. To achieve this, policy considerations are outlined as follows:

Policies to promote healthy eating

This should especially take into account the population that is vulnerable to poor nutrition

Figure 6. Food Dependency Ratio in CARICOM Countries, 1995 and 2011



and should deliberately focus on the important factors that influence food choices. There is easy access to unhealthy foods (which are high in unhealthy fats and oils, high in sodium and sugars and wheat flour-based products) due to low prices compared to high prices for healthy foods. This has sharply increased the incidences of obesity, overweight and chronic non-communicable diseases, which are now the leading cause of premature mortality in the Caribbean. Hence, policies should impose high taxes, strict food labeling, rules and the regulation of marketing and advertising of unhealthy foods. Concomitantly, policies to increase the supply and consumption of healthy foods such as incentives and subsidies for production, purchasing and promotion of healthy foods should be enforced.

Policies to promote low costs and clean energy
Energy is critical in the food value chain in the areas of food production, food processing, food packaging and food storage. The Caribbean is characterized by prohibitive high energy prices which makes the cost of production and processing of nutritious foods costly. Therefore, policies that encourage the use of alternative energy that is low-cost and environmentally efficient such as renewable energy should be enforced. Important considerations in this policy as outlined by IICA Agro-energy strategy (IICA, 2007) include: capacity development and public education; catalyzing production of biofuels for transport; catalyzing production of bioenergy for electricity generation, and development of small and medium-sized enterprises for biofuels. Additionally, governments and private sectors should financially support renewable energy projects and research in alternative energy, strengthen weak existing policies and ensure the implementation of new policies that encourage the availability, affordability and usability of energy for the production of safe and nutritious foods from local value-added commodities.

Policies that foster technological innovation
The Caribbean region is functioning within an increasingly competitive global economy and should aim to become food- and nutrition-secure through technological innovation in the food sector. Technology is a cross-cutting tool, which improves efficiency, quality and productivity. While the Caribbean region has applied some form of technology in food production, it has not yet garnered the full potential of technological advancement in food and nutrition, since the region still relies heavily on inefficient, traditional and outdated methods. Therefore, policies that encourage sustainable technological advancement in the area of biotechnology (quick and accurate diagnosis of plant and animal pests and diseases, mass propagation of important crops) and precision agriculture in irrigation, drainage and fertilizer technologies should be implemented. These policies should encourage technological innovation in indigenous and developmental research.

Policies that build human resources
Human resources play an integral role in FNS as they provide the workforce to the sectors involved in the production and processing of foods. In the Caribbean region, workforces lack the necessary education, training and motivation necessary for the development of the food sector. Hence, policies that are geared toward training, capacity building and re-tooling should be considered, particularly in youth development without gender discrimination. To boost productivity and increase the contribution of agriculture to the GDP of the Caribbean whose economies are currently dominated by oil and gas, and tourism, involvement of youth in agriculture is imperative. To date, Agricultural Science, which relates to food production and food security, has been expunged from most schools' curricula in most Caribbean nations. Policies should enforce the reinstatement into the curricula effective education in agriculture, food science and value addition to agricultural products. Also, agriculture apprenticeship programs and clubs should be established to provide information, knowledge and education to equip the youth for their involvement in food production. Policies should also allow enterprising agribusiness and agriculture youth access to arable land for farming purposes through leases

for land tenure, enterprise-development training courses, loans, extension services and technical advice. Policies on infrastructural and financial aids and subsidies should be established for the youth to own enterprises and grow local produce.

Policies on international trade issues

Trade is considered an engine of growth, development and poverty reduction. However, the Caribbean with small undiversified economies that are less competitive has been experiencing slow trading activity and growth in exporting goods over the years, which has affected FNS. Therefore, there is a need for dedicated policies in the area of strengthening agricultural negotiations capacity and agricultural policy planning units in each country and at the regional level. This will aid in the effective monitoring and conducting of trade-related activities.

Policies on strengthening institutional settings

With the realities of food and nutrition insecurity upon us, government policies must be geared toward regional institutional strengthening and capacity building in agricultural research and development. Policies that enhance financial support for public institutions and universities and linkages with international funding and donor agencies must be strengthened. This will promote agricultural modernization through the acquisition of new technologies. A strong integrated research linkage taking a biome approach in the next 50 years, involving interactive strategies between the Caribbean and areas sharing biome and climate similarity such as Florida, the Yucatán, Central America and Puerto Rico, could immensely help in addressing the myriads of Caribbean challenges and facilitate the advancement of the region toward FNS.

Policies that promote sustainable use and management of natural resources

Policies on protecting, conserving and managing natural resources (terrestrial, coastal or marine or a combination of these) on which the FNS of the present and future generation depend are critical to the sustainable development of the Caribbean. The uncoordinated manner in which built development, slash-and-burn on hillsides and in critical watersheds, expansion of roads, utility networks, forest fires, and invasion by non-native species, overexploitation of biodiversity resources and impacts of pollution and climate change are handled has led to the degradation and fragmentation of natural ecosystems. Policy considerations should focus on: the revision of outdated legislations on the protection of natural ecosystems to include the ecosystem approach to the management and impacts of climate change; introducing effective land-use planning framework to address the zoning of the countries of the Caribbean to ensure balance between land for agriculture, built development and protected natural areas; strengthening state agencies for the enforcement of policies for monitoring and surveillance of natural resources; designating and empowering one agency for the management of natural resources rather than the complicated involvement of multiple agencies in the administrative arrangements that weakens enforcement, monitoring and surveillance using the existing policies.

9. Summary and Recommendations

The United Nations' Sustainable Development Goal 2 is geared toward ending hunger, achieving food security and improving nutrition through the promotion of sustainable agriculture. The Caribbean has been plagued by an unsustainable food import bill that has consistently stood at approximately US$ 4 billion in recent years. This high import bill has compromised food security in the region due to rising concerns about external supply shocks and the increased volatility of global food supplies, causing sudden and dramatic increases in regional food prices. Apart from the import bill, the Caribbean agricultural system is overwhelmed by high production costs that are aggravated by severe labor shortages, small farm holdings, variable soils, strong uses that outcompete agriculture, pushing it to marginal lands on mountain ranges, low farm productivity and smaller scales-of-production. These are some issues that have contributed to agriculture becoming unattractive, thus forcing many farmers to abandon agriculture, or sell their produce to niche markets, which have hampered the ability of the region to compete in global markets. Moreover, agriculture in the region relies mainly on outdated technologies that are inadequate, inconsistent and often not holistic, resulting in low and variable plant and animal crop productivity. While some of these conventional technologies have made some contribution to research and innovation, the region still lags behind in the application of advanced, cutting-edge biotechnology and technology tools to achieve sustainable development and a food-secure region.

Recommendations

- The agricultural system must be engineered for efficiency and lower cost of production by integrating technologies such as precision agriculture and biotechnology tools into the Caribbean's agricultural sector which can potentially optimize the sustainability, productivity and lucrativeness of regional agriculture.
- The high food import bill, although it cannot be reduced to zero, must be maintained at an acceptable level that ensures the FNS of the region. Local commodities (cassava, yam and sweet potato) should be used in the production of value-added food products such as flour to replace a high fraction of food imports from wheat flour. The aquaculture industry should be developed to an extent that it comfortably supplies some of the protein source demand. Local commodities should be used in the formulation of feeds for the thriving poultry industry.
- Food supply, quality and safety issues must be addressed. The capacity of the resource-poor small holders of hillside farms must be increased to supply sufficient quality and safe foods to meet the demand of the population. Sustainable conservation agriculture techniques accompanied by integrated research in developing diagnostic strategies and integrated control mechanisms of pests and diseases could be a critical way forward.
- The Caribbean is endowed with abundance of renewable resources such as sunshine, wind and geothermal. Renewable electricity is cheaper to generate and more environmentally-friendly than fossil fuel-based electricity. Therefore, governments of the Caribbean must invest in renewable energy projects and also remove the bottlenecks that hinder international investors and developers from entering Caribbean energy markets.
- Policies are needed to support food and nutrition initiatives, but more importantly, they must be implemented and sustained. Governments must have the political will to develop the necessary modern regulatory and policy frameworks for agro-food production and to create the right investment climate. Investment in infrastructure and export-support systems is necessary.
- The existing agro-food production system must be stabilized, improved and refocused on promising products and markets by reconnecting the supply chain and strengthening food- manufacturing capabilities.
- More regional agro-food companies are complying with international standards. This should be strengthened to increase export opportunities.
- The demand for Caribbean local and fresh agro-food products is on the rise nationally, regionally and internationally because they are nutritional products that fit with a healthy lifestyle. Production of these commodities should be encouraged.
- Governments in the region must value the importance and potential of the agro-food developments in achieving the FNS of the region. Incentives that increase the production capacity of farmers should be provided.
- There should be more interlinked and established networks and commitments among research institutions, funding agencies and governments in the region to aid in sustained support and research that will address the FNS challenges in the region. Moreover, it is envisaged that through these

linkages and established networks, costs can be reduced and capacities can be developed.

- The range of soil types coupled with rich natural biodiverse ecosystems provides a unique opportunity to develop a sustainable approach integrating modern agriculture with traditional approaches to facilitate FNS in the region. Measures to address degradation threats to the endowed natural resources should be implemented.

References

Ahmad, N. (2011). Soils of the Caribbean. Technical Centre for Agricultural and Rural Cooperation.

Aide, T. M., Clark, M. L., Grau, H. R., López-Carr, D., Levy, M. A., Redo, D., & Muñiz, M. (2013). Deforestation and reforestation of Latin America and the Caribbean (2001–2010). Biotropica, 45(2), 262-271.

Alderman, H., Chiappori, P.H., Haddad, L., Hoddinott, J., Kanbur, R. (1995). Unitary versus collective models of the household: Is it time to shift the burden of proof? The World Bank Research Observer 10 (1), 1 -19

America, S. (2007). Subregional Report on Animal Genetic Resources.

Arnell, N.W. (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. Global Environmental Change, 14(1), 31-52.

Ballayram, B.L. & Henry, F. (2015). Food security and health in the Caribbean imperatives for Policy implementation. Journal of Food Security 3(6), 137-144.

Beard, J.S. (1949).The Natural Vegetation of the Wind-ward and Leeward Islands, Clarendon Press, Oxford, UK.

Beckford, C., Campbell, D., Barker, D. (2011). Sustainable food production systems and food security: economic and environmental imperatives in yam cultivation in Trelawny, Jamaica. Sustainability 3, 541-561.

Bennett, S.P., Garcia, G.W. & Lampkin, P. (2007). "The Buffalypso: the water buffalo of Trinidad and Tobago." Italian Journal of Animal Science 6, 179-183.

Bueno, R., Herzfeld, C., Stanton, E., & Ackerman, F. (2008). The Caribbean and Climate Change: The Costs of Inaction. Stockholm Environment Institute and Global Development and Environment Institute, Tufts University.

Caribbean's's Marine Environment. (2016). The Caribbean's marine and coastal environment. (http://www.caribbeanchallengeinitiative.org/index.php?option=com_content&view=article&id=410&Itemid=251#.WP4pI_nyuM8).

Caribbean Medical News. (2017). Jamaicans eating themselves into the grave, health expert warns. J. Best. (http://caribbeanmedicalnews.com/2017/03/jamaicans-eating-themselves-into-the-grave-health-expert-warns/).

CARPHA. (2015). Food Safety, should we be concerned? (http://carpha.org/articles/ArticleType/ArticleView/ArticleID/61).

CARSEA. (2007).Caribbean Sea Ecosystem Assessment, A contribution to the Millennium Ecosystem Assessment. (http://www.cep.unep.org/publications-and resources/databases/document-database/other/caribbean-sea-assessment-report-2007.pdf/view).

Cashman, A., Nurse, L., & John, C. (2009). Climate change in the Caribbean: the water management implications. Journal of Environment & Development.

Cashman, A. (2014). Water security and services in the Caribbean. Water 6(5), 1187-1203.

CEPF. (2010). Ecosystem Profile- The Caribbean Islands Biodiversity Hotspot – 2010.

Chandrashekara, K.N., Raju, S.R., & Chandrashekara, C. (2012). Molecular and Biotechnological Approaches in Plant Disease Management. Ecofriendly Innovative Approaches in Plant Disease Management, Vaibhav K. Singh, Yogendra Singh and Akhilesh Singh (Eds.), International Book Distributors, India. pp. 271-290.

Cockcroft, C.E., Herrera-Estrella, L., & Borroto Nordelo, C.G. (2003). Agricultural Biotechnology in Latin America and the

Caribbean. Handbook of Plant Biotechnology.
Conservation International. (2007). Biodiversity hotspot: Caribbean islands. (biodiversityhotspots.org/xp/hotspots/caribbean/Pages/biodiversity.aspx#http://www.biodiversityhotspots.org/xp).

CTA. (2011). Agritrade Expert Analysis, Caribbean: Agricultural trade policy debates and developments.

De Caires, S.A., Wuddivira, M.N., & Bekele, I. (2015). Spatial analysis for management zone delineation in a humid tropic cocoa plantation. Precision Agriculture 16(2), 129-147.

de Gannes, V., & Borroto, C.G. (2016). Appropriate and Sustainable Plant Biotechnology Applications for Food Security in Developing Economies. Agricultural Development and Food Security in Developing Nations- 178pp.

de Gannes, V., Eudoxie, G., Hickey, W.J. (2013a). Prokaryotic successions and diversity in composts as revealed by 454-pyrosequencing. Bioresource Technology, 133, 573-580.

de Gannes, V., Eudoxie, G., Hickey, W.J. (2013b). Insights into fungal communities in composts revealed by 454-pyrosequencing: implications for human health and safety. Frontiers of Microbiology 4, 164. doi: 10.3389/fmicb.2013.00164.

Economic Commission for Latin America and the Caribbean (ECLAC). (2009). Food and Nutrition Insecurity in Latin America and the Caribbean. (http://www.cepal.org/en/publications/3723-food-and-nutrition-insecurity-latin-america-and-caribbean).

Economic Commission for Latin America and the Caribbean Subregional Headquarters for the Caribbean (ECLAC). (2008a). Biotechnology: Origins and Development in the Caribbean. United Nations Economic Commission for Latin America and the Caribbean Subregional Headquarters for the Caribbean. LC/CAR/L.186. 22 December 2008. 39pp.

Economic Commission for Latin America and the Caribbean Subregional Headquarters for the Caribbean (ECLAC). (2008b). Policy Brief. Biotechnology with special reference to the Caribbean. United Nations Economic Commission for Latin America and the Caribbean Subregional Headquarters for the Caribbean. LC/CAR/L.184. 9 December 2008. 11pp.

Edwards, H.J., Elliott, I.A., Eakin, C., Irikawa, A., Madin, J.S., McField, M., & Mumby, P J. (2011). How much time can herbivore protection buy for coral reefs under realistic regimes of hurricanes and coral bleaching? Global Change Biology 17(6), 2033-2048.

Evanson D. (2009). Preliminary Assessment of Bioenergy. United Nations Development Programme (UNDP) Barbados and the OECS, December 2009

Eudoxie, G D., & Wuddivira, M. (2014). Soil, Water, and Agricultural Adaptations. Impacts of Climate Change on Food Security in Small Island Developing States. Ganpat WG, Isaac WA (Editors). 255pp.

FAOSTAT, D. (2013). Food and agriculture organization of the United Nations. Statistical Database.

FAO. (1993). Status report on Caribbean aquaculture. (http://www.fao.org/3/contents/26d9132a-Cf8b-5bc6-86fe-00d2ed61f902/AB490E00.htm).

FAO. (2010). Global Forest Resources Assessment 2010 Country Report: St. Vincent and the Grenadines. Rome, Italy: FAO.

FAO. (2013). CARICOM Food Import Bill, Food Security and Nutrition. (http://www.fao.org/fsn-forum/caribbean/sites/caribbean/files/files/Briefs/Food%20Import%20brief%20.pdf).

FAO. (2015). Goat and sheep production in the Caribbean set to improve thanks to FAO artificial insemination workshops. (http://www.fao.org/americas/noticias/ver/en/c/298223/).

FAO. (2015). State of food insecurity in the CARICOM Caribbean: Meeting the 2015 hunger targets: Taking stock of uneven progress. (http://www.fao.org/3/a-i5131e.pdf).

FAO. (2009). The State of Food and Agriculture: Livestock in the Balance. (http://www.fao.org/publications/sofa-2009/en/).

FAO. (2016). Panorama of Food and Nutritional Security in Latin America and the Caribbean. (http://www.fao.org/americas/recursos/panorama/en/).

Friedrich, T., Timmermann, A., Abe-Ouchi, A., Bates, R., Chikamoto, O.M., Church, M.J.., Dores, J.E.., Gledhill, D.K.., González-Dávila, D.M.., Heinemann, M.., Ilyina, J.H.., Jungclaus, E.., McLeod, A., Mouchet & Santana-Casiano, J.M.. (2012). Detecting regional anthropogenic trends in ocean acidification against natural variability Nature Climate Change (2): 67-171. doi: 10.1038/nclimate1372 (2012)

Gómez-Pompa, A. (2004). The role of biodiversity scientists in a troubled world BioScience 54(3), 217-225

Guerra, M.M.M., de Almeida, A.M., & Willingham, A.L. (2016). An overview of food safety and bacterial foodborne zoonoses in food production animals in the Caribbean region. Tropical Animal Health Production 48, 1095.

Guha-Sapir, D., Below, R., & Hoyois, P. (2015). EM-DAT: International Disaster Database. 2015.

Gustavo, F., & Tennant, P. (2011). Opportunities and constraints to biotechnological applications in the Caribbean: transgenic papayas in Jamaica and Venezuela. Plant Cell Rep 30, 681-668.

Hall, J.W., Brown, S., Nicholls, R.J., Pidgeon, N.F., & Watson, RT. (2012). Proportionate adaptation. Nature Climate Change 2(12), 833-834.

Haraksingh, I. (2001). Renewable energy policy development in the Caribbean. Renewable Energy 24(3), 647-655.

Henry, F.J. (2011). Obesity prevention: the key to non-communicable disease control. West Indian Medical Journal 60(4), 446-451.

IICA. (2007). Agroenergy and biofuels atlas of the Americas. (http://repiica.iica.int/docs/B0497i/B0497i.pdf).

Indar, L., Francis, L., Quesnel, S., Bissessarsingh, E., & Olowokure, O. (2015a). Foodborne diseases in the Caribbean, 2005–2014: changing epidemiology and implications for prevention and control. Board 178. International Conference on Emerging Infectious Diseases. Atlanta, Georgia, USA. Program and Abstracts Book, 109.

Indar, L., Olowokure, B., & Pérez, E. (2015b). The burden and impact of acute gastroenteritis and foodborne diseases in the Caribbean. Board 177. International Conference on Emerging Infectious Diseases. Atlanta, Georgia USA. Program and Abstracts Book, 109

Izquierdo, J., & de la Riva, G.A. (2000). Plant biotechnology and food security in Latin America and the Caribbean. Electronic Journal of Biotechnology 3(1), 1-8.

Kumar, S. (2014). Plant disease management in India: advances and challenges. African Journal of Agricultural Research 9(15), 1207-1217.

Lugo, A.-E., Schmidt, R., & Brown, S, (1981). Tropical forests in the Caribbean. Ambio 10(6), 318-324.

Maunder, M., Leiva, A., Santiago-Valentín, E., Stevenson, D.W., Acevedo-Rodríguez, P., Meerow, A.W., & Francisco-Ortega, J. (2008). Plant conservation in the Caribbean Island biodiversity hotspot. Botanical Review 74(1), 197-207.

Martínez, R., Palma, A., Atalah, E., & Pinheiro, A.C. (2009). Food and nutrition insecurity in Latin America and the Caribbean.

McIntyre, A., El-Ashram, A., Ronci, M., Reynaud, J.P., Che, N., Wang, K., & Yun, H. (2016). Caribbean Energy: Macro-Related Challenges.

Moris, J., & Bunker, K. (2014). Four Reasons Why Natural Gas is the Wrong Choice for Electricity in the Caribbean. Rocky Mountain Institute.

Ogero, K.O., Mburugu, G.N., Mwangi, M., Ngugi, M.M., & Ombor, O. (2012). Low cost tissue culture technology in the regeneration of sweet potato (Ipomoea batatas (L) Lam). Research Journal of Biology 2(2), 51-58.

Quisumbing, A.R., & Maluccio, J.A. (2003). Resources at marriage and intrahousehold allocation: evidence from Bangladesh, Ethiopia, Indonesia, and South Africa. Oxford Bulletin of Economics and Statistics 65(3), 0305-9049.

Roberts, C., & Georges, B. (2013). Development of Quality Planting Material of Roots and Tubers in the Caribbean Region. Technical Report CARDI, Publication HQ/025/1.

Peres, N.A.R., Timmer, L.W., Adaskaveg, J.E., & Correll, J.C. 2005. Lifestyles of *Colletotrichum acutatum*. Plant Disease 89, 784-796.

Rampersad, S.N. (2011). Molecular and phenotypic characterization of *Colletotrichum* species associated with anthracnose disease of papaya in Trinidad. Plant Dis 95, 1244-1254.

Robbins, A.M.J., Eckelmann, C-M. & Quiñones, M. (2008). Forest fires in the insular Caribbean. Ambio 37(7/8), 528-534.

Robinson, D.A., Campbell, C.S., Hopmans, J.W., Hornbuckle, B.K., Jones, S.B., Knight, R., & Wendroth, O. (2008). Soil moisture measurement for ecological and hydrological watershed-scale observatories: a review. Vadose Zone Journal 7(1), 358-389.

Senauer, B., García. M., & Jacinto, E., 1988. Determinants of the intrahousehold allocation of food in the Rural Philippines. American Journal of Agricultural Economics 70, 170-180.

Silva, S., Best, R., & Tefft, J. (2011). Reducing the CARICOM food import bill and the real cost of food: policy and investment options. Rough Draft- . Proyecto GTFS/RLA/141/ITA.

Steinfield, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., & de Haan, C. (2006). Livestock's long shadow: environmental issues and options. Rome, Italy: FAO.

The Statistical Institute of Jamaica (STATIN). (2006). Provisional report on external trade of Jamaica, 1991–2004. Statistical Institute of Jamaica, Jamaica.

The World Bank. (2016). "World Development Indicators." (http://data.worldbank.org/indicator).

Tennant P., Ahmad M.H., &Gonsalves, D. (2002) Transformation of Carica papaya L. with virus coat protein genes for studies on resistance to Papaya ringspot virus from Jamaica. Trop Agric (Trinidad) 79, 105-113.

Thorton, P.K. (2010). Livestock production: recent trends, future prospects. Phil Trans R Soc B (2010) 365, 2853- 2867 doi:10.1098/rstb.2010.0134

Seminar, Kingston, Jamaica, 24–26 Oct 1994. pp. 39-46, United Nations, Department of Economic and Social Affairs, Population Division. (2015). World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241. (https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf).

Walters A, L.M., & Jones, K.G. (2016). Caribbean food import demand: an application of the CBS differential demand system. Journal of Food Distribution Research 47(2).

Williams-Bailey, W., & Pemberton, P. (1980). Nelson's West Indian Geography: A new Study of the Commonwealth Caribbean and Guyana Australia: Thomas Nelson & Sons.

Wuddivira, M.N., Ekwue, E.I., & Stone, R.J. (2010). Modelling slaking sensitivity to assess the degradation potential of humid tropic soils under intense rainfall. Land Degradation & Development 21(1), 48-57.

Wuddivira, M.N., & Atwell, M. (2012). Appropriate soil conservation practices for hillside food production in the Caribbean. In: Sustainable Food Production Practices in the Caribbean. W.G. Ganpat and W.P. Isaac (Eds.). Kingston, Jamaica: Ian Randle Publishers. pp. 1-19.

World Fishing and Aquaculture (2012). The Caribbean. (http://www.worldfishing.net/news101/regional-focus/the-caribbean).

Yearbook, F.S. (2014). Latin America and the Caribbean Food and Agriculture. Santiago, Chile: FAO, 2014.

Young, F, (1994) Papaya ringspot virus in Jamaica. In: Proceedings of the Papaya Industry

Acknowledgments

The authors thank: the **Caribbean Academy of Sciences** (CAS) for nominating us to undertake this project, Prof. **Winston Mellowes** (CAS president) for providing relevant reference materials and Mr. **Terry Sampson** (of the Faculty of Food and Agriculture, The University of the West Indies, St. Augustine) for his ingenuity in developing the high-resolution maps and images used in this chapter. Mr. Sampson's creativity in coming up with maps that reflect the varied food crops and the ecological and bio-diverse areas of the Caribbean is highly commendable.

Box 1

Biotechnology Applications: Potential Roles and the Way Forward In Caribbean Food Security

Vidya de Gannes, Department of Food Production, Faculty of Food and Agriculture, The University of the West Indie.
Mark N. Wuddivira, Senior Lecturer and Deputy Dean in the Faculty of Food and Agriculture, University of the West Indies.

Technologies from the green revolution alone, can no longer be the basis for agriculture in terms of food production in the Caribbean. The biotechnology revolution provides the opportunity to develop the region's strengths, conquer its weaknesses and grasp the opportunity presented by the greatest challenge yet to confront mankind" (ECLAC, 2008). The benefits from the unremitting application of biotechnology to food production and food security in the developed world have proven to be tremendous. For example: plant tissue culture has led to the mass production of disease free crops on a year round basis; the application of bio-products (bio-fertilizers and bio-pesticides) have caused major benefits to the environment and agriculture as an environmentally safe alternative to the use of synthetic pesticides and fertilizers; the utilization of molecular means have provided rapid and accurate diagnosis to pests and diseases which led to improved management programs and a reduction in loss of crops and animals to farmers; the utilization of molecular markers in the development of crop varieties with new and enhanced traits such as resistance to pests and diseases have been shown to boost food production.

Therefore, there is no doubt that the potential impact of biotechnology on food production and food security will be promising in the Caribbean. However, even though, the biotechnology revolution heralds this new race, the Caribbean is still lagging behind and the full potential of biotechnology is yet to be garnered. Thus, major issues which impede the full and sustained application of this powerful tool must be addressed. The region is endowed with the potential availability of human, natural and energy resources. Many Caribbean countries have legislated policies to utilize biotechnology to enhance their economies (Barbut, 2011), but not much effort has been embarked hitherto to provide rigorous training and expertise in this field. Hence, programs at academic and technical institutions must provide the necessary training and sustained support for staff and students in this field. Additionally, where molecular laboratories have been developed in some of these countries, there is still the need for growth in human-skilled training, technological and infrastructure capacity and enhancement of delivery of diagnostic services. The improvement and sustainability of these technologies, will incur costs, hence, financial commitments from governments, funding agencies, international and regional organizations/institutions all have major roles to play in this regard. There is still an urgent need for vigorous outreach services to sensitize and educate the Caribbean population about the significant benefits of biotechnology. Moreover, networks must be established in the Caribbean as they relate to biotechnological applications and they must be readily accessible for the population to tap into.

References

Barbut, M. 2011. Global Environment Facility, Regional Project for Implementing National Biosafety Frameworks in the Caribbean Sub-region. Project proposal. 37p.

ECLAC (Economic Commission for Latin America and the Caribbean) Report, 2008. Biotechnology: Origins and Development in the Caribbean. Subregional Headquarters for the Caribbean, UNO. 53p.

BOX 1

Sustainable Agriculture and Healthy Food in Chile

Spring Vineyard. Elqui Valley, Andes part of Atacama Desert in the Coquimbo region, Chile © Shutterstock

Chile

[1] Carlos Muñoz
[2] Cristian Mattar
[3] Roberto Neira
[4] Marcos Mora
[5] Jacqueline Espinoza
[6] Óscar Seguel
[7] Osvaldo Salazar
[8] Rodrigo Fuster
[9] L. Antonio Lizana
[10] Cristian Cofré
[11] Anna Pinheiro
[12] Lorena Rodríguez

Exports created two types of agriculture in **Chile**: one to supply food for the local population, developed by Peasant **Family Agriculture, in small, low-tech plots of land; and commercial agriculture, with a great deal of technology and significant foreign investment,** designed to produce for world markets.

Summary

Chile is located in the far SW of South America. It occupies an area of 756,100 km², making it the world's longest country and, possibly also the narrowest.

It has a population of 17 million, with a growth rate of 1%, where 13% is over 60 and 13% is rural population. Life expectancy at birth is 79, and the agricultural sector represents 8.6% of the country's labor force.

Its agriculture, marked by a great diversity of climates and soils, permits the cultivation of a broad range of species, which include aquacultural ones. They not only provide a significant portion of the population's staple food but also contribute significantly to world food, especially salmon, fruit and wine, which makes it possible to generate a Gross Domestic Product (GDP) of $258.16 billion USD, representing 8% of the total, expressed in GDP per capita, which totaled over $23,000 USD in 2014.

The country has highly trained human capital and a solid infrastructure for conducting R&D&I, which has allowed it to be successful in eradicating the child nutritional deficit that prevailed until the first half of the last century, through the implementation of effective public policies. At present, however, the problem is related to a worrying level of obesity, which also affects the adult population, for which aggressive public policies are beginning to be promoted.

1. Introduction

Chile is located in the far SW of South America, occupying an area of 756,098 km², which extends for 4,329 km from 17°30' to 56°30'. This is equivalent to one tenth of the Earth's circumference, making Chile the longest country in the world. But it is also one of the narrowest, since it has an average width of only 180 km, around the West parallel 70°.

This layout creates a variety of climates, ranging from desert at the North end to steppes in the South. In the Central portion, between latitudes 27° and 43° S, Mediterranean and temperate climates predominate. Precipitation occurs mainly in the winter, increasing toward the South and decreasing from the coast to the mountain range. This section of the country is generally free of extreme-weather phenomena such as polar winds, hail, tornadoes or excessive snow, which makes it very suitable for agriculture, which, however, must mostly be irrigated. Moreover, this zone forms a sort of island separated, in the North, from the rest of the mainland by the world's most arid desert, in the South, by everlasting ice, in the West, by the Pacific Ocean and, in the East by the Andes, which separate it from neighboring countries.

There is enough information to indicate that agriculture in Chile was fostered by the peoples who inhabited this territory before the arrival of the Spaniards and that it evolved as a result of successive invasions, first by the Incas, the most developed people in South America and then, by the Spaniards. The influence of the Incas reached as far as Chiloé (50°S), when they introduced new crops and irrigation techniques and roads to facilitate the trading of agricultural products. Thus, agriculture evolved from an activity mainly intended to supply food to the population, until export agriculture became a major contributor to the country's Gross Domestic Product (GDP) when, toward the late 19th century, a period of food-product exports began that was consolidated in the 80s. This consolidation also contributed to the expansion of trade liberalization, encouraged by free trade treaties and other economic complementarity agreements strongly promoted from the early 1980s onward. Currently, food-product exports are concentrated on fruits, shipped fresh to the Northern hemisphere when they are out of season there, and artificially reared salmon exported to various markets around the world. The wine industry has also developed significantly since the 80s, becoming a key player in the Chilean agri-food sector and the global wine industry. Moreover, small quantities of other products such as milk, meat and honey are exported, without much added value.

In the context described, the advent of export agriculture created two types of agriculture: one dedicated to supplying food for the local population, developed by Peasant Family Agriculture, in small, low-tech plots of land; and commercial agriculture, with a great deal of technology and significant foreign investment, designed to produce for world markets. The country is currently committed to generating and using new production techniques, with environmental and socially sustainable criteria, including several certification systems, such as Corporate Social Responsibility Systems (CSR), Good Agricultural Practices (GAP), Good Hygienic Practices (BPH), Good Manufacturing Practices (BPM), and increasingly products that mention their attributes such as carbon footprint, water footprint, environmental footprint, fair trade and antioxidant content.

From a nutritional point of view, the country has successfully eradicated the child nutritional deficit prevalent until the first half of the last century, through the implementation of effective public policies, including free breakfasts and school lunches for the most vulnerable population. Nowadays, however, the problem has shifted to the worrying level of obesity, which also affects the adult population (Araya, 2006). Current public policies are designed to encourage the consumption of healthier foods, with low sodium, fat and sugar content, for which active population education campaigns have been launched, together with a new food-labeling law, taxes on sugary drinks and a law regulating the advertising of processed foods.

2. Demographic inventory

According to figures from the 2012 census, the total population of Chile is 16,634,603 people, and it is estimated that by the end of 2017, it will exceed 17.5 million people. According to the same census, the population growth rate declined from 1.24% in the decade from 1992 to 2002 to 0.99%

[1] Carlos Muñoz, Chapter Coordinator: University of Chile, Faculty of Agronomic Sciences, carlosmunozschick@u.uchile.cl **[2] Cristian Mattar,** University of Chile, Faculty of Agronomic Sciences. **[3] Roberto Neira,** University of Chile, Faculty of Agronomic Sciences. **[4] Marcos Mora,** University of Chile, Faculty of Agronomic Sciences. **[5] Jacqueline Espinoza,** Office of Agricultural Studies and Policies (PASO), Ministry of Agriculture. **[6] Óscar Seguel,** University of Chile, Faculty of Agronomic Sciences. **[7] Osvaldo Salazar,** University of Chile, Faculty of Agronomic Sciences. **[8] Rodrigo Fuster,** University of Chile, Faculty of Agronomic Sciences. **[9] L. Antonio Lizana,** University of Chile, Faculty of Agronomic Sciences. **[10] Cristian Cofré,** Ministry of Health. **[11] Anna Pinheiro,** Ministry of Health. **[12] Lorena Rodríguez**, Ministry of Health.

for the decade from 2002 to 2012, a downward trend that is expected to continue in the following decades.

Of this total, 87% of the population is urban and only 13% rural. There is also a tendency for the rural population to continue to decline as the country develops.

In the Latin-American context, Chile is the country that has increased its life expectancy at birth most quickly. Between 1970 and 2015, it increased from 60.5 to 77.4 years in men and from 66.8 to 83.4 years in women. Likewise, life expectancy after 60 has increased rapidly, totaling 20.9 years in men in 2016 and 24.4 years in women. At the same time, the number of senior citizens increased by a factor of 5.3 between 1950 - when population aged 60 or over totaled 416,741 - and 2010, when the number rose to 2,213,436.

The magnitude of the increase in life expectancy, coupled with declining fertility, will cause high, sustained growth of the elderly population, at least for the next two or three decades, which involves important equity issues, since there are obvious differences in the population linked to socioeconomic status, gender and place of residence, which will need to be addressed.

Agricultural activity is labor-intensive, and the sector that generates most employment in the country. In 2014, the forestry and livestock sector created 685,000 jobs, including seasonal work, representing 8.6% of the country's workforce.

3. Agricultural inventory

The Office for Agricultural Studies and Policies (ODEPA) of the Ministry of Agriculture regularly publishes a report summarizing available data on Chilean agriculture. According to the latest report, published in 2015 (ODEPA, 2015), mainland Chile has an area of 75.6 million hectares (ha), 51.7 million of which are suitable for silvo-agriculture and 35.5 million of which are used for agricultural livestock raising or forestry. However, due to geographical and economic factors, the area under cultivation currently stands at just 2.12 million ha. This area is distributed among 1,303,210 ha of annual and permanent crops, 401,018 ha of sown fields and 419,714 ha of fallow land. A total of 17,070,776 ha are covered by native forest and bushes; 12,549,478 by natural meadows; 2,707,461 by forest plantations, and 1,062,352 by improved pastures. Of the remaining area, 15,942,424 ha comprise sterile, arid or stony lands, and 242,742 have an indirect use in infrastructure, mainly roads and canals.

Of the 1.3 million ha with annual and permanent crops, 704,575 ha are used for annual crops, 296,587 ha for fruit trees, 137,593 ha for wine-grape vines and 78.072 ha for vegetables. **Table 1** shows the five main crops for each of these groups. As for meat production, poultry accounts for the largest share, with 669,100 tons (t) in meat carcasses, pork, 520,100 t; beef, 224,100 t; lamb, 10,000 t and horsemeat 7,600 t. The country also has approximately 460,000 head of dairy cattle with a yield of 2.691 million liters of milk per year.

This agricultural area and production have generated a GDP totaling US $ 258.16 billion in 2014, expressed in GDP per capita, calculated as purchasing power parity by the International Monetary Fund (IMF), of $23,057 USD. Of this total, the silvo-agricultural sector contributed just 2.3%, but if the activities that add value to the primary products and services produced in the sector are considered, the contribution rises to about 8% of GDP.

Table 2 displays the evolution of the fruit area in Chile, which shows how dynamic the sector is. There have been significant changes in land use, related to the increase or decrease of the area-under-cultivation of the different species, due to variations in international demand - especially in developed countries -, water and labor availability and the possibilities of mechanization.

4. The current Chilean agricultural development model

In the 1950s, agriculture was considered the weakest aspect of the Chilean economy, since it was the country that exported least and imported most agricultural products. This was the starting point from which Chile embarked on this new phase of modernization and agrarian transformations. In this context, agricultural, livestock, forestry and fishery exports in the 1960s amounted to $52.5 million USD. By the 1980s, they stood at approximately $1.84 billion USD, a significant, sustained increase, which has continued to this day. This evolution, in the case of fruit, which is perhaps one of the most emblematic, was possible due to the country's geographic situation, giving it the opposite season to the Northern hemisphere, a favorable exchange rate and the development of a National Fruit Development Plan promoted by the Production Promotion Corporation (CORFO) in the 1960s. This plan led to the training of a large contingent of professionals through a joint program with the University of California (US) and a flexible vision of agricultural entrepreneurs to adapt to the commercial requirements of international markets, as well as a trade liberalization policy in which Chile initially explored a partnership in blocs and subsequently opted for multilateral liberalization. Regarding the latter, Guerrero and Opitz (2017) report that Chile has signed 26 trade agreements with over 64 countries, including trade blocs such as the European Union. **Table 3** displays Chile's trade balance with the world. It shows that the agricultural sector is the most important one for exports and imports, in addition to which it has the most positive trade balance, followed by the forestry sector.

An agroexport model was generated, whose growth and development engines have been fruit growing, mainly table grapes, apples and stone fruits. This was followed by winemaking, seeds, berries, poultry and pork and even certain dairy products, such as cheeses. This model, initially led by transnational corporations, both in production and supply of inputs, has given way to medium and large producers who have joined the export chain directly, acting as producers and exporters.

Table 1. Area occupied by the 5 main species of the relevant categories of agricultural crops in Chile

Category	Area (ha)	Main species	Area (ha)
Annual Crops	704.575	Wheat	263.000
		Corn	125.200
		Oats	90.449
		Potato	50.524
		Raps	49.448
Fruit	296.587	Table Vines	48.500
		Apple trees	36.205
		Avocado trees	29.000
		Walnut trees	27.941
		Cherry trees	20.591
Wine vines	137.593	Red wine varieties	101.752
		White Wine Varieties	35.841
		Pisco Varieties	8.202
Vegetables	78.072	Maize for human consumption	9.727
		Lettuce	6.673
		Tomato	5.038
		Onion	4.454
		Marrow	3.989

Source: ODEPA.

Table 2. Evolution of area cultivated with fruit trees in Chile (ha). 2010-2016

Species	Year 2010 (ha)	Year 2016 (ha)	% Variation 10/15	Share (%)
Table vine	52.655	48.582	-7,7	15,7
Walnut tree	15.451	30.964	100,4	10,0
Avocado trees	34.057	29.933	-12,1	9,7
Red apple tree	27.633	29.168	5,6	9,4
Cherry trees	13.143	24.498	86,4	7,9
Olives	12.874	20.343	58	6,6
European plum	12.442	11.952	-3,9	3,9
Canning peach	10.676	9.481	-11,2	3,1
Kiwis	10.922	8.866	-18,8	2,9
Pear trees (European and Asian)	6.225	8.781	41,1	2,8
Almond trees	7.617	8.113	6,5	2,6
Green apple tree	7.396	6.895	-6,8	2,2
Orange trees	7.435	6.766	-9	2,2
Lemon trees	7.235	5.911	-18,3	1,9
Nectarine trees	5.376	5.339	-0,7	1,7
Japanese plum trees	6.209	5.326	-14,2	1,7
Peaches to be eaten fresh	3.249	2.015	-38	0,7
Apricot trees	1.469	887	-39,6	0,3
Other fruit trees	25.426	45.706	79,8	14,8
Total	**267.491**	**309.528**	**15,7**	**100,0**

Source: Prepared by ODEPA with information from CIRÉN. 2017.

Table 3. Trade balance of crop-livestock products by sector: Chile and the world (thousands of dollars)

Sector	Jan-Dec 2016	Share (%)
Exports by sector		
Total crop livestock	15.037.317	
Agricultural	9.090.265	60,5
Livestock	1.237.317	8,2
Forestry	4.709.735	31,3
Imports by sector		
Total crop livestock	5.137.768	
Agricultural	3.320.246	64,6
Livestock	1.562.740	30,4
Forestry	254.782	5,0
Trade Balance for products		
Total crop livestock	9.899.549	
Agricultural	5.770.019	58,3
Livestock	-325.423	-3,3
Forestry	4.454.953	45,0

Source: prepared by ODEPA with information from the National Customs Service. Figures subject to review by value variation reports (IVV).

In the case of wine, the situation is somewhat different, since vineyards have traditionally been family-owned, but in the 1980s some of them became open corporations with professional staff. This is the case of vineyards such as Concha y Toro, Santa Rita and San Pedro (Mora, 2017). Maintaining this rate of development with large export figures, opening and consolidating international markets, compliance and adaptation to new requirements, among others, entails moving toward more sustainable agriculture. Particular importance is given to water availability, water and fertilizer efficiency, the relationship between mining and agriculture and agriculture and forestry, projections for the use of natural resources in general and climate change, as well as the search for a harmonious relationship with the land and its people.

5. Perspectives and projections for Chilean agriculture

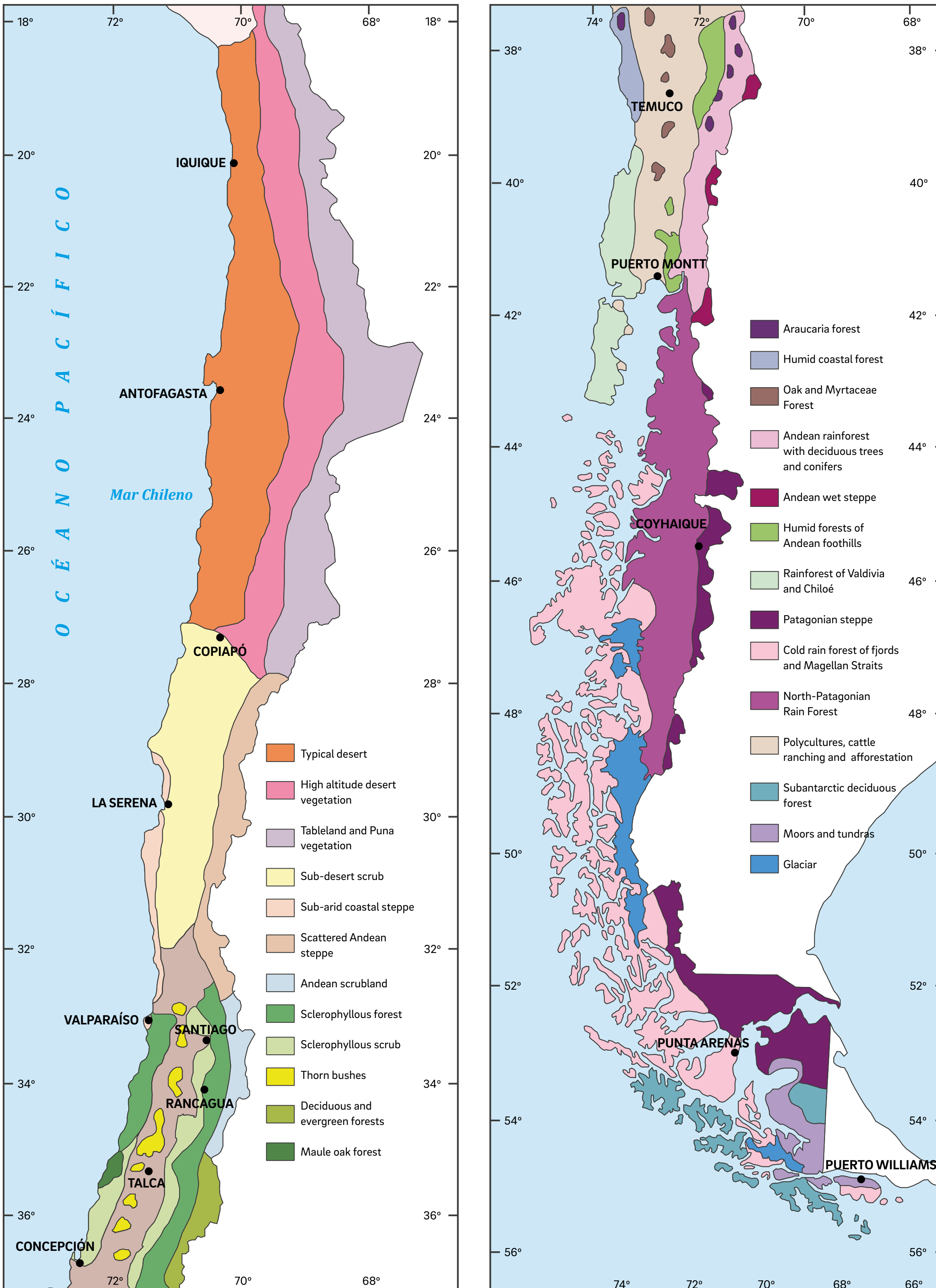
Chile is self-sufficient in exportables (fruit, wines, salmon and other items mentioned earlier). However, the same is not true of products that constitute the basis of its diet, as in the case of wheat and maize, the latter being closely related to pork and chicken productive chains, the main protein sources for feeding the population. As for wheat, the main source of food raw material in Chile, the area under cultivation has declined drastically since 1970, currently standing at approximately 285,000 ha. Although the same period has seen a significant increase in yield, local production is insufficient, meaning that it has been necessary to import this cereal. Soil no longer used for wheat production has been employed in new plantations, including small fruits trees (blueberries), European hazelnuts and other more profitable crops.

In the remaining crops, Chile is relatively self-sufficient, as in the production of vegetables and grain legumes, which are sporadically supplemented with imports, when circumstances so require.

From the point of view of production process management, there are a number of shortcomings regarding the use of productive resources, the mitigation of the negative environmental effects of production, the diversification of production, food safety and, in economic aspects, such as the development of markets, marketing training for producers and the improvement of distribution channels. The latter must be made more transparent and reliable, so that producers can also begin to play a commercial role.

This is an analysis from the point of view of food security under the current conditions of production and trade liberalization. However, this self-sufficiency and sustainability is no longer only conditioned by natural processes, but requires greater technology applied to productive and commercial processes and, above all, in relation to the energy required for the production process. According to Rodríguez et al. (2015), Chile faces an energy paradigm based on fossil-fuel use, which will lead to land-use changes and affect agricultural development. In this relationship between agriculture and climate change, GreenHouse Gas (GHG) emissions are an essential point, since they are derived from modern farming systems. For example, it is possible to highlight them in the use of synthetic fertilizers, land-use change to increase production for a growing population, and methane emissions due to the increased demand for animal protein linked to population growth. The latter also implies a decoupling between production and consumption, which leads to transport and processing activities in which GHG are also generated. Consequently, agriculture should not only consider climate-change adaptation, but also have the potential to contribute to its mitigation. Today and in the future, the relationship between agriculture and climate change must necessarily be linked to other sectors, including the environment, energy and trade. This will involve the creation of new instances of coordination, as well as the building of new professional and academic capacities in the areas mentioned. Consequently, maintaining the sustainability of the Chilean agri-food sector will require expanding the institutional and *ad hoc* public policy to encourage the search for innovative and creative multisectoral solutions, in a multidisciplinary professional and academic context internationally connected through

Map 1. Map of Biogeography of Chile and Vegetation Zones



Source: Educar Chile http://ww2.educarchile.cl/UserFiles/P0001/Image/CR_Imagen/Mapas%20IGM/mapas_chile/biogeografia.gif treaties and trade agreements. On the road to achieving competitive and sustainable agriculture, it is important to recognize the work embodied in the National Plan for Adaptation to Climate Change (Ministry of the Environment, 2015). This plan emphasizes the availability, management, research, innovation and optimization of water use, agroclimatic risks, integrated pest and disease control, genetic improvement and investment in relation to climate- change adaptation and information, among other aspects.

6. Aquaculture in Chile

Aquaculture is the set of activities designed to breed aquatic plant and animal species. In this section, we will focus exclusively on animal aquaculture, with particular reference to salmon farming, which has become a major contributor to Chile's GDP. The SalmonChile Website (HYPERLINK "http://www.salmonchile.cl/es/historia-en-chile.php" \\ l "1921-1974" provides an accurate summary of the history of salmon farming in the country. It notes that the introduction of exotic aquaculture species in Chile occurred in the first half of the last century thanks to the initiative of the Fisheries Development Institute (IFOP), an entity created by the Corporation for the Promotion of Production (CORFO). For over 50 years, it worked on the introduction of technologies for the cultivation of various aquaculture species. In 1974, rainbow trout (*Oncorhynchus mykiss*) began to be farmed for domestic consumption and export, and in 1976 the first Coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tshawytscha*) salmon eggs were imported to the Los Lagos region for purely commercial purposes. In 1978, the state decided that this activity required a certain degree of regulation and created the Under-Secretariat of Fisheries and the National Fisheries Service (SERNAPESCA). In the early 1980s, salmon farming had been established, and by 1985 there were 36 farming centers operating in Chile, with total annual production amounting to more than 1,200 t. Years later an unprecedented boom in the salmon industry began, culminating in the definitive consolidation of the industry and the creation of the Salmon and Trout Producers Association of Chile AG, now SalmonChile. In 1990, national salmon farming ventured into salmon breeding and the first eggs from Coho salmon were obtained in Chile. This milestone is remembered as the first scientific advance in Chile and the starting point for the industry's takeoff. However, July 2007 saw the first case of Infectious Salmon Anemia (ISA), a disease caused by a virus of the *Orthomyxoviridae* family of the genus *Isavirus*. Officially reported in a farm in Chiloé, it affects Atlantic salmon farmed in sea water. This disease created a sectoral crisis that affected the industry's productive process. Like all crises, the process also created opportunities that drove the industry's new productive model. The Chilean salmon aquaculture industry is the now second largest export sector in the country and the world's second largest salmon producer after Norway, creating over 70,000 direct and indirect jobs, with a presence in more than 70 markets.

The Chilean aquaculture development model proved extremely successful. It was based on intensive aquaculture, with significant investments in technology and with great similarities to the development of agriculture, especially livestock production. Aquaculture was identified as one of the most important activities for Chile's economic development and international competitiveness, as a result of which it is now the world's second largest salmon producer. As for the profits obtained, they totaled US $3,526 million in 2015 for 590,101 t. Of these, Atlantic salmon (Salmo salar) accounted for 68%, Coho 21% and rainbow trout 11% (SalmonExpert, 2016).

In other words, aquaculture in Chile followed international guidelines, operating primarily on the basis of introduced species. Mass introductions were carried out in the 19th and early 20th centuries, especially of rainbow trout on all continents with the exception of Antarctica, with almost no considerations for the environment. This species, which is native to the northern hemisphere like other salmonid species, was introduced in virtually all the hydrographic sources capable of maintaining it. In South America, it lives as a naturalized population from the Venezuelan Andes to the southern areas of Argentina and Chile, and is farmed in 50%

of its countries. When this took place, it was considered a great contribution to the aquatic fauna of the geographical areas where it was introduced, due to its beauty and sport-fishing potential. However, very little is known about the ecological damage produced to the diversity of local systems or the number of displaced species, which must have been considerable. Nevertheless, the introduction of salmonids into Chile constituted the basis of its aquaculture development. In their analysis of the status of the conservation of aquatic resources in South America, Neira et al. (1999) report that in Chile over 30 aquatic species have been introduced for their development in fish farms (Infante and Neira, 2002).

Both fishing and aquaculture have an environmental cost. However, an in-depth analysis shows that the threat of aquaculture is far less than that posed by continuing to supply protein demand through fishing in natural marine stocks, owing to increased control over production, harvesting, processing and transport, resulting in less waste and energy expenditure. Fishing for certain species of economic interest affects those that are accidentally caught through by-catch, as in the case of sharks trapped by nets spread to catch swordfish, which seriously affects them because of their low population recovery rate and, more importantly, the so-called trash-fish caught by the increasingly efficient ocean-trawling technologies, which Alverson et al. (1994) estimated at 28.7 million t annually, most of which is simply discarded. In fishing for certain species of shrimp, by-catch often comprises a high percentage of juveniles of other commercially important species.

Aquaculture can not only significantly contribute to global food demands, but also directly contribute to the conservation of aquatic resources and their genetic diversity. To this end, the concept of sustainable use of natural resources must be developed in conjunction with the concept of sustainable aquaculture, in any of its development models rather than in opposition to it. Most of the species used in aquaculture today are very similar to wild populations. In many cases this activity depends on the collection of juveniles or eggs from natural populations. The growth and development of aquaculture is following patterns very similar to that observed in livestock production in recent decades. The development of livestock production, from extensive cattle, sheep, goat and other animals, to intensive cattle production and even the industrial production of poultry, pigs, rabbits and so on, together with their extraordinary contribution to world food, produced a significant reduction of biodiversity and genetic variability. Natural poultry, pig and cattle populations were replaced by a few highly selected breeds, and crosses and synthetic genetic lines with enormous productive efficiency, yet little genetic variability. This occurred mainly because wild populations were used directly. In many cases, they were removed from their natural environment or their natural environments were invaded or severely modified, and they were selected on the basis of human requirements. These mistakes must strenuously be avoided with aquaculture resources and fortunately, there is still time to do so.

7. Nutritional Research

A full summary of the history of nutrition and food research in Chile is presented in the publication *Desarrollo de la nutrición y alimentación en Chile en el siglo XX* (Nutrition and Food Development in Chile in the 20th Century) (Valiente and Uauy, 2002). It reports that in Chile, food has always been considered a human right, which has driven the permanent commitment of the government, the community, professional groups and academics to develop this area. Accordingly, nutrition and food research in Chile began early in the 20th century, under the aegis of a handful of leaders in food and nutrition. These include Drs. Eduardo Cruz-Coke, Jorge Mardones-Restat, Alejandro Lipchutz, Anibal Ariztía, Julio Meneghello, Adalberto Steeger, Arturo Scroggie, Arturo Baeza-Goñi, Herman Schmidt-Hebbel, Francisco Mardones Restat and Fernando Monckeberg, as well as Professor Julio Santa María. They undertook their actions in academic groups comprising various professions, working at the service of the country, especially in favor of the underprivileged and vulnerable, such as children, pregnant women, the elderly, and the poor and marginalized groups. These professionals served at various centers such as the Dietitian School of the University of Chile, founded in 1939; the Nutrition Unit of the Ministry of Health, created in 1952; the Department of Nutrition of the Catholic University, formed in 1956; the Laboratory of Pediatric Research, of the University of Chile, established in 1957 and the Department of Nutrition and Diabetes of the San Juan de Dios Hospital.

These centers have now evolved and been consolidated at the following centers:

The Institute of Nutrition and Food Technology (INTA) of the University of Chile. This is the main center for basic research in nutrition and related sciences, a leader in the area of childhood diarrhea and malnutrition, endocrinology, anemias and micronutrients, and clinical nutrition, with an emphasis on chronic diseases and aging and a long history of studies of the conditioning factors of food, especially its supply, consumption and biological utilization. This Institute gives courses on Nutrition in Pediatrics, Food Surveillance Systems and Food and Nutrition Policies and Programs. In terms of teaching, it offers several Master-degree Programs in Healthy Foods, Clinical Nutrition, Human Nutrition and Aging and Quality of Life. (http://www.inta.uchile.cl).

The Department of Nutrition of the Medicine Faculty of the University of Chile. This department undertakes research related to the science of nutrition and food, creating methodologies in the fields of public health and clinical nutrition, and performs nutritional interventions and advances in the areas of metabolism, biochemistry, cell biology and molecular biology. It contributes to the training of undergraduate students in medicine, nutrition and dietetics, dentistry, nursing and medical technology. At the graduate level, it participates in the Master-degree Programs in Human Nutrition and the Doctoral-degree Program in Nutrition and Food, and Public Health (http://www.medicina.uchile.cl/facultad/campus-y-departamentos/campus-norte/112599/nutricion).

The Department of Nutrition and Dietetics of the San Juan de Dios Hospital. It has pioneered the study, teaching and control of diabetes mellitus. It also has a Food Education Center and provides individualized dietary therapy to patients referred from the outpatient and hospital rooms requiring special diets and enteral formulas (http://biblioteca.usac.edu.gt/tesis/06/06_3057.pdf).

The Department of Nutrition, Diabetes and Metabolism of the Catholic University. It studies problems such as obesity, diabetes mellitus and dyslipidemias, integrating human genetics, metabolic studies, clinical practice and public health. The department is the pillar of nutrition at the Catholic University, participating in teaching at the undergraduate level in Medicine and other degree programs, as well as postgraduate teaching in the area of (http://medicina.uc.cl/nutricion/).

The Nutrition and Food Department of the Ministry of Health. This department seeks to protect the population's health, by promoting healthy eating habits and ensuring the consumption of safe food of good nutritional quality. To this end, it develops regulations and programs to control the factors, elements or agents present in food, which pose a risk to the health of consumers and/or which may have a major influence on the morbidity and mortality profile (http://www.minsal.cl/alimentos-y-nutricion/).

The Department of Food and Nutrition of the Institute of Public Health. This is the country's main food laboratory. It undertakes epidemiological-surveillance activities, performing chemical, microbiological, parasitological, toxicological and other analyses in food matrices. It has two sections: Food and Nutrition Chemistry, and Microbiology of Food and Water. The former has laboratories on nutrients, additives, contaminants, bio toxins, pesticide residues, residues of veterinary drugs, dioxins and gluten (http://www.ispch.cl/saludambiental/alimentos_nutricion/).

In addition to the aforementioned working groups, Chile has professional organizations that focus on nutritional matters, such as the College of University Nutritionists of Chile AG (http://www.

nutricionistasdechile.com). There is also the Chilean Nutrition Society (& fA) (https://www.sochinut.cl), which publishes the Revista Chilena de Nutrición (http://revistasochinut.org).

In addition to these organizations, in 2005, the Government of Chile created a Presidential Advisory Commission called the Chilean Agency for Food Safety (ACHIPIA), tasked with reviewing the institutions that control, inspect and inspect food in Chile and proposing a National Food Safety Policy (http://www.achipia.cl).

Last, it should be noted that several universities provide degree programs related to nutrition, at both the professional and technical level. Universities offering ten semester courses include the University of Chile and the Catholic University of Chile, together with several other regional universities that also supply these programs such as the University of Valparaiso, University of Talca, University of Tarapacá and the University of Magallanes, which offer degree courses in Nutrition and Dietetics, while the University of Los Lagos provides a Nutrition and Food program.

8. Agricultural research

According to Elgueta (1982), agricultural research began in Chile in the 19th century, when the National Agricultural Society (SNA) - a private trade organization created in 1838 - realized that agricultural education and research were essential for agricultural development. Thus, in 1851, the Practical Agricultural School was created to train agricultural workers in "modern" agricultural techniques. Subsequently, in 1869, the country's first Agricultural Experimental Station was created, in an area adjacent to the city of Santiago that became known as the Agricultural Training College Farm. Later on, in 1872, within the Training College Farm, the SNA created the Agricultural Institute, where the first agricultural professionals were trained (Agronomists and Agricultural Engineers), for which teachers trained in France were brought over. In 1881, three hectares of the Training College Farm were specifically set aside for testing varieties, which marked the beginning of genetic improvement in Chile. In 1915, the Agricultural Institute was renamed the Agronomic Institute. In 1927, it was transformed into the Faculty of Agronomy and Veterinary Medicine, and in 1928, it was incorporated into the University of Chile.

At the same time, in 1924, the Ministry of Agriculture, Industry and Colonization was created, which was granted development faculties in 1927. Two years later, the Department of Genetics and Agronomy was created, and subsequently renamed the Department of Genetics and Plant Science. This department also launched breeding programs, performing variety assessments, especially on wheat and other cereals, and fodder species. These evaluations were undertaken at various experimental stations created throughout the country. In the mid-1950s, the Department of Genetics and Phytotechnology was transformed into the Department of Agricultural Research, which in 1964 became a private, publicly funded organization called the Institute of Agricultural Research (INIA). To this day, it is responsible for conducting agricultural research for the Ministry of Agriculture.

INIA was created by the Institute of Agricultural Development, the Corporation of Production Promotion, the University of Chile, the Pontifical Catholic University of Chile and the University of Concepción. It has national coverage and ten Regional Research Centers. Its main capital comprises approximately 200 plant researchers and it is financed by public and private funds, research projects and the sale of technological inputs. Its mission is to generate and transfer strategic knowledge and technologies on a global scale to produce innovation and improve the competitiveness of the Chilean agri-food sector. It aims to become a leading institution in the generation and transfer of sustainable knowledge and technologies for agro-food innovation.

By the beginning of the last century, other universities joined the teaching and research effort of SNA and the University of Chile. In 1904, the Catholic University of Chile created the degree course in agronomy. Over time, other universities began to offer degree courses in agronomy and set up experimental stations to support teaching. This is how the agronomy degree program came into being at the University of Concepción (1954), The Austral University of Chile (1954), Tarapacá University (1963), the Catholic University of Valparaíso (1963), the University of Talca and the University of La Frontera (1982).

Since its inception, agricultural research was designed to guarantee the country's food security, understood as guaranteeing food for the population, since from the time of Independence, this was regarded as a fundamental task for sustaining the future of the nation. That era was characterized by the predominance of the agricultural sector in the country's economy. It was not until the late 20th century that research emphasized agricultural exports.

As in the rest of the world, breeding programs were primarily responsible for the sustained increases in the yields of the main food crops. They were created with food security in mind and following the CGIAR (Consultative Group on International Agricultural Research) global model, culminating in the Green Revolution, which permitted an exponential increase in yields, but also involved the overuse of inputs such as water, fertilizers and pesticides. It was not until the late 20th century that a concern for genetic improvement arose, not only for the benefit of farmers, but also of consumers (food quality), and the issue of sustainability came to the fore.

At the same time, the National Commission of Science and Technology (CONICYT) created several regional centers linking agronomic and nutritional objectives on the basis of preexisting regional capacities (http://www.conicyt.cl/regional/category/centros-regionales/centro-regional/).This is how the Regional Center for Healthy Food Studies (CREAS) was created, in the Valparaíso Region, together with the Center for Advanced Studies in Fruticulture (CEAF) in the O'Higgins Region; the Center for Studies in Processed Foods (CEAP) in the Maule Region; and the Center for Agronomic Nutritional Genomics (CGNA) in the Araucanía Region. In 2016, CORFO financed the first center for food innovation as part of a consortium with several Chilean universities.

Chile also has several associations for the dissemination of agronomic advances, such as the Academy of Agronomic Sciences (http://www.academiaagronomica.cl), the College of Agricultural Engineers (http://www.ingenierosagronomos.cl), the Agronomic Society (http://www.sach.cl) and the College of Engineers in Natural Resources (http://www.cirn.cl). All these institutions significantly contribute to the political and social support of the advances in sustainable agriculture that will be developed in the country.

9. Aquaculture research

Although Chilean aquaculture began with the introduction of exotic species, the second half of the 19th century saw the introduction of the golden carp (*Carassius auratus*) in 1856, the common carp (*Cyprinus carpio*) in 1878 and the European common trout in 1883. At the beginning of the 20th century, one of the major milestones was the construction of the Rio Blanco Pisciculture in 1902, where the first rainbow-trout embryos (*Oncorhynchus mykiss*) were improved in 1905. Subsequently, in 1914, the fish farm of Lautaro was built on the banks of the Cautín River in the Araucanía Region to farm trout in southern Chile. This was followed by a second phase characterized by the creation of mollusk farming centers (*oyster farming*), with the construction of the Quetalmahue Oyster Farm in 1930; "Ranching" initiatives designed to create commercial fisheries, based on the introduction of salmonids and the drawing up of central aquaculture-development plans (oyster, mussel and fish farms), when the Quellón Mussel Farm was built in 1943. Institutions were also created to research aquaculture. The Institute for Fisheries Development (IFOP) was founded in 1964. During this period, a concerted effort was made to create human capacities associated with the aquaculture sector and fisheries, through the creation of courses such as Marine Biology, Oceanography and Fisheries Engineering, including the groundbreaking creation of the Aquaculture Engineering degree major at the University of Chile in 1976.

The most significant change, however, took place in the 1980s, which was already preceded by the start of the northern oyster cultivation (*Argopecten purpuratus*) in 1974 and the giant mussel (*Choromytilus chorus*) farmed since 1978. This marked the beginning of *Glacilaria*, chorites (*Mytilus chilensis*), Chilean oyster (*Ostrea chilensis*), abalone (*Haliotis* spp.) and Turbot (*Scophthalmus maximus*) farming, but above all the salmon industry with three species: Pacific salmon or Coho (*Oncorhynchus kisutch*); Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*). The University of Chile played a key role initiating the first Genetic Improvement Program for Coho Salmon in 1992 and the first Genetic Improvement Program for Northern Scallop, both in collaboration with the Institute of Fisheries Promotion, and implemented the first Associate postgraduate programs, such as the Master in Aquaculture in 1996 and the first Doctorate in Aquaculture in 2004, the latter in conjunction with the Catholic Universities of the North (UCN) and Catholic University of Valparaíso (UCV). These were joined by the Master in Aquatic Resource Management of the UCV, the Master in Aquaculture of the UCN, and those of the Catholic University of Temuco and the University of Santo Tomás. These activities helped launch high-quality research in the country to support the aquaculture industry.

In Chile there are several research institutes associated with aquaculture, both public and private. State institutes include the Instituto de Fomento Pesquero (www.ifop.cl) with national presence, Fundación Chile (www.fundch.cl), also located throughout the country, albeit on a smaller scale, in the Chinquihue Station (http://www.fundacionchinquihue.cl/web/), located in the Los Lagos Region, and with the Catholic University of the North, the Aquapacífico Center (http://fch.cl/aquapacifico) in Tongoy. Those in the private sector include Aquainnovo (http://www.aquainnovo.com), the Salmon Technological Institute (INTESAL) –answerable to the Salmon and Trout Producers Association (http://www.intesal.cl/es/)- and the Science for Life Foundation (http://www.cienciavida.org) among others.

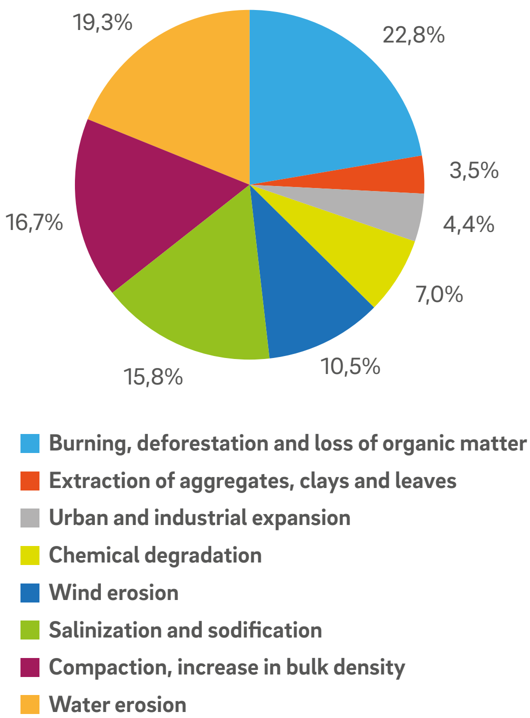
10. The soil resource

Soil is one of the pillars of Chile's agricultural development. Chile's agricultural soils are located in various climates that enable the growth of a broad variety of crops such as cereals, oilseeds, grain legumes, forage crops, and horticultural, fruit, ornamental and industrial crops such as sugar beet.

An interesting dimension to analyze is the relationship between agricultural and urban land. In this regard, Rivas and Traub (2013) point out that it is necessary to recall that underlying the agricultural and forestry sector there are a series of economic activities that provide a social, economic and cultural matrix that lend identity and cohesion to the non-urban area of Chile. In this respect, in order to become a global agri-food power, the development of the agri-food sector must have a normative framework that guarantees certain minimal conditions for the economic, social and environmental development of the sector that will ensure the sustainability and availability of natural and productive resources. At the same time, Chilean soils have also been widely used for forestry purposes, displacing agricultural activity in certain areas, which has had a significant impact on agricultural activity. This is the case of monocultures of Monterey pine (Pinus radiata) and eucalyptus (Eucalyptus globulus), both used for both wood and cellulose pulp. The exponential growth of the forestry industry occurred as a result of the Forest Development Law (Decree No. 701), which allowed state subsidies of up to 75% of the total cost of afforestation for forestry companies and which now enables the forest sector to contribute 2.7% to Chile's GDP.

Chile's agricultural production tends to be heavily dependent on natural resources particularly on the soil resource, which has undergone varying degrees of degradation, with water erosion the main cause of this deterioration (**Figure 1**). This has had a major impact on the reduction of productive potential. This must be considered for future agro-food policies, not only to boost production but also to encourage its conservation.

Figure 1. Various degrees of soil degradation in Chile



11. Energy resources

With regard to energy resources, most of the Chilean agricultural sector uses energy from fossil fuels with high carbon emissions, like other Latin-American countries. The success of agricultural firms is closely linked to energy demand and use for their productive processes. Therefore, having efficient, constant energy supply systems is key to agricultural development. The energy costs of agricultural production processes, such as irrigation, milking, frost-control mechanisms and various agroindustrial processes, are important factors in companies' costs. Due to the above, the sector is seeking solutions to reduce these, especially through energy efficiency and the use of techniques based on Non-Conventional Renewable Energy (NCRE). These techniques have had an enormous impact on certain activities. Solar and wind energy also allow the surplus to be exported to the national electricity grid, based on Law 20,698, which favors the generation and use of NCRE. However, these efforts are not sufficient due to the high amounts of energy consumed by agriculture. In fact, Chile is making a significant effort to have a resilient system linked to energy consumption by sector and subsector. At present, only macrofigures are available for the agricultural sector (**Figure 2**), where a total consumption of 63,700 GWh/year is estimated. Of this total, less than 2% is used in irrigation for a cost equivalent to more than 200 MM USD/year.

In a context where the global trend is to reduce carbon emissions and generate low GHG emissions, it is essential to propose an agricultural production policy with low energy requirements and negative environmental effects. This requires focusing efforts on contributing to climate change rather than a strategy focused on adaptation to climate change, in order to reduce carbon emissions, which on average are estimated at 10 Pg C/yr (Houghton et al. 2012). That is why, in order to develop sustainable agriculture, it is necessary to consider a diversification of energy sources, generating energy self-consumption propitiated by the current laws to encourage the use of NCER.

12. Water resources and climate change

A review of 58 studies related to climate change and 47 focused on water security and climate change shows that the impacts of climate change on the availability of water resources in Chile will be reflected in both a rise in average environmental temperature and a decrease in annual rates of mean precipitation (Fuster et al., 2017). As an example, studies show that for the 2010-2015 period, the Central Chile zone experienced a precipitation deficit of 21% with respect to the 1990-1999 decade. This was known as a "mega-drought", in which a quarter of the deficit experienced was attributed to climate change of anthropic origin (Boisier et al., 2016). This deficit generated a marked decrease in the water supply expressed in the reduction of water flows and water-storage reservoir levels (Bravo et al., 2014).

Regarding climate-change projections in the country, an increase in temperatures was calculated throughout the national territory for the p2031-2050 period with respect to the 1961-1990 period, with a gradient from highest to lowest from North to South and from mountain range to ocean, with values ranging from 0.5°C (Magallanes) to 2.5°C (Altiplano). At the same time, the tendencies projected by the same author indicate a decrease in precipitation in the Central-South zone of between 10 and 15% for the 2031-2050 period, consistent with most of the models applied. A downward trend in precipitation was considered for the North, although this projection is not robust. Finally, in the South, a 5% decrease in rainfall is expected for Patagonia, whereas for Magallanes, rainfall will increase by 5%.

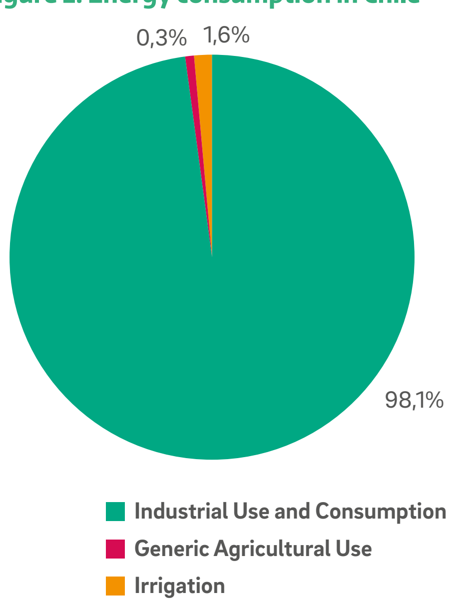
Other effects of reduced precipitation are evident in glaciers, which in general, throughout much of mainland Chile and South America, have experienced major shrinkage and losses of volume, directly impacting the dynamics of rivers and lakes (Durán-Alarcón et al. 2015). These impacts have been described in the Central zone with evidence of increases in flow rates in the melting season in watersheds that have experienced a marked decrease in ice cover. In the southern part of the country, glacial retreat has been accompanied by the sudden emptying of subglacial lakes, which have created sharp increases in flow (Dirección General de Aguas, 2012), whereas in Patagonia it has been estimated that between 2003 and 2011, glaciers reduced their mass at a rate of 29 ± 10 Gt per year.

From the perspective of climate change, potential impacts on the components of the cryosphere - whether glaciers, snow or permafrost - predict that changes in temperature and precipitation levels could alter normal snow accumulation and melting patterns. However, impacts on ecosystems dependent on these bodies of water have not been quantified to date. Although the evidence indicates that most of Chile's glaciers are experiencing a systematic regression, the lack of knowledge about the effect that climate change will have on its evolution makes it impossible to project these trends in a prediction model. Likewise, a shortage of information on the dynamics of permafrost and rock glaciers makes it impossible to infer their future behavior in response to a change in climate.

But not only would the availability of water resources be affected by climate change: there is ample scientific evidence indicating that the main climate forcants that modulate both the interannual variations of precipitation and the frequency and intensity of extreme hydrometeorological phenomena in Chile are affected by climate change. Boisier et al. (2016) have projected that the effect of climate change on climate forcing will have a direct impact on the frequency and intensity of extreme events such as droughts and floods. Therefore, under the RCP 8.5 emission scenario, for example, a significant increase in the period of recurrence of drought events with a duration of three years or more in Central Chile is projected for the 2050-2100 period, in relation to the 1950-2000 period.

Last, projected changes in climate under different scenarios are expected to have a direct effect on both the quantity and the timing of the flows of the countr's basins, which together

Figure 2. Energy consumption in Chile



with the expected impacts on the various components of the cryosphere, will condition the availability of water resources to meet human and ecosystem needs.

Nevertheless, it is important to point out that the analysis of the availability of water resources in a context of climate change must consider at least the physical availability determined by climatic patterns and the legal availability established by Water Use Rights (DAA). Although the latter is a legal aspect, it contributes to intensifying the effects of climate change: since the potential consumption of water does not decrease on the basis of physical availability; water systems will therefore be increasingly under pressure. Thus, water security due to climate change will be potentially affected mainly by: (I) the decrease in the physical availability of the resource; (ii) the increase in the frequency of extreme events, and (iii) the rise in turbidity and pollution, resulting from the increase in the frequency of extreme events, which affects water quality.

13. Food losses

All agricultural activity involving the production, handling, transport and exhibition-for-sale of a fresh agricultural product is affected by a reduction of the initial volume. This loss, whatever its origin, ultimately leads to a loss for the producer, who owns the product until it is sold. This loss, which is irreparable, translates into a reduction of the general availability of food, in addition to an expenditure of energy consumed in producing something that will not achieve its intended purpose.

FAO began work on food loss in the 1980s, earmarking $10 million for this purpose. Since then, many other institutions have gradually been incorporated, mainly from the governments of countries in the Northern Hemisphere, complementing and providing critical information on food losses. FAO saw the need to propose a scheme to classify information, depending on the form and timing of losses. Thus it determined the differences between what it called "losses" and "waste". Losses occur during harvesting and throughout the postharvest process and handling of a product that does not reach the consumer. Conversely, waste is the loss of food that takes place after it is acquired by the consumer, which includes value-aggregation processes (local and industrial processing). Generally speaking, in developing countries, the ratio is 60% losses and 40% waste, whereas in developed countries, the reverse is true.

Globally, a loss of 1.3 billion t of food per year is estimated. In Chile, there is very little research on food losses and on the causes of the waste and the volumes they entail. Most of the available information is estimates made on the basis of projections using a few local indices. This is the case of the fruit industry, where Chile produces 5 million t of fruit, 2.4 of which are for domestic consumption. If 10% of this were lost, we would be talking about 240,000 t. A study by the Center for PostHarvest Studies (CEPOC) of the Faculty of Agronomic Sciences of the University of Chile determined the causes of losses during the selection and packaging process for export. In the case of table grapes; it was determined that deficiencies in pruning bunches, excessive weeding and small grapes or those damaged by thrips were the main causes of discarding. These determinations served to improve the agronomic practices of clustering, the application of agrochemicals and the thinning of berries, which allowed a substantial increase in the percentage of exportable fruit. Currently, the quality-control work in the selection, packaging and packaging rooms of fruits have made it possible to maintain an acceptable level of quality in fruit exports. However, reports on insufficient condition and quality are continuously received from remote export markets. As an example, cranberry in destination markets may display quality and condition problems such as soft, dehydrated and bruised fruits, which is solved by harvesting at low temperatures (22%), using MAP bags (28%), applying postharvest CPPU (15%) and harvesting when the fruit is totally blue (5%).

The main study on losses in products commercialized for the domestic market in free fairs/farmers' markets and supermarkets was conducted by Boitano (2011). The weekly declines of fresh products at the Free Trade Shows of the Metropolitan Region of Santiago reached a total of 2,391 t, equivalent to 19% of the total. Of these, 1,745 t (22%) were vegetables, 496 (18%) fruits and 150 (7%), potatoes. Some products have more significant losses. This is the case of lettuce, of which 144,060 t are produced and 11,530 t are lost, which amounts to 40% (11,530 t), representing a loss of US $2,128/ha. At the end of 2009, an initiative was implemented to take advantage of products considered non-tradable, but in good condition, which are delivered to non-profit institutions, and farmers can treat them as waste food in their tax declarations. The organization's activities have expanded and it reports that as of December 2016, 16.2 t of food have been recovered, equivalent to more than 46,000 food rations delivered to 187 solidarity organizations that have reached almost 140,000 vulnerable people.

14. Nutrition and food policy

Currently in Chile, the prevalence of overweight and obesity in children and adults reaches figures that rank Chileh among the top countries in the Organization for Economic Cooperation and Development (OECD) with more than 10% obesity in children under the age of 6, over 25% in elementary students and over 60% with overweight among those over 15. The prevalence of other Non-Communicable Diseases (NCD) is also very high in this population, with more than 30% of people with hypertension, about 40% with dyslipidemia and more than 10% of people with type 2 diabetes *mellitus*. Prevention of these diseases is closely linked to lifestyle, particularly diet. In this respect, the 2010 National Food Consumption Survey shows that 95% of the Chilean population requires changes in their diet and does not comply with healthy eating recommendations.

The strategies Chile is implementing are based on the approach of health, social determinants of health and food environments. This policy addresses the sociodemographic, cultural and economic factors in which people live, including availability and access to healthy food, eating habits and culture, food marketing and advertising, school and work environment, and information available on food (nutrition labeling), among the most relevant factors. Modifying food environments requires structural government policies, and legislative, regulatory and fiscal policies such as taxes and subsidies. Chile, adopting the recommendations of international experts and based on available scientific evidence (OECD, DELSA/HEA, 2010), has implemented Law 20,606 on the nutritional composition of food and its advertising. Likewise, taxes on sugary drinks were increased, the strategy of promotion and social participation was reformulated, and Law 20.860 on food advertising was implemented. Finally, multidisciplinary programs have been implemented to treat people with malnutrition due to excess in Primary Health Care (PHC), based on healthy living counseling.

Recently, Chile has implemented several measures as basic policies for a healthier life:

- Law 20606 on the nutritional composition of food and its advertising: This Law came into force in June 2016, with the purpose of protecting the population's health, especially that of children, by incorporating a regulatory framework that (i) provides clearer and more comprehensible information to consumers through clear warnings stating "HIGH IN" sodium, sugars, saturated fats and calories; (ii) forbids advertising directed at children under 14 years of age of "HIGH IN" food, and (iii) it prohibits the sale, gift and promotion of "HIGH IN" foods in pre-basic, elementary and middle-school educational establishments. Thus, healthy choices are encouraged through more information, ensuring healthy supplies in schools and reducing the incentive to purchase less-healthy foods. The implementation of this Law involved a mass media campaign for 6 months before its entry into force and after its passage, in order to deliver the positive

message of preferring fresh, natural foods, homemade culinary preparations and making the population aware of the new "HIGH IN" stamps to encourage them to choose foods with fewer stamps or without them.
- Increased taxes on sweetened beverages: As a fiscal tax measure, the Tax Reform Act of 2014 incorporated a corrective tax on sugary non-alcoholic beverages, modifying the tax rate of these products according to their sugar content. Thus the tax on products that did not exceed the established sugar content limit was reduced by 10% and increased by 18% when it exceeded it. The maximal limit was 6.25 g of sugars per 100 ml of product.
- Reformulation of the promotion and social participation strategy: The new Healthy Municipality, Communes and Communities strategy is designed to strengthen the role of the country's regions in bringing about changes in community environments that encourage a healthy lifestyle. With regard to the issue of healthy eating, municipalities are urged to program interventions such as municipal ordinances prohibiting the sale of "HIGH ENERGY" foods in the vicinity of schools and health centers, complementing Law 20,606; new points for free fairs/ farmers' markets; social mobilization events in favor of a healthy life; citizen dialogues and intersectoral health forums around healthy eating; and schools for social managers and leaders that would enable them to continue local actions to improve food environments.
- Law 20,860 on food advertising: This Act supplements Law 20,606 by increasing advertising restrictions, so that all advertising of "HIGH IN" foods on cinema and television during daytime hours (6:00 a.m.-11 p.m.) is prohibited. This Law also prohibits the advertising of "breast milk substitute" foods.
- Healthy Living Program in PHC for people with malnutrition due to excess: This program is aimed at the population over 2 which is overweight, obese or has other risk factors. There is a doctor, nutritionist, psychologist and physical education instructor, who apply a series of protocolized individual and group activities in order to modify food and sedentary behavior and decrease risk factors among the population attended. This program is run in over 80% of the country's primary health centers.

The impact of all these measures on the population's health must be evaluated in the long term. For the time being, and after the first few months of its implementation, there are tentative findings regarding the attitudes and perceptions of consumers on the main axes of action of the new labeling and advertising regulation. Studies undertaken by several academic institutions and market-research centers agree that the population evaluates the measures implemented positively and approximately 40% declare that they are willing to make changes in their food-purchasing habits. In a study commissioned by the Ministry of Health, the results show that 43% of the population compares the stamped food labels at the time of purchase and that they influence their decisions in more than 91% of cases. Moreover, 94% of the respondents approve of the obligation to label food as "HIGH IN".

Another relevant effect as a result of the regulation is related to the technological modifications implemented by the food industry, to decrease the concentration of critical nutrients such as sugars, sodium and saturated fats, as well as energy. According to an official report by the Chilean food industry, in approximately 18% of the foods that participated in the study, adaptations were made in their formulation to improve their nutritional composition. The findings reported so far are positive regarding their immediate effect and promising in the long term. These may be the first achievements resulting from the modification of the food environment. The challenge is to give continuity to these policies, strengthen them and evaluate the change in eating habits and the prevalence of obesity and other NCD.

Valiente and Uauy (2002) argue that the Chilean case proves that it is possible to improve health and nutrition in the absence of substantial progress in economic terms, despite the persistence of certain vulnerable groups which, although they are able to afford food, do not have access to a quality diet, and also display inequalities in access to health, resulting in quality-of-life indices below the national level.

On the other hand, there is a very significant group of adults suffering from diseases related to overeating and poor dietary composition. In this regard, Masi and Atalah (2008) report that people older than 70 represent 4.4% of the national population, a percentage that will almost double (8.2%) by 2025. Moreover, they add that the financial constraints of many senior citizens, together with the psychological, sensory and metabolic alterations that occur at this age, mean that a significant fraction of them receive poor nutrition. As a way of addressing this problem, Masi and Atalah (2008) report the existence in Chile of two programs targeting this group of persons: One is the "Complementary Feeding Program for the Elderly" (PACAM) and the other the "Golden Years Milk Drink" (BLAD), which have had effects in the short term, although their long-term impact is still being studied.

15. Final Conclusions

Chile has a solid institutional, political, scientific and technical base, which would enable it to be at the forefront of sustainable agriculture and healthy nutrition. Chile's performance in the face of challenges in agriculture and nutrition continues to meet the highest international standards and allows us to address enormous challenges due to its solid institutions that have created various lines of development. Looking ahead, Chilean agriculture is expected to be able to consolidate its production systems to meet to the new domestic and international agri-food demands. These emphasize products derived from modern, innovative agriculture that guide their development, prioritizing the sustainability of the natural resources used in their production and the food requirements of a society that increasingly demands products that will make it possible to adopt a healthy diet.

References

Alverson, D.L.; Freeberg, M.H.; Pope, J.G.; Murawski, S.A. (1994). A global assessment of fisheries by catch and discards. FAO Fisheries Technical Paper N° 339, Roma: FAO.

Araya L, Héctor; Atalah S, Eduardo; Benavides M, Xenia; Boj J, Teresa; Cruchet M, Sylvia; Ilabaca M, Juan; Jiménez de la Jara, Jorge; Mardones S, Francisco; Muñoz P, Fernando; Pizarro Q, Tito; Rodríguez O, Lorena, & Rozowsky N, Jaime (2006). Prioridades de intervención en alimentación y nutrición en Chile. *Revista chilena de nutrición*, 33(3), 458-463. https://dx.doi.org/10.4067/S0717-75182006000500001

Boisier, J., Rondanelli, R., Garreaud, R. and Muñoz, F. (2016). Anthropogenic and natural contributions to the Southeast Pacific precipitation decline and recent megadrought in central Chile. *Geophysical Research Letters*, 43(1), pp. 413-421. DOI: 10.1002/2015GL067265

Boitano, L.A. (2011). *Análisis de la cadena de distribución en la comercialización de productos frescos en Chile: frutas y hortalizas.* Memoria de Título. Ing. Civil Industrial. Facultad Ciencias Físicas y Matemáticas, Universidad de Chile.

Bravo, M., Flores, R., Galindo, R., Garreaud, R., Muñoz, E., Serey, A. y Viale, M. (2014). Determinación de posibles impactos en la gestión de los abastecimientos humanos de agua situados en la zona metropolitana de Chile, provocados por fenómenos asociados al cambio climático. *Aquae Papers*, 5, 6-29. http://dgf.uchile.cl/rene/PUBS/AquaePapers5es.pdf

Dirección General de Aguas, Ministerio de Obras Públicas (2012). Variaciones recientes de glaciares en respuesta al cambio climático: Características glaciológicas de los glaciares San Rafael, Nef y Colonia, campo de hielo norte. Series de Informes Técnicos (SIT) N° 302. http://documentos.dga.cl/GLA5500.pdf

Durán-Alarcón, C.; Gevaertb, C.M.; Mattar, C.; Jiménez-Muñoz, J.C.; Pasapera-Gonzales J.P.; Sobrino J.A.; Silvia-Vidald, Y.; Fashé-Raymundo, O.; Chavez-Espiritu, C.W.; Santillan-Portilla, N. (2015). Recent trends on glacier area retreat over the group of nevados Caullaraju-Pastoruri (Cordillera Blanca, Perú) using landsat imagery. *Journal of South American Earth Sciences*, 59, 19-26. https://doi.org/10.1016/j.jsames.2015.01.006

Elgueta, M. (1982). La investigación agrícola en Chile: Evolución histórica. en: Elgueta, M. y E. Venezian (eds). *Economía y organización de la investigación agropecuaria.* Talleres Gráficos INIA, Santiago, Chile. pp 109-141

Fuster, R., K. Astorga, C. Escobar, K. Silva y R. Urbina (2017). *Estudio de seguridad hídrica en Chile en un contexto de cambio climático para elaboración del plan de adaptación de los recursos hídricos al cambio climático.* Informe Final. Santiago Chile. 129 pp. In press.

Guerrero A. y Opitz R. (2017). *Inserción de la agricultura en los mercados internacionales.* Oficina de Estudios y Políticas Agrarias. 115 pp.

Houghton, R. A., House, J. I., Pongratz, J., van der Werf, G. R., DeFries, R. S., Hansen, M. C., Le Quéré, C., and Ramankutty, N. (2012). Carbon emissions from land use and land-cover change. *Biogeosciences*, 9, 5125–5142. DOI:10.5194/bg-9-5125-2012.

Infante, R. y Neira, R. (2002). Diagnóstico del sector acuicultor en Chile. *Prospectiva Chile 2010: 4. La Industria de la Acuicultura.* MINECON. pp. 59-78.

Masi, Celia & Atalah, Eduardo (2008). Análisis de la aceptabilidad, consumo y aporte nutricional del programa alimentario del adulto mayor. *Revista médica de Chile*, 136(4), 415-422. https://dx.doi.org/10.4067/S0034-98872008000400001

Ministerio de Agricultura de Chile, Ministerio de Medio Ambiente de Chile (2013). *Plan de Adaptación al cambio climático del Sector silvo-*

agropecuario. Propuesta Ministerial elaborada en el marco del Plan de Acción Nacional de Cambio Climático 2008-2012, 63 p.

Ministerio del Medio Ambiente, Gobierno de Chile (2015). *Plan Nacional de Adaptación al Cambio Climático.* Santiago de Chile, agosto de 2015, Imprenta Maval. 80pp. http://portal.mma.gob.cl/wp-content/uploads/2016/02/Plan-Nacional-Adaptacion-Cambio-Climatico-version-final.pdf

Mora, M. (2017). *Structural features of the wine sector in Chile.* In press.

Neira, R.; Bustos, E. & Avila, M. (1999). National and regional perspectives on aquatic genetic resources in Latin America. In: R.S.V. Pullin, D.M. Bartley y J. Kooiman (eds.), *Towards Policies for conservation and sustainable use of aquatic genetic resources.* ICLARM Conf. Proc. 59:59 pp.

Oficina de Estudios y Políticas Agrarias (ODEPA) (2015). *Panorama de la agricultura chilena*. Oficina de Estudios y Políticas Agrarias, Ministerio de Agricultura de Chile. 138 pp.

Rivas T. y Traub, A. (2013). *Expansión urbana, cambio de uso del suelo, pérdida del patrimonio agropecuario, recursos públicos*. Oficina de Políticas Agrarias, Ministerio de Agricultura, 6 pp. http://www.odepa.cl/wp-content/files_mf/1387811651expansionUrbana.pdf

Rodríguez, A., López, T., Meza, L. & Loboguerrero, A. (2015). *Innovaciones institucionales y en políticas sobre agricultura y cambio climático*. *Evidencia en América Latina y el Caribe.* CEPAL. 133 pp.

SalmonExpert (2016). Resultados 2015 y proyecciones 2016. Magazine articles. Publicado el 25/03/16. https://goo.gl/P5HoaM

Valiente B., Sergio & Uauy D., Ricardo. (2002). Evolución de la nutrición y alimentación en Chile en el siglo XX. *Revista chilena de nutrición*, 29(1), 54-61. https://dx.doi.org/10.4067/S0717-75182002000100008

Food and Nutrition Security in Colombia

Popular market in the Department of Huila, Colombia. Photography of Neil Palmer

Colombia

[1] Elizabeth Hodson de Jaramillo
[2] Jairo Castaño
[3] Germán Poveda
[4] Gabriel Roldán
[5] Paul Chavarriaga

Its abundance of agricultural and natural resources, water, biodiversity and human talent means that **Colombia has the potential to supply food for humanity, as long as it preserves its ecosystems.**

Summary

As a result of its position and physiography, Colombia has an enormous diversity of climate zones, together with abundant agricultural and fresh water resources, an exceptional biodiversity and a wealth of natural resources. Its agriculture is characterized by technified monocultures by region (such as sugar cane, coffee, flowers, cotton, banana, banana, sorghum, maize, rice, African palm, potato and cassava). There are crops for domestic consumption, while high-value crops such as coffee, sugar cane and African palm are exported. Agriculture in Colombia will be seriously affected by climate change, both in terms of food security and agricultural socioeconomics.

In relation to food and nutritional security (SAN), Colombia ranks 10th in the Food Sustainability Index and the ninth in sustainable agriculture (2016 Food Sustainability Index), and although the percentages of malnutrition have decreased, they still persist in low-income as well as indigenous populations. A total of 12,5% of the population is undernourished. The country reflects the nutritional transition of its population, and has problems of both underweight and overweight in all the population groups.

Climate change mitigation and adaptation activities have been undertaken to address the challenges of sustainable agricultural production. Despite the current budget reduction for Science and Technology, colombian scientific and technological capacities are solid, with a long history, and there have been developments in alternative solutions to boost agricultural productivity in the diverse farming systems with territorial considerations. The aim is to boost the agricultural supply to guarantee food security and promote agricultural exports and farmers' welfare. The many initiatives implemented include: The Colombia Plants Strategy; the Mission for the Transformation of the Colombian Countryside and the Green Growth strategy.

I. National characteristics

Colombia is located in the NW region of South America (**Figure 1**), with an area of 2.129.748 km², 1.141.748 km² of which correspond to its continental territory and 988.000 km² to its maritime area. Of the latter, 658.000 km² are located in the the Caribbean Sea, and 330.000 km² in the Pacific. It is the fourth largest country in South America. It is organized in 32 decentralized departments and the Bogota Capital District, seat of the National Government. It is divided into six natural regions based on their ecosystems, relief and climate: Amazonian: Andean; Caribbean: Orinoco; Pacific; and islands (Archipelago of San Andrés and Providencia in the Caribbean Sea, Malpelo and Gorgona

Islands in the Pacific) (IGAC, 2012). Due to this diversity, it has abundant agricultural and freshwater resources, exceptional biodiversity and a wealth of natural resources such as nickel, copper, iron, coal, natural gas, oil, gold, silver, platinum and emeralds (OECD, 2015).

Approximately 82,5% of the country's total area is below 1,000 meters above sea level (masl), with average temperatures above 24°C. In the highlands, the climate is cold, with temperatures ranging from 12° to 17°C. Above the cold lands in the Andes are the high Andean forests and moors. Above 4.000 masl, where temperatures are very low, some glacial zones still exist. The country has approximately 42,3 million hectares (ha) suitable for agricultural production (DANE, 2015; DNP, 2015a). Agricultural potential amounts to 26,5 million ha, of which nearly 11 million are suitable for agriculture, 6 million for livestock raising, 4 million for agroforestry, 3 million for forestry production and 2 million are in bodies of water (MADR, 2016). The agricultural sector has been crucial to the Colombian economy, because of its contribution to the Gross Domestic Product (GDP), employment and exports (OECD, 2015). According to figures from the third National Agricultural Census (CNA), in 2015, Colombia had 7,1 million ha in crops. Agricultural development has been achieved despite major social and productive lags (DANE, 2015). A total of 74,8% of the area (5,3 million ha) is used for permanent crops, and 16% for transitional crops (1,2 million ha). Of the total rural area, 56,9% (62,8 million ha) corresponds to natural forests, while 38,3% (42,3 million ha) is used for agriculture.

Demographic characteristics

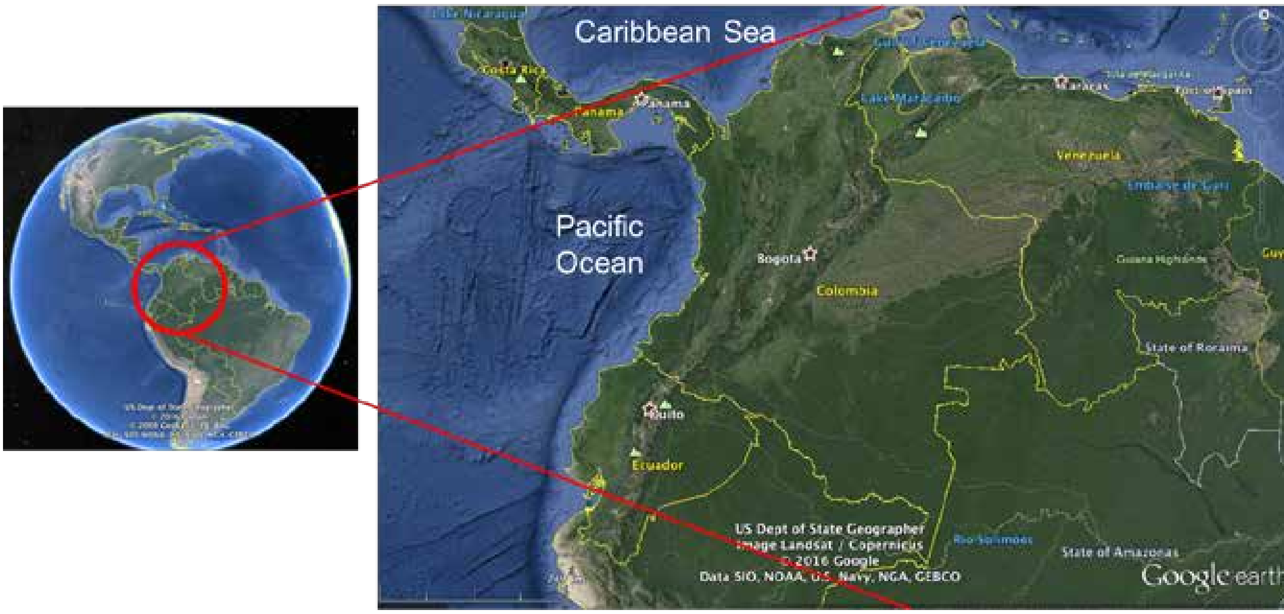
The population is largely the result of miscegenation among Europeans, Indians and Africans, with indigenous and Afro-descendant minorities. The Colombian Caribbean is home to a significant number of people of Middle Eastern ancestry (DANE, 2005). According to the National Administrative Department of Statistics (DANE), on June 30, 2015, the country had a population of 48.747.708. Most of the population is located in the Center (Andean region) and North (Caribbean region) of the country, whereas in the East (Llanos Orientales) and South (Amazonia), there are large areas with very few inhabitants. There has been significant movement by the rural population to urban areas coupled with emigration to other countries. The most highly developed area in Colombia corresponds to the Andean region in cities such as Bogotá, Medellín and Cali. Although over 99,2% of Colombians speak Spanish, a hundred Amerindian languages are also spoken in the country. Life expectancy is 74,79 years, infant mortality is 15,92 per thousand, coinciding with Inter-American Development Bank (IADB) figures for Latin America and the Caribbean. The driving elements of the demographics of the region are lower fertility and increased longevity. In 2015, the fertility rate was 2,15 children per woman (Marczak & Engelke, 2016).

Agriculture

Agriculture is characterized by technological monocultures by region: sugar cane; coffee; flowers; cotton; banana; banana; sorghum; maize; rice; African palm; potato and cassava. Colombia is the world's largest producer of soft

[1] Elizabeth Hodson de Jaramillo, Professor Emeritus of the Faculty of Sciences of the Pontíficia Universidad Javeriana. Member of Number of the Colombian Academy of Exact, Physical and Natural Sciences, ehodson8@outlook.com
[2] Jairo Castaño, Distinguished Professor at the Faculty of Agricultural Sciences, University of Caldas. Member of the Colombian Academy of Exact, Physical and Natural Sciences, jairo.castano_z@ucaldas.edu.co **[3] Germán Poveda,** Full Professor in the Universidad Nacional de Colombia, Sede Medellín, Department of Geosciences and Environment, Faculty of Minas, Medellín, Colombia. Member of the Colombian Academy of Exact, Physical and Natural Sciences, gpoveda@unal.edu.co
[4] Gabriel Roldán, Member and Director de Publications at the Colombian Academy of Exact, Physical and Natural Sciences, groldan@une.net.co **[5] Paul Chavarriaga,** Leader of the CIAT Genetic Transformation Platform. Professor at the Pontíficia Universidad Javeriana-Cali, p.chavarriaga@cgiar.org

Figure 1. Location of Colombia in America



coffee. "Colombian Coffee" is a designation-of-origin protected by the European Union since September 27, 2007. This denomination is given to 100% Arabic coffee (*Coffea arabica L.*) produced in Colombia's coffee regions, located between Latitude N 1° to 11°15, longitude W72° to 78° and specific ranges of altitude that may exceed 2,000 masl (Valencia, 2012). The country has 21.4 million head of cattle, the largest number in Latin America after Brazil. A total of 66,2% of producers own fewer than 100 ha, while 53,8% own fewer than 50 ha (DANE, 2015).

To a large extent, food and nutritional security depends on the production of cereals in small plots (smallholdings) that allows them to be supplied and traded in local markets. The most important cereals are rice and corn. Perennial crops for domestic consumption and export account for 41% of agroindustrial employment. High-value export crops include coffee, sugar cane and African palm. Cacao production has mainly been implemented by small producers; Colombia has a very high potential to be a major cacao producer worldwide, and there are programs to promote its planting (Ramírez-Villegas et al., 2012). Cacao and fruit trees are chains with significant participation by small and medium producers, whereas maize, soy, rice, palm, rubber and forestry are mainly the province of large producers since they require large cultivated areas for profitable and sustainable project development (MADR, 2016).

Agriculture in Colombia will be seriously affected by climate change, both in terms of food security and agricultural socioeconomics. The country has undertaken activities to mitigate and adapt to this threat and is promoting links among research centers (national, sectoral and international), in search of alternatives for the various crop systems and their territorial characteristics. The aim is to evaluate germplasm in various regions and to study their behavior in response to a variety of conditions (both biotic and abiotic) in order to select the materials with the best agronomic behavior (Ramírez-Villegas et al., 2012). In order to support programs for the evaluation and selection of new germplasm, the International Center for Tropical Agriculture (CIAT) in Colombia and other research centers are using drones. Thematic networks for research and experimentation have been established that should be further strengthened in various regions, especially in the country's current circumstances (after the signing of the peace agreement with the FARC guerrillas), which seek to strengthen territorial development by offering suitable alternatives to different social sectors and, additionally, to increase the area under cultivation in Colombia (MADR, 2016).

Food and nutrition security

Colombia ranks 10th in the 2016 Food Sustainability Index and ninth in sustainable agriculture according to the report prepared by The Economist Intelligence Unit and the BCFN Foundation (https://www.eiuperspectives.economist.com/sustainability/food-sustainability-index-2016).

Approximately 13,2% of children under 5 in Colombia suffer from chronic malnutrition. A total of 42,7% of the country's indigenous population live under conditions of food insecurity (FAO, 2015a). In 2013, Colombia's Intersectoral Food and Nutrition Security Commission (CISAN) officially launched the 2012-2019 National Food and Nutrition Security Plan, with the aim of ensuring that the entire Colombian population has access to and consumes food in permanent, timely fashion, in sufficient quantity, variety, quality and safety (OSAN, undated). There are several factors that affect the situation in the Colombian countryside and represent a huge challenge: the incidence of armed conflict; limited access to goods and services such as drinking water, aqueduct, sewerage and sanitary solutions; energy; health and food security. A total of 57,5% of rural households are food-insecure, compared to 38,4% of urban households (MADR, 2016).

Foreign trade

Colombia's main export product is oil. Other key activities include the textile, food, automotive and petrochemical industries, food processing, coffee production, oil, beverages, cement, gold, coal, emeralds, nickel, cut flowers and bananas (DANE, 2016).

Although Colombia only accounts for a low share of the world's agricultural market, several studies have demonstrated its potential to become a key player in the increase of the world food supply; "*It is one of the five most important countries to be a global food pantry because of its location and availability of land*" (FAO & Earthscan, 2011; MADR, 2016). In 2015, the GDP of the Colombian agricultural sector was 32,9 trillion Colombian pesos (equivalent to $11,75 billion USD), accounting for approximately 6,1% of the Gross Domestic Product (GDP). As for the labor market, the population employed in rural areas is equivalent to 16,1% of the national total (MADR, 2016). Agricultural products currently account for approximately 11% of Colombia's total exports, with a predominance of traditional products such as coffee, flowers, bananas and plantains, and sugar (OECD, 2015). Exports from the agricultural and agroindustrial sector (2010-2015 averages) show a total average of 4,2 million tons (t) for a total average value of $6.734 million USD, distributed as follows: coffee 34%, flowers and buds 19%, bananas and plantains 12%, sugar cane 6%, confectionery without cacao 4%, coffee extracts and essences 4%, palm oil 3%, livestock 2%, baked products 1% and other products 15% (MADR, 2016). Forty percent of agricultural imports are led by domestic products for which there is a high demand, such as corn, wheat and soybeans. The average amount of imports between 2010 and 2015 was 10.1 million t with an average value of $5.934 billion USD. The country has a positive trade balance mainly because of traditional products such as coffee, bananas and flowers, which are exported and whose external prices produce a trade surplus (MADR, 2016).

Challenges of Colombian agriculture

Annual agricultural output growth rates have fluctuated over the past two decades with a relatively low growth rate of 1,6% since 1990 (OECD, 2015). The main economic obstacles are the low productivity of the production units, the lag in transport infrastructure and the production, transformation and aggregation of agricultural value, low use (due to inaccessibility or low interest in the instruments available for the sector) of productive planning instruments and the incipient mitigation of agroclimate risks and access to productive land (MADR, 2016).

According to the Third National Agricultural Census (DANE, 2015), 69,9% of Agricultural Production Units (APU) have less than 5 ha and accounted for less than 5% of the area surveyed. On the other hand, 0,4% of APU have 500 ha or more and occupy 41,1% of the area surveyed. The main problem lies in the concentration of land ownership. **Figure 2** shows municipal agricultural production presented by the Agricultural Rural Planning Unit (UPRA) for 2012, highlighting the country's most productive regions. After 50 years of armed conflict, which has limited the development of the country's agricultural sector, and since the signing of the peace agreement at the end of 2016, the agricultural area is expected to expand, with significant prospects for rural development in areas previously occupied by guerrillas, while agribusinesses have an enormous potential to promote rapid growth and the restructuring of agriculture. The main challenges of the agricultural sector, essential to its growth, are: reducing energy prices to meet production; levering the agricultural and agroindustrial potential of its lands (it only uses 24% of its 22 million hectares suitable for agriculture); development opportunities by improving socioeconomic conditions in rural areas; access to financial services; and sensible management of the devaluation of the Colombian peso (ASOBANCARIA, 2016).

Many of the problems associated with agriculture and food production in Colombia stem from a set of factors recently summarized by the "MTCC" (DNP, 2015b) Mission for the Transformation of the Colombian Countryside- (DNP, 2015b). A summary of this Mission is available in **Box 2** of Section VII of this chapter, "Food and Nutrition Security Policies". The diagnosis indicates that in Colombia: i. Conflicts over land use remain; ii. There is a high concentration of informal property ownership; iii. In many areas, land use does not reflect its ideal use; iv. There is a lack of protection and poor regulation of natural resources; v. There has been asymmetrical development between the countryside and the city; vi. There are major inequalities within the rural sector; vii. Over the past 15 years, poverty has been reduced but urban-rural gaps have increased; viii. There has been some progress in social inclusion, but not in productive inclusion; ix. The scattered population in the rural sector is poorer than in

Figure 2. Municipal Agricultural Production in Colombia (UPRA, 2014)

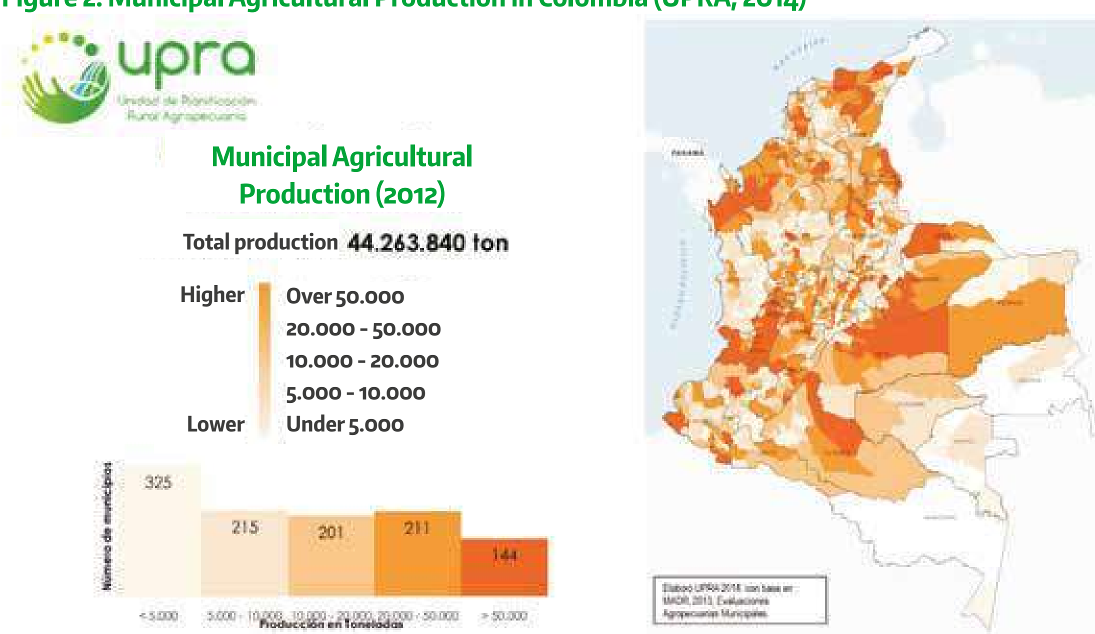


Table 1: Research Institutes in the National Environmental System, Colombia

Institute	Mission / Objectives
Alexander von Humboldt Biological Resources Research Institute (IAvH)	Promote, coordinate and undertake research that contributes to the knowledge, conservation and sustainable use of biodiversity as a factor for the development and well-being of the Colombian population.
José Benito Vives de Andreis (INVEMAR) Institute of Marine and Coastal Research	Develop research on renewable natural resources and the environment in marine and coastal ecosystems.
Amazonian Institute of Scientific Research (SINCHI)	Advance biological and social research in the Amazon region, with sustainable use of its resources. Promote business plans to adopt productive systems with good environmental and social practices in the Amazon Region and encourage the strengthening of production chains and the marketing of local products
Pacific Environmental Research Institute (IAP)	Undertake research on the Pacific Coast environment (knowledge, innovations and traditional practices, related to the natural, social and ethnocultural reality of the Biogeographical Chocó).
Institute of Hydrology, Meteorology and Environmental Studies (IDEAM)	Obtain, analyze, study, process and disseminate information on the physical environment.

the municipal headwaters, and x. The gap is higher in large cities. There are serious problems regarding the provision of social services in the fields of education and health, as well as a social security system that is almost non-existent for the rural population. It is thought that the lack of dynamism of the agricultural sector in Colombia is linked to the disarray of its institutions, as well as weak policy instruments and the Ministry of Agriculture and Rural Development's unstable budget. The section on Food and Nutrition Security Policies summarizes the main recommendations of the MTCC in relation to public policies and public investment decision-making instruments for rural and agricultural development for the next 20 years, which will help transform the Colombian countryside.

II. Institutional Context

National Agricultural Research Systems

Numerous research centers attached to the Ministries of Agriculture and Environment or trade unions, as well as groups in universities and the private sector, are formulating and implementing research and development projects focused on improving productive efficiency in the agroindustrial sector. They also seek resilient productive systems, with environmental, social and economic sustainability, and adaptation to climate change, which involve environmental, social and economic considerations. There have been significant advances in a number of sectors and, with the support of government policies, links between the academic and research sectors are being strengthened as described below.

The Ministry of Agriculture and Rural Development (MADR), which is responsible for agricultural policy and rural development, attempts to promote rural development through a territorial approach and by strengthening the productivity and competitiveness of agricultural products, as well as promoting links between institutional actions in the rural environment in a focused and systematic way, under the principles of competitiveness, equity, sustainability, multisectoriality and decentralization, for the country's socioeconomic development (MADR, 2016). To this end, it has seven organizations: The Rural Development Agency; National Land Agency; Territorial Renewal Agency; Colombian Agricultural Institute (ICA); Rural Planning Unit (UPRA); National Aquaculture and Fisheries Authority (AUNAP), and the Land Restitution Unit. It also has five associated bodies: Agrarian Bank of Colombia; Finagro; Corabastos; Vecol and the Mercantile Exchange of Colombia; and two Mixed Participation Corporations: The Colombian Corporation for Agricultural Research (CORPOICA) and the Colombia International Corporation.

Agricultural research in Colombia by government institutions is channeled through CORPOICA (http://www.corpoica.org.co/menu/qhc/), whose goal is to undertake research and technological development to transfer innovation processes to the agricultural sector in order to improve productivity and competitiveness. It has 13 regional research centers distributed throughout the country and offers extensive technological advice on permanent crops and on transitional and agroindustrial crops in diverse species, as well as on livestock and small animal species.

National Environmental System Institutes

The main players in sustainable development and applications based on biodiversity in Colombia are the research institutes attached to and linked to the Ministry of Environment and Sustainable Development (MADS), whose function is to propose sustainable technological developments in order to create products that incorporate knowledge and added value based on renewable natural resources (**Table 1**).

Research Centers and Universities

In 1938, agricultural production unions began to create their own Agricultural Research Centers known as CENI, financed by the private sector and focused on commercial crops: Ceniacua (cultivated shrimp and others); Cenibanano (banana and plantain); Cenicafé (coffee); Cenicaña (sugar cane); Cenicel (cereals and legumes); Ceniflores (floriculture); Cenipalma (oil palm) and

Box 1. National Water Study 2014 (IDEAM, 2015a)

The study undertakes a diagnosis of the status of water as both a resource and a threat in Colombia. It identifies the hydrographic subzones and watersheds that should be prioritized, to improve water resource management in terms of vulnerabilities, pressures for use and impacts on quality. It also evaluates the country's Water Footprint in relation to the amount of water used for goods and service production. The main conclusions of the study are:

- Colombia has a water yield 6 times the world average and 3 times that of Latin America. Its groundwater reserves triple this supply and are distributed throughout 74% of the country.
- Water distribution varies between the different hydrographic areas. The Magdalena-Cauca and Caribbean regions, which are home to 80% of the population and produce 80% of national GDP, produce just 21% of the total surface water supply.
- The most critical water conditions, such as pressure due to use, pollution, vulnerability to shortages and climatic variability and regulatory conditions are concentrated in the Magdalena-Cauca and Caribbean areas, comprising 110 municipalities with a population of 18 million inhabitants.
- Various water quality indicators (biodegradable and non-biodegradable pollutants, nutrients, heavy metals and mercury) are severely affected in nearly 150 cities and municipalities, including Bogotá, Medellín, Cali, Barranquilla, Cartagena, Cúcuta, Villavicencio, Manizales and Bucaramanga.
- The amount of biodegradable organic matter discharged into water systems in 2012 was estimated at 756.945 t/year, whereas non-biodegradable organic matter (chemical substances) was estimated at 918.670 t/year, with Bogotá, Cali, Medellín and Cartagena being the main contributors. At the same time, 205 tons of mercury are discharged into the soil and rivers.
- Over 300 million tonnes/year of sediment are transported by rivers, the largest contributor being the Magdalena River at the Calamar station with 140 million t/year.
- 318 municipalities with 12 million inhabitants could experience shortages during the dry season.
- A high dependency on green water was observed in agricultural and livestock sectors, which makes these economic sectors vulnerable to climate change.
- Sixteen Hydrogeological Provinces with 61 aquifer systems and a potential water supply of 5.848 km³ of groundwater were identified, mainly located in regions under high pressure due to use, pollution, vulnerability to shortages, variability and climate change.
- The total water demand in different sectors at the national level is 35.987 Mm³. The sectors with the greatest demand are: agricultural (46,6%), energy (21,5%), livestock (8,5%) and domestic (8,2%).
- The water concessioned annually amounts to 1.032 million m³. Of these, 498 million m³ (48%) correspond to the agricultural sector (450 million m³ are extracted in Valle del Cauca for the sugar industry), 25% to industrial consumption and 17% to household consumption.

CONIF (agroforestry products). CENI are linked to productive sectors, which together employ 4.684.000 Colombians, whose work in 1.414 million ha generates annual global production that meets the national demand for the various products and allows annual exports for a value of $4.448 millions USD. Production of the various goods is distributed throughout the country. They are grouped together in a network (CENIRED), to promote the scientific and technological development of the agricultural sector, the use of sustainable technologies through participatory research, and to manage, finance and monitor research and technological development plans, programs and projects through agreements, contracts and other modalities based on strategic alliances (http://www.cenired.org.co/index.php/corporativo-cenired).

A key complement to the strengthening of research capacity in the agricultural sector in Colombia is Palmira, home to the International Center for Tropical Agriculture (CIAT), which is part of the CGIAR Consortium, an international organization composed of 15 member centers committed to research for a future with food security. Several institutions have technical and scientific cooperation activities and receive advice or training and technical training from CIAT.

There are also associations - Research Centers/Consortia - most of which work with emerging and leading-edge technologies such as molecular techniques, some for the genetic transformation of material-of-agricultural-interest, as well as phytochemistry/bioproducts, in biological control and development of biofertilizers. Their main objective is the strengthening of business, the development of productive processes and supply services and the efficient scaling and commercialization of products developed by research groups.

For strengthening of capacities, especially in relation to human resources training and training in state-of-the-art technologies such as meta-genomics, proteomics, molecular markers and bioinformatics, the National Agency for Science and Technology - Administrative Department of Science, Technology and Innovation (COLCIENCIAS) - has attempted to rationalize the use of scientific, technical, infrastructure and financial resources by promoting the establishment of Centers of Excellence, which bring together various institutions and research groups from universities throughout the country around an issue-of-interest with defined objectives. The following institutions promote research, development and innovation: Colombian Center for Genomics and Bioinformatics of Extreme Environments (GEBIX); Center for Bioinformatics and Computational Biology of Colombia (CBBC); Center for Basic and Applied Interdisciplinary Studies (CEIBA); Center for Research and Studies on Biodiversity and Genetic Resources (CIEBREG), and the National Research Center for Agro-industrialization of Tropical Medicinal Aromatic Plant Species (CENIVAM).

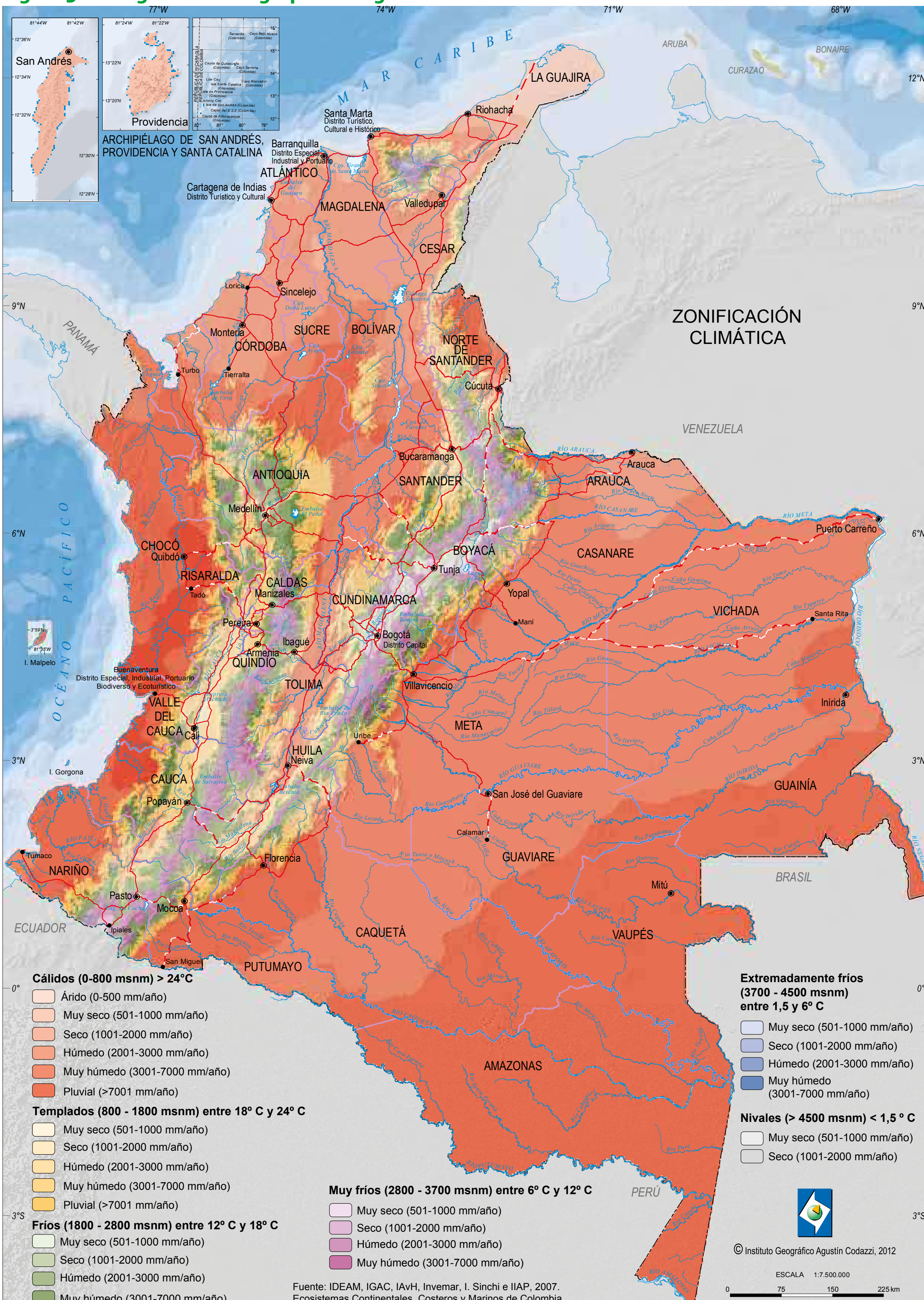
The country has solid research capacity at its universities. Most of these public and private universities have various research groups associated with agricultural production and food-security activities in fields such as conventional genetics, phytopathology, soil microbiology, environmental microbiology, functional foods, natural products, agricultural and environmental biotechnologies, molecular biology, genomics, proteomics and metabolomics, genetic transformation of organisms by recombinant DNA, gene editing, bioprospecting and bioprocesses.

III. Characteristics of Natural Resources and Ecosystems

Water resources and future challenges

Colombia's location in the NW corner of South America accounts for its abundance of waters, due to: (1) the oscillation of the Intertropical Convergence Zone; (2) the transport of moisture by several wind currents over the Caribbean Sea, the Pacific Ocean and the Eastern Plains; (3) orographic rainfall in the three Andes mountain ranges that cross the country from the SW to the NE; (4) its portion of the watersheds of the Amazon and Orinoco Rivers, and (5) strong soil-atmosphere interactions (Poveda et al., 2011). The natural supply of water varies significantly in the country's five geographic regions: (I) Caribbean; (ii) Andean; (iii) Pacific; (iv) Orinoco, and (v) Amazonia (**Figure 3**). Moreover, the country's water supply and availability is conditioned by the

Figure 3. Ecological and Geographical Regions of Colombia



hydroclimatic variability over a wide range of time scales, from the interannual scale to the diurnal scale, and the effects of climate change and deforestation (Poveda, 2004).

Evidence of climate change in Colombia

The effects of climate change in Colombia include an increase in average and minimal temperatures in a large number of stations and mixed precipitation trends without a clear regional pattern, except on the Pacific plain, where an upward trend has been observed (Carmona & Poveda, 2014). The study by Mayorga et al. (2011) finds that of 310 stations with records of monthly precipitation, 71% demonstrate upward and 22%, downward trends. Mean and extreme flows exhibit negative trends in nearly all of Colombia (Poveda et al., 2011; Carmona & Poveda, 2014). The study by Hurtado & Mesa (2015) finds positive trends in Colombia's precipitation series for the 1975-2006 period, mainly in the Pacific, Orinoco and Amazon basin regions. Climate change is also causing the disappearance and rapid retreat of Colombia's tropical glaciers (Rabatel et al., 2013).

Water resources and future challenges

Several factors have prevented the proper management of Colombian land, such as the social and political situation, inequality, poverty, armed confrontations and drug trafficking, and the weaknesses of its education, research and technological development systems, leading to the degradation and alteration of the country's fragile soils (MADS, 2013a). Twenty-nine percent of Colombian soils are infertile (ultisols and oxisols), while suitable agricultural soils (andisols and molisols) constitute an area of 8.5 million ha (7,5%). Of the country's 114 million ha, 32 million (28,7%) are unsuitable due to overuse (15%) or underuse (13%) and 87 million ha should be declared Protected and Conservation Areas (IGAC, 2012). Degradation processes include erosion (48% of the territory), sealing, contamination, loss of organic matter, salinization (5%), compaction and desertification (0,7%), mainly in the Caribbean, Andean and Orinoquia regions, and incipiently in the Amazon and on the Pacific Coast (MADS, 2013a). The degraded areas are home to the main urban centers (IDEAM-MADS, 2014).

Energy challenges

The main and cheapest source of energy in Colombia is hydroelectric, followed by thermoelectric power (gas, diesel and coal). The country has an effective, installed capacity of 14.478 MW, of which 9.836 MW (67,9%) are hydro, 4.566 MW thermal (31,5%); 57,8 MW cogeneration and 18 MW wind power plants (**Table 2**). Seventeen new hydroelectric projects with a capacity of 3.961 MW are currently being built, at a cost of over $10 billion USD. With this new energy, Colombia will achieve a generation capacity of 18.385 MW to supply the demand forecast for 2018 (ACOLGEN; http://www.acolgen.org.co).

Biodiversity, conflicts and challenges

Colombia has the world's largest number of species-per-unit area, making it the second most mega-diverse country after Brazil. Occupying 0.7% of the planet's area, it is home to approximately 10% of the world's fauna and flora (FAO, 2015). This biodiversity is a source of numerous ecosystems and human livelihood and welfare systems, including the provision of services such as food, timber and non-timber forest products (skins, meat and ornamental fauna), genetic resources, natural ingredients, medicinal plants, pharmaceuticals and cosmetics, and water. The V National Report to the Convention on Biological Diversity (MADS-UNDP, 2014) identifies the following five factors associated with loss of biodiversity and ecosystem services: (i). changes in land use (livestock, illegal crops and infrastructure); (ii). reduction, loss or degradation of native ecosystems and agroecosystems (agribusiness, mining, hydroelectric generation, urbanization and fishing overexploitation); (iii). biological invasions; (iv). water contamination and toxicity, and (v) climate change.

Effects of forest trends

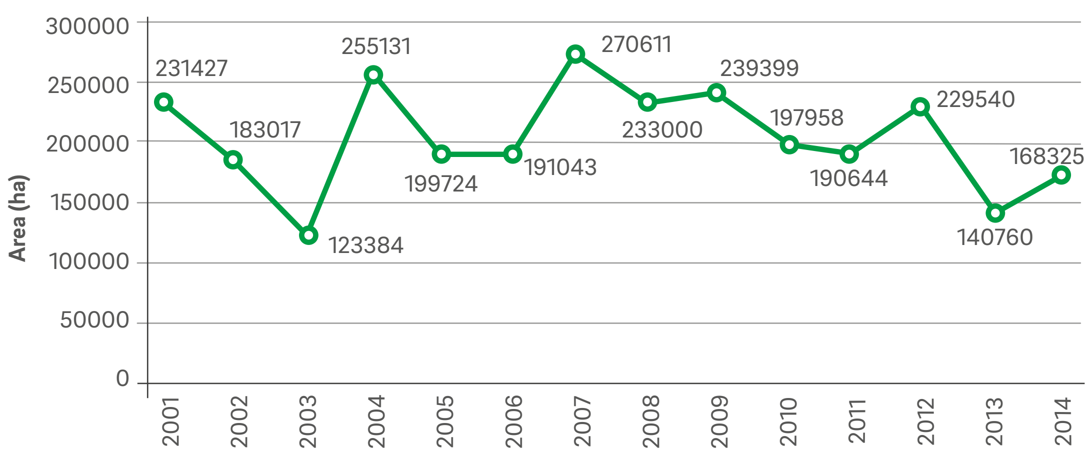
Deforestation and changes in land use are some of the greatest threats to Colombia's sustainable, economic development. In 2014, the country had 8.867 metric t of carbon stored in its living forest biomass (Hansen et al., 2013) after losing 2.822.693 ha of forest in the 2001-2014 period (**Figure 4**).

Table 2. Energy Generation capacity (GWh) forecast for various scenarios and energy sources, during the 2017-2022 period. Taken from UPME, 2016

Scenarios	Hydroelectric	Minor+ Liquids	Liquids	Gas	Coal	Wind	Solar Photovoltaic	Geothermal + Biomass
ESC 0.0	980.828	64.997	23	52.398	120.502	62.683	2.221	22.857
ESC 1.0	990.453	64.997	80	74.528	121.655	32.811	795	21.188
ESC 2.0	992.164	64.997	49	75.159	89.584	62.684	685	21.188
ESC 3.0	997.464	64.997	82	86.812	100.198	32.811	1.547	22.589
ESC 4.0	988.101	65.347	35	60.588	107.701	62.683	867	21.188

Source of table: UPME

Figure 4. Annual series of forest loss in Colombia during the period 2001-2014



Source: Compiled by the authors based on data from Global Forest Watch http://www.globalforestwatch.org/

Factors such as the expansion of agricultural and livestock borders and mining have led to deforestation in Colombia, destroying ecosystem services in forests such as the regulation of hydrological extremes, erosion control, protection against global warming by carbon sequestration and evapotranspiration, protecting biodiversity, and nutrient storage and recycling.

Impacts of climate variability on agriculture

Effects of El Niño

According to the Ministry of Agriculture, the occurrence of the El Niño phenomenon reduces Colombia's agricultural yield. Historically, the most severely affected crops have been manioc, cassava, African palm, barley, rice, coffee and potato, as well as milk production, which is declining. During 2015-2016, El Niño was responsible for a 20% decrease in Colombia's agricultural output, doubling mortality in the livestock sector. Short-cycle crops saw the greatest decline in production (3,4%), although long-cycle crops increased their yield by 2,5%. Cereals and fruits were affected by frost, which increased production costs, as were potato, milk and rice. Over 600,000 ha of coffee plantations were affected by the intense heat wave. El Niño also causes a high impact on agricultural pests and diseases (IICA, 2015; OIRSA, 2014).

Effects of La Niña on the agricultural sector

The intense rainfall that occurs in Colombia during La Niña causes flooding, landslides and erosion. The La Niña event in 2010-2011 caused economic losses of 11.2 billion pesos through damages to infrastructure, agricultural crops and livestock, transportation, mining and tourism. The effects of climate variability and climate change on rural communities engaged in coffee cultivation in Colombia are reported in Poveda et al. (2017).

Potential impacts of climate change

Several studies indicate that climate change will negatively impact the Colombian economy. The study by Burke et al. (2015) predicts for Colombia a 77% decrease in GDP per capita between 2015 and 2100 due to climate change. The DNP-IDB study (2014), albeit with various limitations, uses the results of various climate-change models and scenarios and finds that the agricultural sector would suffer the greatest losses due to reductions in yields per hectare, caused, among other factors, by the decrease in climatic range, summarized in **Table 3**.

The study by Ramírez-Villegas et al. (2012) explores the possible impacts of climate change on Colombian agriculture, mentioning the challenges that would affect the main crops and regions and suggesting adaptation actions. It estimates that by 2050, climate change in Colombia will impact approximately 3.5 million people, affecting 14% of GDP in agriculture, employment, agroindustries, supply chains, and food and nutrition security. Most crops and cultivated regions will experience negative impacts unless adaptation measures are adopted, these impacts including increased flood frequency and changes in the prevalence and presence of pests and diseases, increasing the vulnerability of small farmers (Ramírez-Villegas et al., 2012).

Building resilience to extreme events

The National Planning Department of Colombia with the support of the Ministry of Environment and Sustainable Development (MADS) coordinates the National Plan for Adaptation to Climate Change (PNACC), designed to reduce the risk and socioeconomic impacts associated with climate variability and change in Colombia by: i) increasing knowledge about the potential risks and opportunities and incorporating climate risk management into sectoral and territorial development planning, and ii) reducing the vulnerability of socioeconomic and ecological systems to climatic events. Due to limited scientific research on climate change and variability in Colombia, it is suggested that in Latin America, public discussion be conducted with society and governments on the severity of the various social, environmental, ecological and economic threats and the effects of climate change. It is suggested that the discussion focus on the following key issues:

- What are the main scientific questions posed by climate change and deforestation on ecosystems? What will be the most likely effects on the occurrence of extreme hydrometeorological events (droughts and floods) in the various regions in Latin America? How will they impact society and the various sectors?
- How much carbon is stored by the various ecosystems in Latin America, from deserts to wetlands, through dry forests, humid mountain forests, tropical humid forests, savannas in the inter-Andean valleys, the Amazon and the other regions, and ecosystems in the subcontinent?
- What are the evapotranspiration rates of these ecosystems? Evapotranspiration provides a hitherto overlooked ecosystem service (cooling and refrigeration, counteracting the effects of global warming). This ecosystem service must be measured and valued separately from carbon storage.
- What are the most likely impacts of climate change on human health, water availability and food production, electricity generation and other sectors?
- What kind of decisions (economic, financial, social and environmental) must the region take to address the consequences of climate change and deforestation? What types of investments in science and technology are required to address this problem? How will this disparity be addressed?
- What is the budget of the organizations responsible for financing scientific research in the countries in the region (COLCIENCIAS), and of the ministries and regional and municipal governments to support basic and

applied scientific research on the subjects of climate change and deforestation, and all of their consequences in Latin America?

IV. Technology and Innovation

Role of biotechnologies

Biotechnology is one of the areas with greatest potential for the Colombian economy. It is clear that numerous biotechnological advances in various sectors of the economy, in addition to their multiple applications for human and animal health, offer several alternatives to meet the requirements of food and nutritional security and the sustainable intensification of agricultural production, as well as addressing the challenges of crop adaptation to climate change. Complementary issues include the production of bioinputs (biofertilizers and biopesticides) and biodegradation systems for agri-food waste and bioremediation. Properly integrated with other technologies as well as with agricultural and food production, biotechnologies offer a powerful set of tools for crop improvement and production, and has the potential to deliver significant benefits to both the consumer and the environment. It can also revolutionize the strategies needed to conserve biodiversity.

In agrobiotechnologies, Colombia, in addition to its own developments - in bioinputs, crop improvement by molecular techniques and environmental biotechnology - has been an important player in the adoption of Genetically Modified (GM) biotech crops. It began growing

Table 3. Percentage changes in Colombian agricultural productivity for different times and climate-change scenarios, compared to the 2000-2010

	2040*	2070**	2100***	Averange
National				
A2	-6,7	-5,8	-4,4	-5,6
B2	-5,2	-5,5	-5,2	-5,3
A1B	-10,2	-11,4	-12,4	-11,3
Average	-7,4	-7,6	-7,3	-7,4
Technified Maize				
A2	-22,9	-21,8	-22,8	
B2	-21,9	-22,2	-22,8	
A1B	-24,1	-21,9	-19,3	
Average	-23,0	-22,0	-21,6	
Potato				
A2	-15,7	-14,1	-9,1	
B2	-12,3	-12,8	-10,7	
A1B	-19,4	-20,0	-19,3	
Average	-15,8	-15,6	13,0	
Irrigated Rice				
A2	2,3	2,7	2,1	
B2	2,6	2,4	1,8	
A1B	-1,6	-3,9	-6,6	
Average	1,1	0,4	-0,9	

Source: DNP-BID (2014). * Averange 2011-2040; ** Averange 2041-2070; *** Averange 2071-2100

GM carnations in 2002 and is currently one of the 28 countries in the world that plant more than 100,000 ha of GM crops per year (James, 2015). By 2015, a total of 101.131 ha were cultivated in the country, including maize (85.251 ha), cotton (15.868 ha) and ornamental flowers (12 ha) grown in 22 of the country's 32 departments (Data from the Instituto Colombiano Agropecuario -ICA-). By 2015, 24% of the country's maize and 77% of its cotton crops were transgenic (FENALCE, http://fenalce.org/nueva/index.php CONALGODON, http:// Conalgodon.com/). The advantages of adopting GM crops include beneficial environmental effects, due to the reduction in the use of pesticides, yields and incomes from better-quality harvests due to pest reduction (James, 2015).

In the development of its functions, CORPOICA has obtained results in research and technological solutions for plants and livestock. It conducts research in biotechnology and genetic engineering, integrated water and soil management, natural nutrient fixation, pest and disease management and has developments in clean agriculture, through the reduction of pesticides and chemical fertilizers. In agricultural and livestock research, CORPOICA's work focuses on the use of the country's own genetic resources, which are kept in custody in germplasm banks. Among other crops, it stores the Colombian collection of musaceae (bananas) and boasts the world's second largest potato seed collection after the International Potato Center (CIP) in Peru. Making use of the genetic material stored (22,700 seeds of different types), and through conventional breeding techniques, 50 new varieties of maize, soybean, cotton, potato, bean, cassava, lulo and papaya have been comercialized. CORPOICA provides farmers with selected or improved materials in crops such as sugar cane, cacao, maize, eggplant, sorghum and soybeans. It has developed six biological products (bioinputs) including biofertilizers (Rhizobiol for soybean, Monibac for cotton), biopesticides (Baculovirus to control the Guatemalan moth, *Tecia solanivor*, in potato and *Lecanicillium (Verticillium) lecanii* to prevent and control whitefly attack). It also provides services for the analysis of soil, food, nutritional content and the quality control of inputs. Using a climate-smart agriculture approach, it works with Agroclimatic Adaptation and Prevention Models (MAPA) to develop climate change adaptation capacities (http://www.corpoica.org/). The animal germplasm bank (semen) stores 19,000 straws of the seven Colombian Creole cattle breeds, from which some genes-of-interest for breeding have been identified, such as those conferring tolerance to brucellosis in cattle of the Blanco orejinegro Creole breed.

The International Center for Tropical Agriculture (CIAT), based in Colombia, is renowned for its research on rice, cassava, beans, tropical forages and genetic resources and promotes ecoefficient agriculture (https://ciat.cgiar. Org/). Thus, over 90 improved varieties of four basic crops (rice, cassava, beans and fodder) have contributed to boosting food security in Colombia and improving small farmers families' incomes. As a technological innovation for its breeding programs, CIAT is using drones to monitor rice and cassava crops in order to detect efficiency patterns in nitrogen-use and water-use efficiency (drought tolerance). Drones have also shown to be useful to scientists in the evaluation of behavior in the field of specific traits. They reduce the time taken by researchers to develop varieties that tolerate biotic or abiotic stress environments (FAO, 2016b; Global Harvest Initiative, 2016). To provide alternatives to current challenges, a partnership between CIAT and the International Fund for Agricultural Development (IFAD) promises to boost resilience to climate change and improve the livelihoods of thousands of small farmers around the world. Small-scale agriculture, especially in tropical areas, must become more robust, resilient, efficient and sustainable, so that it can meet the increasing demand for food and resources, while offering profitable means for emerging from poverty. CIAT leads research on genome editing in rice in Latin America to remove selection markers of transgenic lines with increased iron and zinc in grains, to validate genes that are candidates for resistance to white leaf virus (RHBV) and hybrid seed production or to validate genes that determine the number of flowers in the panicle and number of grains per plant (Li et al., 2016). This effort is being made in collaboration with foreign institutions (e.g., NIAS in Japan, and the University of Adelaide in Australia), and is supported by collaboration with private enterprise, local universities and National Research Centers. Following the example of what has been achieved with Waxy corn, edited with CRISPR/Cas9, which would not be regulated in the USA (Waltz 2016), work is being conducted on cassava to convert common starch to Waxy-type starch with a high commercial value in Colombian and Asian varieties, and in the development of non-transgenic tolerance to herbicides. In beans, genetic transformation methodologies are being developed to deactivate anti-nutritional genes in the grain using CRISPR/Cas9.

CENI focus on the search for technical solutions and innovation to provide greater competitiveness, efficiency, yield and resilience to the crops of their interest in activities such as the selection and propagation of selected material, plant breeding by various systems including transgenesis (for greater yield, adaptability to climate change, tolerance to pests and diseases), the development of biofertilizers (biofertilizers, biopesticides), supplemented by the evaluation of competitive and sustainable agribusiness models, as well as training in specific techniques. CENI have close contact and cooperate in several projects with organizations in a number of countries: CENICAÑA is one of the first members of the International Sugar cane Biotechnology Consortium. CENIACUA works with Akvaforsk in Norway, the world leader in breeding aquatic species. CENICAFÉ maintains close ties with the University of Cornell, with which it collaborates on Molecular Biology, the University of Maryland and the IRD of France, among others.

Outlook for obtaining new products

Colombia has over 150 biotechnology-based firms distributed among various sectors: 38% in agriculture; 33% in food and alcohol; 8% in biofuels, which is steadily increasing; 5% in pharmaceuticals, and 16% in universities and research centers that have set up companies (Narváez, 2015).

Examples of developments include those of the Biotechnology Institute of the National University of Colombia, with the production of bioinsecticides formulated with native species of *Bacillus thuringiensis* (Bt) for the biological control of pests that attack cotton, rice, maize, sorghum and potato. Within the crop breeding program, six varieties of virus-free potatoes and healthy yam and rubber seeds are available to farmers. Transgenic R12 potato plants, widely accepted in agribusiness, are under development. An additional example is the BIOTEC Corporation, which focuses its research on the production of propagating material (clones) from Isabela grapes and sour sop. BIOTEC also developed a biofungicide, made from the *Trichoderma harzianum* Rifa fungus, for the control of *Botrytis* spp. P. Mich. ex. Pers., which attacks the vine (http://corporacionbiotec.org/index.html).

In biotechnology, there are diverse fields of application with good development and a high scientific and technological capacity, as is the case of the cosmetics and toiletries sector and absorbents, phytotherapeutic and nutritional supplements, as well as the bioinputs sector. Concerning the latter, over 191 products have been registered with the ICA – mostly biopesticides (biological control agents) or biofertilizers (N-fixing inoculants) - and 122 companies are registered as producers or importers of bioinputs for the agricultural sector.

New breeding technologies for genome editing an example of an alternative to improve rice yield and nutritional quality

The National Federation of Rice Farmers (FEDEARROZ) estimated that in 2015, every Colombian in the urban area consumed 36.4 kilos of rice, whereas in the rural area, consumption amounted to 44.2 kilos (http://www.fedearroz.com). Comparatively, in 2014, per capita potato consumption was 63 kilos, indicating that rice is an important item in the Colombian diet. In 2015, over 280,000 tons of white rice were imported into Colombia to meet national demand, indicating a deficit in national production. Genome editing is one of the New Breeding Techniques (NBT) that offers the possibility of significantly increasing rice yield through the editing of genes that influence the number of grains, the type of clusters (vegetative or sexual), grain size and panicle size (Li et al., 2016). In the case of the number of grains, a gene called Gn1a increases the number of flowers (Ashikari et al., 2005), resulting in twice the number of grains in the panicle. The technology is easily transferable to Colombian varieties of rainfed or irrigated rice. The system for editing rice genes is used at CIAT and produces mutant lines that could be considered conventional varieties for regulation, distribution and consumption purposes.

Rice is the world's most widely consumed cereal. Cadmium (Cd) contamination of rice in China was made public in 2013 (https://rendezvous.blogs.nytimes.com/2013/05/20/cadmium-rice-is-chinas-latest-food- Scandal/), especially in Hunan province, where rice crops coexist with artisanal mining operations that contaminate paddy fields with Cd and other heavy metals. However, the main contributor to Cd contamination in agricultural soils around the world are phosphate fertilizers contaminated with Cd (Järup & Akesson, 2009; Polle & Schutzendubel, 2003). Despite the lack of solid data related the level of Cd contamination in Colombian rice fields, there is, however, evidence that this carcinogenic heavy metal may accumulate at undesirable levels in rice, beans and lentils (Méndez-Fajardo et al., 2005). Accordingly, guaranteeing food security in Colombia not only implies maintaining crop yields (and other foods) at levels that satisfy the demand of a growing population, but also entails maintaining the nutritional quality of those foods. Fortunately, there is evidence that the mutation of a single gene (OsNRAMP5) in rice results in undetectable levels of Cd in the plant and grain (Ishikawa et al., 2012). Here again, NBT would play a decisive role in the production of genetically edited Colombian rice varieties, with zero accumulation of Cd. This technology is being used to improve several crops (Khatodia et al., 2016), and could obviously be used in beans, lentils and cacao to reduce the accumulation of Cd provided that at least three conditions are met: The Cd absorption system is similar to that of rice, the number of genes involved is minimal (1 or 2), and there is an *in vitro* system to edit and regenerate cells.

Development of marine resources

In its coastal, marine and island areas, Colombia has strategic ecosystems such as mangrove areas (378.938 ha) and coral reefs (300.000 ha), as well as resources that provide environmental goods and services that can be used as the basis for developing key economic activities. Maritime territory is underused and has not been properly integrated into the country's development. In order to address this situation, activities are being undertaken, such as participation in the South Pacific Information and Data Network to support Integrated Coastal Area Management (SPINCAM), a project promoted by the Permanent Commission of the South Pacific (CPPS). The objective is to establish Indicators for Integrated Management of Coastal Areas (ICZM) in each country of the Southeast Pacific region (Chile, Colombia, Ecuador, Panama and Peru), focusing on environmental, socioeconomic and governance conditions within the context of sustainable development and integrated coastal area management (INVEMAR, MADS and DIMAR-CCCP, 2011). In its turn, the Marine Research Institute (INVEMAR) implements an R&D Program on Assessment and Exploitation of Living Marine Resources (http://www.invemar.org.co/web/guest/descripcion-var), through the formulation of proposals for the sustainable use of living resources as well as marine and coastal ecosystems, and the adoption of clean production technologies, seeking to contribute to decision making and policy formulation and enhancing the sustainable economic development of biodiversity.

The ecosystems that support Colombia's fishery resources in Colombia are scattered and poorly characterized, although mangroves, coral reefs and wetlands have been identified as important ecosystems for this activity. In terms of fishing, in 2012, Colombia ranked 81st in catches and 72th in aquaculture among the 229 countries reported by FAO. This means low production, which is only 1% of that of countries such as Peru. The contribution of fishing to GDP showed a downward trend for the 2004-2012 period. Whereas in 2004 it represented 0,22%, by 2012 its contribution had fallen to 0,17%. Exports, which in 2011 exceeded the Free On

Board (FOB) value, were reached by imports in 2012 and largely surpassed by them in 2013. The main export is tilapia. Colombia is a global leader in the export of ornamental fish (FAO-MADR, 2015).

V. Increased Efficiency of Food Systems

Outlook for increases in agricultural production based on technology

In 2010, the Global Harvest Initiative estimated that agricultural productivity would need to increase by at least 1,75% a year to meet global food requirements by 2050. The development and implementation of appropriate policies, practices and technologies lead to improved food and nutritional security at the global level, accelerate productivity, reduce losses and waste, facilitate the conservation of natural resources and contribute to climate-change mitigation. Emphasis is placed on higher yields, access to nutritious food, increased income for producers and strengthening productivity, competitiveness and resilience for producers (Global Harvest Initiative, 2016). The increase in the Total Factor Productivity (TFP) of crops is achieved through the incorporation of knowledge and appropriate cultural practices, by adopting seed varieties with technological innovations such as higher yield, tolerance/resistance to biotic factors such as pests and diseases or abiotic factors such as drought or flood or the use of bio-inputs. CORPOICA and the CENI have been incorporating practices and technologies into various crops, as mentioned earlier. The growing bio-innovation sector in Colombia includes precision agriculture, the targeted, specific use of microorganisms (fungi and bacteria) that allow higher yields to be generated either as biofertilizers, or by protecting plants from diseases or extreme humidity conditions (Hodson & Díaz, 2013).

In relation to the potential of gene-editing technologies for plant breeding, the greatest impact is likely to be on the nutritional quality of the products. Simple examples include: the suppression of genes responsible for antinutritional compounds or allergens; the increase of cereal yield through the deactivation of negative regulators of the number of grains in the panicles, and the creation of tolerance or resistance to pathogens by modifying the target site of the infective bacterial proteins. For the examples mentioned, prototypes or proofs-of-concept have already been published (such as for rice, Li et al., 2012). Colombian researchers are advancing work in this direction, as yet at the development phase. It is important to reflect on the regulation of the use and release of crops obtained from gene editing. In the US, some are not considered GMO, and are therefore unregulated, which facilitates and lowers the cost of their development and adoption in developing countries. Let us hope, then, that this is the way forward in Latin America and the Caribbean (LAC). These concerns must be addressed because, in many developing countries, excessive legislation or the lack thereof has delayed and hampered the access of small farmers to technological developments that could benefit them.

Efficiency and competitiveness

The country must strive to become increasingly competitive in markets - both local and international – in order to be able to compete with products of different origins and, in the case of Colombia, with high volumes from the US (MADR, 2016). "This situation can only be reversed through a policy that increases the exportable supply and makes it possible to competitively replace part of the large imports of agricultural products that have accumulated over the last quarter of a century. *In both cases, producers must compete with producers from all over the world, since globalized markets are an irreversible reality.* There have been increases in the international demand for promising products in which the country has gained preferential access under its trade agreements. However, the size of the agricultural export supply is the most important structural weakness of the sector and the main obstacle for Colombia to position itself as one of the world's main food suppliers."

In 2015, agricultural GDP grew by 3,1% over the same period in 2014 (an increase of 0,3% above the level reported in 2014 of 2,8%). This is attributed to the positive performance of coffee production, which increased by 11,5% from January to September, and of livestock sectors such as pork (11,8%) and poultry production (6,0%). However, if one excludes coffee, then the agricultural sector grew by a mere 1,1%. The negative performance of some mostly short-cycle crops is associated with the reduction of areas-under-cultivation due to low prices at the time of planting and unfavorable climate conditions caused by the intense El Niño event. This gave rise to crop losses, decreased yields per hectare and poor-quality harvested products (Mejía-López, 2015).

Infrastructure needs

Globalization and trade liberalization have given a special connotation to the concept of infrastructure, making it a central feature of the national agenda. Agricultural infrastructure includes both irrigation and drainage districts, as well as conditions such as roads, collection points for commercialization and rural energy. The yield of a third of the crops in Colombia has been favorably affected by irrigation and drainage districts. This infrastructure is crucial to the well-being of the sector and its productivity, as well as access to land, the proper functioning of markets, the quality of institutions and appropriate access to technology and credit. Agricultural infrastructure is considered part of the public goods of collective use. Accordingly, its deficiencies not only detract from crop productivity and yield, but also hamper the functioning of markets, limiting their spatial and temporal integration. The Colombian State has increased resources to strengthen and improve the provision of public goods for the countryside and has provided funds for land and wasteland allocation programs to the most vulnerable communities, the construction of rural, social-interest housing (with basic sanitation, particularly potable water) and the provision of health services through subsidies (Lozano & Restrepo, 2015). Due to their particularities and specific circumstances, innovation and development activities in seed improvement and variety, fertilizer management, innovation in equipment and machinery, as well as the development of more efficient production processes compatible with sustainable development, these are regarded as a public goods, since the successful application of these developments is associated with the sector's infrastructure assets. Efforts have been made to purchase and assign land and wasteland, subsidize rural housing and support technical assistance. However, further efforts are required to maintain and set up irrigation and drainage districts, the road network, retail and wholesale centers and rural electrification.

Food use and loss minimization. National policy for sustainable food production and consumption

As a response to the desire for a sustainable economic growth model, in search of cyclical production, with environmental criteria throughout the life cycle of the product, in 2010, the Ministry of Environment proposed a Sustainable Production and Consumption Policy to respond to the commitments made by the country at several international forums derived from the Earth Summit (MAVDT, 2010). The policy is designed to change unsustainable patterns of production and consumption by the different actors in society, which will contribute to reducing pollution, conserving resources, promoting the environmental integrity of goods and services and encouraging the sustainable use of biodiversity, as sources of business competitiveness and quality of life.

In the same context, within the framework of the Community of Latin American and Caribbean States (CELAC), in January 2015, the CELAC Action Plan for Food Security, Nutrition and Hunger Eradication 2025 was approved. It was requested by the FAO Community, with the collaboration of the Latin American Integration Association (ALADI) and the Economic Commission for Latin America and the Caribbean (ECLAC) (FAO, 2015c).

Food banks

Food banks are a response to the world's problem of food waste, since the phenomenon focuses not only on access, but also on the use of what is produced and commercialized. Alliances are essential for this: Companies donate products that can no longer be marketed because their useful life has ended; they are unsightly or over-ripe, and former producers deliver crops of which they have an abundance or which are non-tradable because of their shape and size; and food banks recover and redistribute them to vulnerable populations. In Colombia, various activities have been designed to recover food in industry, commerce, power plants and directly from the countryside through the Program for the Recovery of Agricultural Surplus (REAGRO). In 2014, through the Association of Food Banks (ABACO) (http://www.abaco.org.co/home), 18.000 tons of food were rescued from 703 donor companies, making it possible to feed over 400,000 people. Through REAGRO, 2.468 t of fruits and vegetables were recovered from 409 associated producers, benefitting 35.764 people (FAO, 2015c). As an example of the impact on the child population, in 2014, the alliance between Alpina S.A., a food and dairy product company and ABACO benefitted the nutrition of more than 280,000 children, expectant and breastfeeding mothers. Older adults in 11 cities in the country benefitted from the recovery and donation of more than 500 t of products. For Alpina S.A., working on the recovery of products for the donation was the gateway to a higher commitment: contributing to the reduction of Food Loss and Waste (PDA). Thus, in January 2015 the company launched the Bon Appétit Program, which seeks to contribute to the fight against hunger through projects and alliances that work to reduce PDA. The program adopts a three-pronged approach: i) internal improvements to reduce operating losses; ii) working with suppliers, distributors and others to reduce loss and waste throughout the value chain, and iii) sharing the experience with other industries, academic institutions, cooperation and the public sector, in order to create a greater impact on food security in Colombia (FAO, 2015c).

VI. Health Considerations

Malnutrition

According to the 2012 FAO Report, for the 2010-2012 period, 12,5% of the Colombian population was undernourished. According to the latest Colombian Nutrition Situation Survey (ENSIN) in 2010 (ICBF, 2011), the population was experiencing a nutritional transition, since it had problems of underweight and overweight at the same time. Although rates have declined, malnutrition persists in low-income and indigenous populations. The study showed that 3,4% of children under 5 suffered from global malnutrition, 13,2% from chronic malnutrition and 0,9% from acute malnutrition, which exposes them to death from malnutrition or associated diseases, mainly of infectious origin, such as acute diarrheal disease and acute respiratory infections (Mazo-Echeverry, 2014).

According to Colombia's National Institute of Health (INS), in 2016, 101 children under five died in Colombia due to probable cases of malnutrition, with 54,5% of the cases involving infants under the age of 1. The most serious situation is in the Department of La Guajira, where these cases are frequent. 57,5% of rural households are food insecure, compared with 38,4% of urban households (MADR, 2016). It is striking that, between 2005 and 2010, the date of the last ENSIN study (ICBF, 2011), chronic malnutrition in Colombia fell by 17% to 5 percentage points away from the target for 2015. The percentage of stunted growth in children was 13,2%, regarded as low prevalence at the international level. The study found that although Colombians have made progress in the fight against malnutrition (anemia and hunger in the Colombian child population), there have been increases in overweight and obesity in all population groups. As a response to these challenges, a number of activities are underway in connection with the "National Plan for Food and Nutrition Security (NSPAN) 2012-2019" and the Food Guidelines for the Colombian Population, which seek to guide the population on food consumption, in order to promote complete nutritional well-being (OSAN, 2016, National Government, 2013).

Obesity

Colombia is undergoing a process of epidemiological transition reflected in the simultaneous existence of problems of malnutrition, both deficit and excess, with a disturbing degree of obesity and overweight. According to ENSIN 2010, 51,1% of people between the ages of 18 and 64 were overweight or obese, the rate being approximately 10% higher in women (55,1%) than in men (45,6%); the survey showed that the prevalence of excess weight increases with age, reaching 66,3% in the group aged 50-64 years (ICBF, 2011). ENSIN 2005 had found that 48% of the population were obese. By 2010, this percentage had risen to 52%. It was found that 62% of women and 39,8% of men have abdominal obesity, while 24,8% of pregnant women are overweight. This is attributed to Colombian sedentarism, which increased from 43% in 2005 to 47% in 2010, the Creole diet - which includes a high intake of sugar and fats - as well as the increase in processed foods in the diet (**Table 4**). According to MPS-FAO-OSAN (2014) studies, approximately 5% of households have at least one child under 5 years of age with stunted growth and an overweight mother. Among school age children, 0,1% are classified as having stunted growth and obesity while 1,4% are anemic and overweight. Of the women between 13 and 49 years of age, 3,4% are anemic and overweight. Obesity is associated with chronic noncommunicable diseases such as cardiovascular diseases, cancer, respiratory diseases and diabetes. For example, obesity caused the deaths of 2.085 men and 1.906 women in 2013 (Silva-Sarmiento, 2016; Sarmiento et al., 2014).

Expected changes in eating patterns

Food and Nutrition Security (SAN) is a state commitment framed within a rights, intersectoral, interdisciplinary and risk management approach (National Government, 2013). Since 2008, the National Policy on Food and Nutritional Security (PNSAN) has been established, in which the objective is to “Ensure that all Colombians have access to and consume food in a permanent, timely manner, in sufficient quantity, variety, quality and safety" (MPS-FAO-OSAN, 2014). The overall objective is to contribute to the improvement of the FNS of the entire Colombian population, especially the poorest and most vulnerable sectors, by: i) protect the population from hunger and inadequate food; ii) ensure access to timely, sufficient and quality food; and iii) Integrate and coordinate intersectoral and inter-agency interventions.

One of the sensitive issues in food security in the country is insufficient income to purchase food. The concept of food and nutritional security (SAN) in Colombia organically includes all the components in the agro-food chain linked to the main axes of availability, access, consumption, biological use, quality and safety of the food required (Silva-Sarmiento, 2016). One of the activities undertaken to address food security

Table 4. Average eating patterns in the Colombian population

Average Consumption of certain foods in Colombia	
39%	(ages 5 to 64) do not consume dairy products daily
33%	do not eat fruit every day
71%	do not eat vegetables every day
14%	do not eat meat or eggs every day
24%	eat fast food every week
22%	drink sodas every day
33%	have a sweet a day and 20% twice a day
72%	eat products purchased in the street, on a daily or weekly basis
56%	of children and young people (ages 9 and 18 years) eat cold cuts (charcuterie) every day

Source: ICBF Data, 2011.

is the Nutrition Recovery Strategy, a set of actions in health and nutrition designed for the population with a high prevalence of malnutrition in previously targeted areas, whose objective is to contribute to improving and/or restoring the nutritional status of children under 5, expectant and breastfeeding mothers, through actions to ensure the care and promotion of good health and nutrition practices with the co-responsibility of the family and the community, as well as the institutions in the National Family Welfare System (National Government, 2013).

Among the most important measures to improve Colombians' diet is the effort to promote healthy habits such as sports in children, changing eating habits for more balanced systems and promoting the awareness of the entire population through conferences, posters and the mass media. According to the Colombian Institute of Family Welfare (ICBF), one of the most important measures is the production of "*Food guides for the Colombian population, which seeks to establish which foods are suitable for each age and the daily portions a Colombian should eat*". In this respect, (2016), the Ministry of Health and Social Protection recently issued Resolution No. 003803, which establishes the Recommendations for the Ingestion of Energy and Nutrients (RIEN), for the Colombian population (http:/www.leyex.info/leyes/Resolucionmsps3803de2016.pdf). Some of the regional programs currently being implemented include "Bogotá without hunger", Antioquia with its program entitled "Food and Nutrition Improvement for Antioquia (MANA)" and recently in Cauca, the "Cauca without Hunger" program, which have focused on an analysis of the social and economic impact of malnutrition in infants (https://helpx.adobe.com/en/reader.html).

VII. Policies linked to Food and Nutrition Security

The climate is changing as are agriculture and food. There is an urgent need to adapt agriculture to climate change to meet the challenges and achieve the sustainable development goals (SDG). The Sustainable Development Objective 2 commits the global community to "*ending hunger, achieving food and nutrition security and promoting sustainable agriculture*" (United Nations, 2015). Colombia has welcomed these commitments and incorporated them into its development plans. As regards Food and Nutrition Security (SAN), Colombia ranks 10th in the Food Sustainability Index and the 9th in sustainable agriculture (2016 Food Sustainability Index), reflecting the commitment to and advances in these issues in the country, although efforts related to the prevention of food loss and waste, in which the country ranks 16th in the study, should be strengthened.

To achieve sustainable rural development in Colombia, it is essential to boost agricultural activities that strengthen economic activity in the regions, thus generating a better supply of goods and services for the rural population. In the past two decades, the agricultural sector has reduced its share of GDP in the local economy from above 7.5%, to approximately 6.1%, with an average of 7% for the past 15 years (DANE, 2015). Nevertheless, in the Latin American and Caribbean regional context, Colombia is one of the countries in which the agricultural sector has the greatest importance in the national GDP, above the average of 5.1%. In 2016, in order to increase the agricultural supply to guarantee food security in the country and promote agricultural exports with added value, the Ministry of Agriculture and Rural Development of Colombia (MADR) established the strategy "Colombia Siembra" (Colombia plants or sows) (http://colombiasiembra.minagricultura.gov.co). This program attempts to leverage the country's enormous potential for agricultural development and is the result of a process of research, planning and consultation, with the help of producers, industrialists, guilds and public sector organized, which has been proposed to increase the number of hectares planted in the country by one million by 2018, as well as to increase productivity. "Colombia Siembra" will create a favorable environment to boost the investments required in new areas, technological packages, and solutions for water, infrastructure, machinery, research and technology transfer (MADR, 2016).

Within the framework of the first objective entrusted to the Ministry of Agriculture and Rural Development (MADR), "*To promote rural development with a territorial approach and to strengthen the productivity and competitiveness of agricultural products, through comprehensive actions that improve the living conditions of rural people, allow the sustainable use of natural resources, create jobs and achieve the sustained, balanced growth of the regions*". In order to promote the coordination of institutional actions in the rural environment in a focused, systematic way, with the principles of competitiveness, equity, sustainability, multisectoriality and decentralization, for the country's socioeconomic development", and taking into account the country's potential to strengthen food production, through "Colombia Siembra", this ministry will coordinate the efforts of the various actors of the agricultural sector to promote the planting of a million hectares, i.e. increase the total area planted from 7.1 to 8.1 million ha (DANE, 2015). The "Colombia Siembra" Strategy has set itself the goal of establishing the social and economic conditions to promote the planting of a million more hectares of crops to achieve the inclusive, sustainable and competitive development of the Colombian countryside. Part of this undertaking involves developing various types of incentives to foster the increase in the supply of agricultural products in a sustained manner to meet Colombia's domestic demand, and to promote exports to strengthen the positioning of Colombian agricultural products in the international market (MADR, 2016).

The national government has several initiatives to transform the Colombian countryside, which are interlinked and complement each other. The goal of the 2014-2018 National Development Plan, "Everyone for a New Country" is to analyze the country's situation on the basis of the particularities and specificities of the regions and territories in order to address its three development objectives: peace, equity and education, for which there are five transversal strategies and a sixth overarching strategy known as Green Growth (DNP, 2015a). The Development Plans provide the strategic guidelines for the public policies formulated by the Government.

The concept of Green Growth means, "*Fostering economic growth and development, ensuring that ecosystems continue to provide the services that guarantee social well-being. With this focus, it is essential to catalyze investment and innovation, which will be the basis for sustained growth by creating new economic opportunities*" (OECD, 2015). This strategy is linked to the Organization for Economic Cooperation and Development (OECD) guidelines and proposes the efficient use of land and natural resources. It is designed to achieve sustainable, low carbon development; ensure the sustainable use of natural capital and improve environmental quality; promote resilience and reduce vulnerability to disaster risks and climate change. Among other activities, it proposes the design and implementation of an Early Agroclimatic Alert System (SAAT) and the formulation of climate change adaptation and mitigation plans for production systems and priority areas. Due to Colombia's technological backwardness, its National Plan for the Development of Sustainable Aquaculture should be implemented, with strategies to boost the levels of productivity and competitiveness of the national aquaculture in order to become a key productive area in the agricultural sector. It seeks to boost rural competitiveness through the provision of sectoral goods and services to make agricultural activities a source of wealth for rural producers (DNP, 2015a). The implementation of this strategy involves several agencies within the Ministries of Agriculture and Environment with their affiliated institutes, as well as the private sector. Thus, the goal of the Private Competitiveness Council regarding the Green Growth Strategy, is to be an economy that exports goods and services with a high added value and innovation, to achieve a business environment that encourages local and foreign investment, raising the quality of life and substantially reducing poverty levels. Competitiveness must be a national commitment in which entrepreneurs, government, academia and civil society work together (CPN, 2016). An

Box 2. Mission for the Transformation of the Colombian Countryside (DNP, 2015b)

The recent "Mission for the Transformation of the Colombian Countryside" (MTCC) report has proposed a program to settle the country's historical debt with the rural sector and contribute to the construction of peace (DNP, 2015b). According to MTCC, it is essential to: (i) place equity at the center of rural development policies and reduce the enormous inequalities between rural and urban dwellers, among rural inhabitants themselves, between men and women, and between different ethnic groups and between regions; (ii) adopt a participatory territorial approach, consistent with the country's regional heterogeneity, and with the need to promote social participation in all its forms; (iii) create an enabling environment for small, medium and large enterprises; and (iv) ensure the protection of the environment, particularly water, soils and forests. Proposals include: (1) State public policies and explicit goals for the countryside in all ministries, with guaranteed public resources to invest over the next 15 years. (2) More and better social investment in the countryside to narrow rural-urban welfare gaps. (3) Greater investment in public goods for productive development and less direct support in response to temporary situations. (4) Greater involvement of regions and local social organizations in the planning and prioritization of investments, project implementation and social control. This should be supported on six strategies:

1. Social inclusion in the rural sector with a rights focus, prioritizing the elimination of malnutrition in the countryside and a Zero Illiteracy campaign. The goal is to create permanent, specialized directorates within the Education and Health Ministries to design rural policies adapted to the particularities of the countryside. In education, investments should be made in flexible models with relevant content and quality that facilitate productive inclusion and encourage creativity and innovation. In health, the aim is to migrate to models with an emphasis on promotion and prevention, eliminating access barriers and bringing health services closer to families, especially in the most widely scattered municipalities.
2. Productive inclusion and family farming in agricultural, fishery and fishing activities, and non-agricultural activities (new rurality).
3. Increase agricultural competitiveness, invest more in services and public goods for productive development and less in short-term subsidies, improving the adequate public goods provision and establishing macroeconomic policies, foreign trade, financial services and internal marketing.
4. Advance environmental sustainability, recovering and protecting ecosystemic water and soil services, addressing climatic variability, and leveraging natural capital for rural prosperity in a sustainable way. Increase water use rates to encourage its proper use and create sufficient resources for watershed conservation. Some resources would be used in a payment program to conserve water sources and others for payments for environmental services, especially for family farmers established in protected areas. Establish a goal of zero deforestation by 2030 and definitively closing the agricultural frontier, through Forest Reserve Zones (ZRF). Establish an Early Agroclimatic Alert System and contingency plans to address the threats faced by the agricultural, livestock, fishery and forestry systems.
5. Territorial planning and development including environmental, social and productive aspects; regional convergence and narrowing rural-urban gaps; rural development with a territorial approach; and consolidation of territorial associativity. Creation of a Land Fund for redistributive purposes as a tool to reduce the concentration of rural land ownership and allocate land suitable for rural families in conjunction with income generation projects. Create Business Development Zones (ZDE), where schemes such as concession, lease or land rights are used rather than the delivery of land ownership. Gradually implement Integral Rural Development Programs with a Territorial Approach (PDRIET) in regions with a high density of family farmers, high poverty levels and high productive potential. Improve the territorial planning system, with an emphasis on building the capacities of departments, provide separate investment budgets for municipal and rural areas, and support the formation of planning and management provinces and regions as a means of territorial integration.
6. Various recommendations to adjustment the institutional framework and implement a program to promote and strengthen producer organizations and social organizations, adjust participatory forums, empower them and provide them with instruments to respond to the principles of transparency, democracy and participatory planning.

essential complement is the project to improve the National System for the Control and Safety of Food for national consumption and export under a risk approach by the National Institute of Food and Drug Surveillance (INVIMA), in order to support the export of beef and poultry to prioritized countries. One of the objectives is to develop the productive and commercial capacities of rural communities and to draw up a plan for commercial exploitation to ensure agricultural products' access to markets. Several Colombian products have unmet international demand and/or growth projections in the short, medium and long term. Accordingly, this objective seeks to leverage the opportunities for greater access to international markets for products such as cacao, fruit trees, beef, trout and tilapia. It is therefore essential to guarantee a constant supply of products with the quality demanded in the international market (DNP, 2015a).

Another initiative linked to the government's approach to the innovation required in the Colombian countryside, through which public policy guidelines will be defined to have a broad portfolio of policies and instruments that will allow public investment decisions for rural and agricultural development over the next 20 years, is the Mission for the Transformation of the Colombian Countryside (MTCC; see **Box 2**). It seeks to guarantee economic opportunities and economic, social and cultural rights for the rural inhabitants so that they have the option of living the decent lives they want and value (DNP, 2015b). The Mission diligently and conscientiously undertook diagnoses in various sectors and situations and proposes a series of strategies, both general and specific, to implement this transformation of the countryside that the country requires. **Box 2** summarizes the six strategies proposed by the Mission for the Transformation of the Colombian Countryside.

VIII. Conclusions

Agriculture has been a fundamental component of the Colombian economy and will continue to be a priority for economic growth, a source of employment, a factor of rural development to alleviate poverty, and in the country's current conditions, essential to the reintegration processes for the post-conflict process (Lozano & Restrepo, 2015). The main objectives of Colombian agricultural and socio-economic development are the promotion of sustainable rural development with a territorial approach and the strengthening of the productivity and competitiveness of agricultural products. The aim is also to promote the coordination of institutional actions within the principles of competitiveness, equity, sustainability, multi sectorality and decentralization.

In order to promote food and nutrition security in rural areas, actions must be taken to achieve "smart agricultural production" to focus efforts on enhancing the resilience of production systems, and to promote innovations for climate change adaptation that are affordable and suitable for all producers, including small farmers. Science and the addition of knowledge to conventional systems are the most valuable tool in the agricultural productive sector to meet current challenges and achieve some of the millennium goals. It is essential to use all currently available technologies and link them with conventional systems, according to the conditions and particularities of each region and crop: no system should exclude others (whether conventional, technified, biotechnological, organic or family agriculture).

Among the many applications of agrobiotechnologies - the most useful ones for the future in order to develop crops that are better adapted to climate change and environmental and social sustainability (ecologically friendly and with lower production costs) - are the production of bioinputs, both biofertilizers (mycorrhizas and nitrogen fixers), biopesticides for biological control and plant growth promoting bacteria (PGPBs). Colombia has had a successful experience in this field and, in fact, some of these bio-inputs are being exported (Hodson & Díaz, 2013). Other applications include the early detection of diseases through molecular diagnostic systems, the adoption of transgenic crops (GM or biotech) provided they respond to specific production constraints, and the use of recent technologies using molecular advances. One of the most promising of these technologies is one that makes it possible to obtain "Genome-Edited Crops" (GEP), because of its possibilities of addressing several constraints on production as in the case of the use of the gene edition system (such as CRISPR/Cas9 technology) to obtain resistance or tolerances to pests and diseases, improve the nutritional quality of products or seek mechanisms to tolerate abiotic factors (drought, flood, salinity) related to climate change. This technology has several advantages compared with other molecular improvement systems due to its relative simplicity, and the fact that it is highly specific and reliable for gene editing in plant, animal and microbial cells (Li et al., 2012).

In production chains, in which Colombia has experience in production, the potential for improving productivity and increasing the area under cultivation, there is an opportunity for national production to increase its participation in the national and international market. The positioning of Colombian products abroad has advanced and the negotiation of various sanitary and phytosanitary measures has been achieved with 80 countries for over 2.500 traditional and non-traditional agricultural products. Negotiations are currently underway with 225 products to encourage exports by Colombian producers. Among the main markets are the countries with the largest population, such as the Hong Kong region, Canada, the USA and countries in the European Union (MADR, 2016).

In order to achieve a comprehensive approach to the scientific and technological developments available for the strengthening of agricultural productivity, as well as its competitiveness with social, ecological and economic sustainability, it is worth considering the Bioeconomy model, which proposes a system that is less dependent on fossil resources, based on the production and intensive use of knowledge of the biological resources, processes and principles, for the sustainable provision of goods and services in all sectors of the economy. The point is to add knowledge to the sustainable productive use of renewable natural resources. The bioeconomy cascading approach implies that processes are circular and sustainable. It minimizes production of waste or residues, and instead generates new products and services in multiple sectors, since the by-products of one process are used as the raw material of new process. The Bioeconomy development model enables the harnessing of the country's enormous natural wealth and the particularities of each territory, and facilitates its insertion into the world economy through new sustainable products and services, based on the value added by scientific and technological knowledge.

References

Álvarez, O.D., J.I. Vélez, & G. Poveda (2011). Improved long-term mean annual rainfall fields for Colombia, *International Journal of Climatology*, 31, 2194–2212.

Ashikari, M., Sakakibara H., Lin S., Yamamoto, T., Takashi, T. & Nishimura A. (2005). Cytokinin oxidase regulates rice grain production. *Science* 309, 741–745.

ASOBANCARIA (2016). Redacción Asobancaria. 5 retos del sector agropecuario en Colombia para 2016. March 28 2016. Available at: http://marketing.asobancaria.com/blog/retos-sector-agropecuario-colombia-2016

Burke, M., S.M. Hsiang, and M. Edward (2015). Global non-linear effect of temperature on economic production. *Nature*, 527, 235–239.

Cancillería Colombia. S.f. Datos geográficos sobre la superficie y las regiones. Available at: http://www.cancilleria.gov.co/colombia/nuestro-pais/simbolos Retrieved: December 2016.

Carmona, A.M., & G. Poveda (2014). Detection of long-term trends in monthly hydro-climatic series of Colombia through Empirical Mode Decomposition. *Climatic Change*, 123(2), 301-313.

CPN -Consejo Privado de Competitividad (2016). *Informe Nacional de Competitividad 2016-2017*. Puntoaparte Bookvertising, Bogotá, Colombia. 343 pp.

DANE (2005). *La visibilización estadística de los grupos étnicos colombianos.* 56 pp. Available at: http://www.dane.gov.co/files/censo2005/etnia/sys/visibilidad_estadistica_etnicos.pdf
Retrievedei: November 2016.

DANE - Departamento Administrativo Nacional de Estadística (2016). Exportaciones. November 2016. Available at: https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/exportaciones Retrieved: November, 2016.

DANE -Departamento Administrativo Nacional de Estadística (2015). *Resultados del 3er Censo Nacional Agropecuario*. Bogotá, Colombia. Available at: http://www.dane.gov.co/ Retrieved: December, 2016.

DNP - Departamento Nacional de Planeación (Colombia) (2015ª). Plan Nacional de Desarrollo 2014-2018: Todos por un nuevo país. Available at: https://www.dnp.gov.co/Plan-Nacional-de-Desarrollo Retrieved: January, 2016.

DNP - Departamento Nacional de Planeación (Colombia) (2015b). El campo colombiano: un camino hacia el bienestar y la paz. Misión para la transformación del campo. Available at: https://www.dnp.gov.co/programas/agricultura/Paginas/Informe-misi%c3%b3n-FInal.aspx Retrieved: November, 2016.

DNP–BID (2014). *Impactos Económicos del Cambio Climático en Colombia* – Síntesis. Bogotá, Colombia.

FAO–MADR. (2015). Colombia Pesca en Cifras/2014. Organización de las Naciones Unidas para la Alimentación y la Agricultura FAO- Ministerio de Agricultura y Desarrollo Rural MADR. 52 pp. Available at: https://www.minagricultura.gov.co/ministerio/direcciones/Documents/d.angie/PESCA%20EN%20CIFRAS%202014.pdf Retrieved: January, 2017.

FAO & Earthscan (2011). *The State of The World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk.* Rome, London.

FAO (2015b). FAO en Colombia. Available at: http://www.fao.org/colombia/fao-en-colombia/colombia-en-una-mirada/es/ Retrieved: December 2016.

FAO (2015c). Pérdidas y desperdicios de alimentos en América Latina y El Caribe. Boletín 2, April 2015. 31 pp. En: www.fao.org/3/I4655S.pdf Retrieved: November, 2016.

FAO (2016a). Proceedings of the International Symposium on the Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition. Available at: http://www.fao.org/3/a-i5922e.pdf Retrieved: December, 2016.

FAO (2012). *The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition*. Rome, Italy. FAO. 65 pp. Available at: http://www.fao.org/docrep/016/i3027e/i3027e.pdf Retrieved: March 2017.

FAO (2015a). *El estado de la inseguridad alimentaria del mundo*. 66 pp. Available at: http://www.fao.org/3/a-i4646s.pdf Retrieved: November, 2016.

FAO (2016b). The state of food and agriculture. Climate change, agriculture and food security. Available at: http://www.fao.org/3/a-i6030e.pdf Retrieved: December 2016.

Global Harvest Initiative (2016). 2016 Global Agricultural Productivity Report. Sustainability in an Uncertain Season. Available at: http://www.globalharvestinitiative.org/GAP/2016_GAP_Report.pdf Retrieved: January, 2017.

Gobierno Nacional (Colombia) (2013). *Plan Nacional de Seguridad Alimentaria y Nutricional (PNSAN) 2012–2019.* 66 pp.

Hansen, M.C., P.V. Potapov, R. Moore, M. Hancher, S.A. Turubanova, A. Tyukavina, D. Thau, S.V. Stehman, S.J. Goetz, T.R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C.O. Justice, and J.R.G. Townshend (2013). High-resolution global maps of 21st-Century forest cover change, *Science*, 342 (15 November), 850–853. Available at: http://earthenginepartners.appspot.com/science-2013-global-forest

Hodson de Jaramillo, E. y L.A. Díaz (2013). Uso de bioinoculantes en la agricultura: alternativa de manejo sostenible. *Biotecnologías e innovación: el compromiso social de la ciencia*. Hodson & Zamudio, Editores. Bogotá, Colombia, Editorial Pontificia Universidad Javeriana. ISBN 978-958-716-587-6

ICBF - Instituto Colombiano de Bienestar Familiar (2011). Encuesta nacional de la situación nutricional en Colombia 2010 - ENSIN. 509 pp. Available at: http://www.icbf.gov.co/portal/page/portal/PortalICBF/bienestar/nutricion/ensin/LibroENSIN2010.pdf Retrieved: March, 2017.

IDEAM, PNUD, MADS, DNP, CANCILLERÍA (2015a). Escenarios de Cambio Climático para Precipitación y Temperatura para Colombia 2011-2100. Herramientas Científicas para la Toma de Decisiones – Estudio Técnico Completo: Tercera Comunicación Nacional de Cambio Climático.

IDEAM-MADS, 2014. *Política Nacional para la Gestión Integral Ambiental del Suelo (GIAS).* Bogotá, Colombia. IDEAM-Ministerio de Ambiente y Desarrollo Sostenible. 138 pp.

IGAC (2012). Regiones geográficas de Colombia. Available at: http://geoportal.igac.gov.co/mapas_de_colombia/IGAC/Tematicos2012/RegionesGeograficas.pdf Retrieved: December, 2016.

IICA -Instituto Interamericano de Cooperación para la Agricultura (2015). *El fenómeno de "El Niño" en la agricultura de las Américas.* San José, Costa Rica. 19 pp.

INVEMAR, MADS y DIMAR-CCCP (2011). *Estrategia para el fortalecimiento del Sistema de Indicadores Ambientales Marinos y Costeros de Colombia.* Proyecto SPINCAM Colombia. Instituto de Investigaciones Marinas y Costeras INVEMAR, Ministerio de Ambiente y Desarrollo Sostenible y Dirección General Marítima, Centro de Investigaciones Oceanográficas e Hidrográficas del Pacífico. 16 pp. (Serie Documentos Generales No. 48).

James, C. (2015). *20th Anniversary of the Global Commercialization of Biotech Crops (1996 to 2015) and Biotech Crop Highlights in 2015.* ISAAA Brief No. 51. Ithaca, NY, USA. ISAAA.

Järup, L. & A. Akesson (2009). Current status of cadmium as an environmental health problem. *Toxicology and Applied Pharmacology,* 201-208.

Khatodia S., K. Bhatotia, N. Passricha, S.M.P. Khurana and N. Tuteja (2016). The CRISPR/Cas genome-editing tool: application in improvement of crops. *Frontiers of Plant Science,* 7:506.

Li T., B. Liu, M.H. Spalding, D.P. Weeks and B. Yang(2012). High-efficiency TALEN-based gene editing produces disease-resistant rice. *Nature Biotechnology,* 30:390–392

Li M., X. Li, Z. Zhou, P. Wu, et al. (2016). Reassessment of the four yield-related genes Gn1a, DEP1, GS3, and IPA1 in rice using a CRISPR/Cas9 system. *Frontiers of Plant Science*, 7:377.

Lozano, E.I. y J.C. Restrepo (2015). *El Papel de la Infraestructura Rural en el Desarrollo Agrícola* *en Colombia. Serie Borradores de Economía.* Banco de la República de Colombia. N° 904. Available at: http://www.banrep.gov.co/sites/default/files/publicaciones/archivos/be_904.pdf Retrieved: January 2017.

MADR - Ministerio de Agricultura y Desarrollo Rural (2016). Estrategia Colombia Siembra – Documento Estratégico. Available at: https://www.minagricultura.gov.co/planeacion-control-gestion/Gestin/ESTRATEGIA%20COLOMBIA%20SIEMBRA%20V1.pdf Retrieved: December, 2016.

MADS (2013a). *Política Nacional para la Gestión Integral Ambiental del Suelo (GIAS).* Ministerio de Ambiente y Desarrollo Sostenible, República de Colombia, Bogotá.

MADS - PNUD (2014). *Quinto Informe Nacional de Biodiversidad de Colombia ante el Convenio de Diversidad Biológica, Ministerio de Ambiente y Desarrollo Sostenible.* Programa de las Naciones Unidas para el Desarrollo, Bogotá, D.C., Colombia. 101 pp.

Marczak J. and P. Engelke (2016). *América Latina y el Caribe 2030 – Escenarios futuros.* Banco Interamericano de Desarrollo BID - The Atlantic Council of the United States.

MAVDT - Ministerio de Ambiente, Vivienda y Desarrollo Territorial (2010). *Política Nacional de Producción y Consumo Sostenible "Hacia una cultura de consumo sostenible y transformación productiva".* 71 pp. Available at: http://produccionmaslimpia.org/documentos/otros/polit_nal_produccion_consumo_sostenible%202010.pdf Retrieved: December 2016.

Mayorga, R., H. Benavides and G. Hurtado (2011). *Evidencias de cambio climático en Colombia con base en información estadística.* Bogotá, D.C. IDEAM. 34 pp.

Mazo-Echeverry, S. (2014). Panorama de la malnutrición en Colombia y el mundo. FAO. 6 pp. En: http://docplayer.es/18379233-Panorama-de-la-malnutricion-en-colombia-y-el-mundo.html Retrieved: January 2017.

Mejía-López, R. (2015). Balance preliminar 2015 y perspectivas de 2016. Sociedad de Agricultores de Colombia, SAC. Available at: http://www.sac.org.co/es/estudios-economicos/balance-sector-agropecuario-colombiano.html Retrieved: November, 2016.

Méndez-Fajardo S., J.A. Lara Borrero, G. Moreno and A. Ayala (2007). Estudio preliminar de los niveles de Cadmio en arroz, fríjoles y lentejas distribuidos en supermercados de Bogotá y plazas de Manizales. *Fitotecnia Colombiana* 7(2):40-47.

MPS–FAO–OSAN (2014). *Situación nutricional en Colombia bajo el enfoque de determinantes sociales.* Ministerio de Salud y Protección Social - Organización de las Naciones Unidas para la Alimentación y la Agricultura – FAO. Convenio 507-2013. Observatorio de seguridad alimentaria y nutricional (OSAN). Boletín No. 001/2014. 13 pp.

Naciones Unidas (2015a). Transformar Nuestro Mundo: La Agenda 2030 para el Desarrollo Sostenible. Available at: http://www.un.org/es/comun/docs/?symbol=A/69/L.85 Retrieved: January 2017.

Naciones Unidas (2015b). Objetivos de desarrollo sostenible. 17 objetivos para transformar nuestro mundo. Mayo 27 de 2015. Available at: http://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/

Narváez, A. (2015). El mercado de la Biotecnología en Colombia. Diciembre 2015. Estudios de Mercado ICEX España Exportación e Inversiones- Available at: https://www.camarabilbao.com/ccb/contenidos.downloadatt.action?id=6293943 Retrieved: December 2016.

OCDE (2015). Revisión de la OCDE de las Políticas Agrícolas: Colombia 2015 Evaluación y Recomendaciones de Política. Available at: http://www.oecd.org/countries/colombia/OECD-Review-Agriculture-Colombia-2015-Spanish-Summary.pdf Retrieved: November 2016.

OIRSA - Organismo Internacional Regional de Sanidad Agropecuaria, SV (2014). El OIRSA alerta sobre riesgos sanitarios y fitosanitarios ante el posible aparecimiento de El Niño (en línea). San Salvador, SV. Available at: http://bit.ly/1LtH8k2 Retrieved: October 2015.

Ortega-Bonilla, R.A. y D.M. Chito-Trujillo (2014). Valoración del estado nutricional de la población escolar del municipio de Argelia, Colombia. *Revista de Salud Publica,* 16(4):547-559. Available at: https://helpx.adobe.com/es/reader.html Retrieved: March, 2017.

OSAN. Observatorio de Seguridad Alimentaria y Nutrición en Colombia. Available at: http://www.osancolombia.gov.co/ Retrieved: December 2016.

Polle A. and A. Schützendübel (2003). Heavy metal signalling in plants: linking cellular and organismic responses. In: Hirt H. and K. Shinozaki, Editors. *Plant Responses to Abiotic Stress*. Springer-Verlag. Berlin-Heidelberg. pp. 187–215.

Poveda, G., D.M. Álvarez and O. A. Rueda (2011). Hydro-climatic variability over the Andes of Colombia associated with ENSO: a review of climatic processes and their impact on one of the Earth's most important biodiversity hotspots. *Climate Dynamics,* 36 (11-12), 2233-2249. DOI: 10.1007/s00382-010-0931-y

Poveda, G., S. López, A. Isaza and P.R. Waylen (2017), Geographic delimitation of regions exhibiting bimodal, transitional and unimodal annual cycles of rainfall within the inter-tropics, *Earth Interactions*, Submitted for publication.

Rabatel, A., et al. (2013). Current state of glaciers in the tropical Andes: a multi-century perspective on glacier evolution and climate change. *The Cryosphere*, 7, 81-102.

Ramírez-Villegas, J., M. Salazar, A. Jarvis, et al. (2012). A way forward on adaptation to climate change in Colombian agriculture: perspectives towards 2050. *Climatic Change* 115: 611. Doi: 10.1007/s10584-012-0500-y

Sarmiento, O.L. , D.C. Parra, S.A. González, I. González-Casanova, A.Y. Forero, and J. García (2014). The dual burden of malnutrition in Colombia. *American Journal of Clinical Nutrition,* 100(6):1628S-1635S. Doi: 10.3945/ajcn.114.083816. Epub 2014 Oct 29. Available at: https://www.ncbi.nlm.nih.gov/pubmed/25411305 Retrieved: March, 2017.

Silva-Sarmiento, G. (2016). *Desnutrición en Colombia- Desde lo social, lo económico y lo político.* 19 pp. Available at: https://scp.com.co/wp-content/uploads/2016/06/1.-Desnutricion.pdf Retrieved: December, 2016.

The Economist Intelligence Unit. 2016. Global Food Sustainability Index 2016. The Economist Intelligence Unit Ltd., UK. Available at: http://foodsustainability.eiu.com/ Retrieved: April 2017.

UPME - Unidad de Planeación Minero-Energética (2016), Plan de Expansión de Referencia Generación-Transmisión 2016-2030, Bogotá, Colombia. 479 pp.

Valencia, A. (2012). Editorial. Federación Nacional de Cafeteros. Detrás del café de Colombia. Perspectiva desde el origen. Edición No. 5. Junio 2012. Available at: http://www.cafedecolombia.com/cci-fnc-es/index.php/comments/una_mirada_al_estado_actual_y_al_futuro_de_la_produccion_de_cafe_en_colombi/

Waltz E. (2016). CRISPR-edited crops free to enter market, skip regulation. *Nature Biotechnology* 34, 582.

WHO (2013). Fact Sheet 311. Obesity and overweight. Available at: http://www.who.int/mediacentre/factsheets/fs311/en/ Retrieved: December 2016.

Acknowledgments

The authors would like to thank Dr. **Enrique Forero**, President of the Colombian Academy of Exact, Physical and Natural Sciences, for his support for this chapter, and **Neil Palmer**, CIAT photographer, for the photograph of the popular market in the Department of Huila, Colombia.

Box 2

The Water Footprint in the Agricultural Sector

Carolina María Rodríguez Ortiz. Center of Science and Technology of Antioquia. crodriguez@cta.org.co
Claudia Patricia Campuzano Ochoa. Center of Science and Technology of Antioquia, University Institution Colegio Mayor of Antioquia. ccampuzano@cta.org.co; claudia.campuzano@comayor.edu.co

The concept of the "water footprint" was developed by A. Hoekstra and A. Chapagain in 2003, based on the earlier concepts of virtual water (Allan, 1993) and green water (Falkenmark, 1995).

The concept of VIRTUAL WATER was presented by Tony Allan when he studied the possibility of importing virtual water as a partial solution to the problems of water scarcity in the Middle East and is defined as the quantity of water used directly and indirectly for the realization of a good, product or service. Every object that surrounds us needs thousands of liters of water to be produced, we call this water "virtual" because we do not see it; however, it is present in the food, goods and services we consume on a daily basis. This refers to the water that is contained in the products and does not return to the territory from which it was extracted for its production. In this sense, when importing or exporting products, we import or export water.

The concept of Green Water originally meant soil moisture and was first included by Professor Malin Falkenmark in order to draw attention to the water available for biomass growth and its participation in evapotranspiration. The FAO updated the definition of GREEN WATER, considering it as the vertical flow of water, ie water stored in the soil that supports rainfed vegetation and does not recharge surface or underground water sources. In this way, a definition of BLUE WATER was implicitly generated, which came to mean horizontal water flow, ie, surface water sources, rivers and lakes, and groundwater sources, aquifers. (FAO, 2000).

This new concept takes into consideration the use of hidden water employed along the chain of production of goods or services for consumption. Hidden water is the indirect use of water in producing food and products for consumption. The water footprint has three components:

1. **The green water footprint:** Refers to the consumption of groundwater stored from rainfall that maintains vegetation without irrigation. It meets a need without requiring human intervention.
2. **The blue water footprint:** Refers to the consumption of water extracted from surface or underground to meet the needs of a process. It measures the loss of available water (evaporation, change of watershed, product incorporation) due to specific consumption. It requires human intervention.
3. **The grey water footprint:** Is defined as the amount of fresh water required to absorb the amount of pollution in a body of water, taking into account the environmental quality norms and limits established for quality for both the environment and people.

Many countries, economic sectors and companies have begun to incorporate the concept as a complementary indicator of Integral Water Resource Management (IWRM). In 2010 Colombia began an initiative for the estimation of the water footprint in the agricultural sector. Studies were developed at the basin scale using the methodology of the IWFN with a Multisectoral Assessment of the Water Footprint in the Porce river basin. This study was an essential first step to allow the incorporation of the Water Footprint concept into a major document and consultation on water issues in Colombia to be used as a basis for decision making (the National Water Study - ENA 2014).

Specifically, the agricultural sector is recognized as one of the main water consumers, concentrating 85% of the world's freshwater consumption (Mekonnen & Hoekstra, 2011; Zeng et al., 2012). Irrigated agriculture accounts for 19% of the total area cultivated worldwide (ECLAC & DNP, 2014). At the

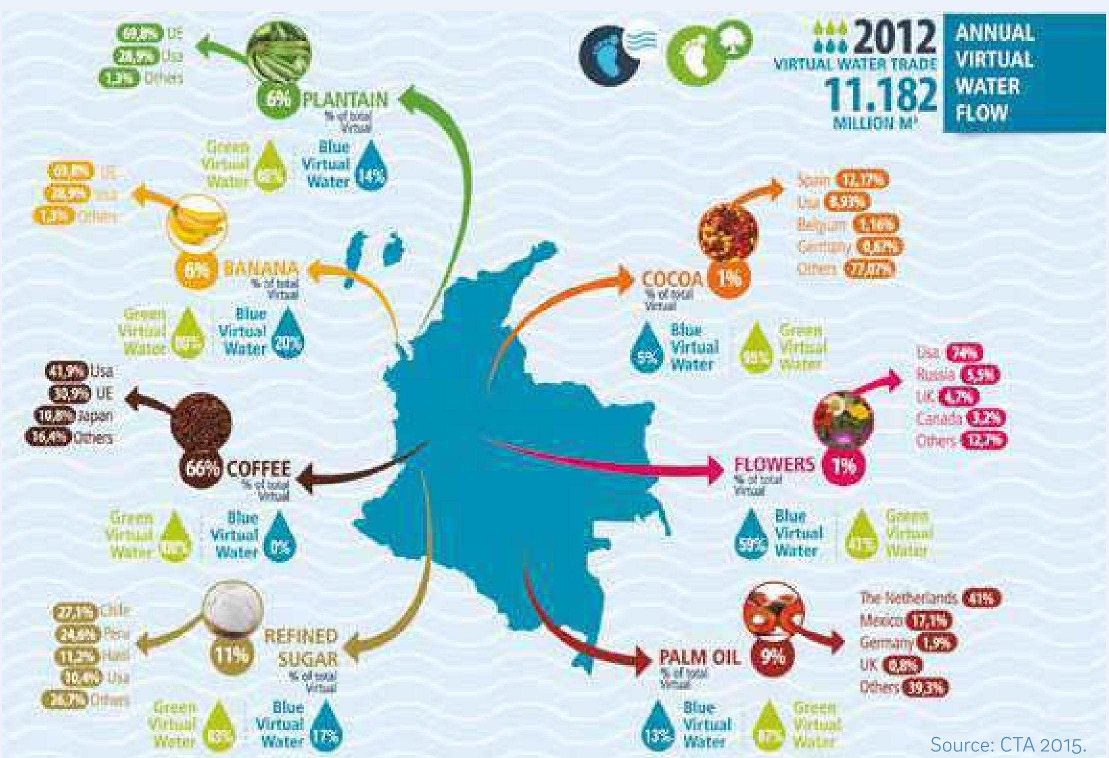
Table 1. Our Water Footprint. How Much Water does it take to Produce...

1 litre tap water > **1 litre**	1 kg corn > **900 litres**	1 whole orange > **50 litres**	1 dozen eggs > **2,400 litres**
1 litre bottled water > **5 litres**	1 kg wheat > **1,300 litres**	1 glass orange juice > **170 litres**	1 kg chicken meat > **3,900 litres**
1 cup tea > **30 litres**	1 kg soybeans > **1,800 litres**	1 whole apple > **70 litres**	1 kg pork > **4,800 litres**
1 cup coffee > **140 litres**	1 loaf bread > **960 litres**	1 glass apple juice > **190 litres**	1 kg beef > **15,500 litres**

Source: www.waterfootprint.org

international level, the organization that has led the standardization of the concept is the Water Footprint Network (WFN). The WFN has already carried out global analyzes of the water footprint of many products, which can be consulted on the WFN website; in **Table 1** are some examples.

In Colombia, 70% of the water use is attributed to the agricultural sector, corresponding to irrigation water (blue water). Even though the use of irrigation water in Colombia is marginal, compared to the use of green water (IDEAM, 2015), which corresponds to 89% of agricultural water use, we evaluate the virtual water flow of our export products, as follows:



Source: CTA 2015.

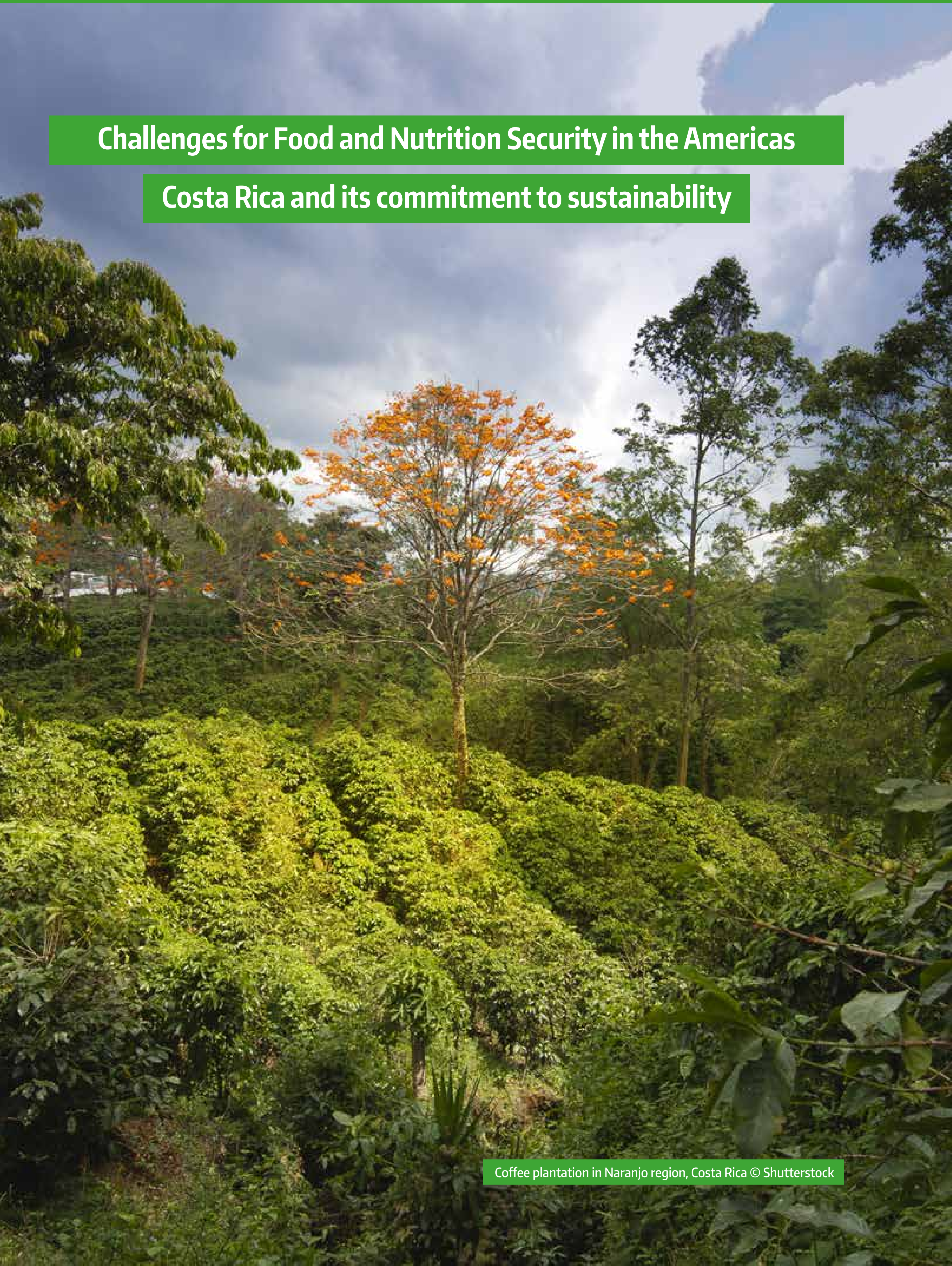
In Colombia, developments based on the concept of water footprint are needed to integrate the agricultural sector and the environmental sector. This concept is valuable in supporting decision making regarding the productive zoning of the country and the identification of the fitness of the territory for establishing highly demanding irrigated water crops, without endangering the ecosystems and the goods and services they offer.

The water footprint has proven to be a robust tool to communicate understandable results for all sectors and actors present in a watershed. The results and conclusions aim to become a tool that supports other indicators designed for the integral management of water resources, in the local and national contexts, as well as in a tool to better manage our consumption habits.

It is important to remember when interpreting the water footprint that it is not a measure of relative scarcity. That is there are resources other than water such as labor, energy and capital that are also scarce and whose level of use is not captured by the concept.

Challenges for Food and Nutrition Security in the Americas

Costa Rica and its commitment to sustainability



Coffee plantation in Naranjo region, Costa Rica © Shutterstock

Costa Rica

[1] Víctor M. Jiménez, [2] Catalina Acuña-Gutiérrez, [3] Marilín Agüero, [4] Alfredo Alvarado, [5] María L. Ávila-Agüero, [6] Marialis Blanco, [7] Marcela Dumani, [8] Patricia Esquivel, [9] Andrés Gatica-Arias, [10] Eric Guevara, [11] Andrés Hernández-Pridybailo, [12] Raquel Hernández, [13] Andrea Holst, [14] Karol Madriz, [15] Julio F. Mata-Segreda, [16] Olman Quirós-Madrigal, [17] Ricardo Radulovich, [18] Álvaro Salas-Chaves, [19] Paúl Solórzano-Cascante

Costa Rica should support development models that consider nature; **its production systems should be more environmentally friendly** by reducing the use of agrochemicals, and making more and better use of soil, pest control, water resources, waste and residue management practices.

Summary

As a small nation with high biodiversity and an extensive system of protected areas, Costa Rica will face particular challenges regarding food security over the next few years. Thus, whatever development model the country chooses, it must achieve a compromise between conservation and production (agricultural, energy and so on). Although the country's malnutrition levels are below 5%, socioeconomic asymmetries - which have been increasing in recent years - put a growing proportion of the population at risk. Costa Rica also has a high disaster risk (due to volcanism, seismicity and climatic events), which is likely to be increased by climate change. Moreover, the country's population is aging and growing very little in absolute numbers, which is also reflected in the predominance of farmers growing older. It is important to mention that the country relies heavily on food imports, mainly of basic grains, to cover the needs of its population. Food production uses a large amount of imported seed and propagating material, which are often not suited to local conditions, as well as very intensive use of agrochemicals, with negative consequences for health and the environment. Over the next few years, it will be crucial to maintain solid public higher-education and research structures in the agricultural field. Although there is no shortage of water in the country in general, water is unevenly distributed at certain times and between regions. Another important challenge is that overweight and obesity show an increasing and alarming upward trend.

A comprehensive approach considering many actors and positions is required to ensure food and nutrition in Costa Rica over the next fifty years. To this end and to be consistent with a long tradition that has earned the country recognition, the government should continue with its policies to conserve protected areas and biodiversity. At the same time, it should increase productivity and yields in land with a clear agricultural vocation. This is important for reducing dependence on imported food in order to meet the basic needs of the country's inhabitants. In order to achieve broad access to sufficient nutritious food, it is essential to reduce the gaps in the population's socioeconomic conditions. Production systems should be more environmentally friendly by reducing the use of agrochemicals, and making more and better use of soil, and integrated pest, water resources, waste and residue-management practices. It will also be important to encourage, where possible, the use of local species or those adapted to local conditions, some of which are little known and underutilized, which are important for the diet beyond caloric intake (as a source of micronutrients, vitamins and functional compounds). This requires considering the enormous biodiversity present in the country and encouraging genetic improvement in order to reduce dependence on imported seed and propagation materials, since

these were often developed for other climatic and edaphic conditions, as well as different productive systems. It is essential to achieve greater differentiation of products that follow certain quality standards in terms of production, marketing and nutritional value over the next few years, and for this to provide some form of competitive advantage. Prevention and mitigation measures must be taken against disasters that can be caused by specific events (hurricanes, volcanoes, earthquakes, etc.) or climate change. It will be important to continue the construction and maintenance of water collection, storage and supply works to reduce water shortages in particular areas and at specific times. Agricultural activity must be made attractive so that young people choose to remain in the countryside rather than migrating to cities. State funding for research on priority issues for the country must be increased, and incentives created so that the private sector also becomes interested in supporting research. It is also necessary to continue promoting high-level human resource training, preferably at top universities abroad, to promote agricultural research. Likewise, technical and vocational education must be promoted with the participation of various institutions (such as the Instituto Nacional de Aprendizaje, technical and vocational colleges and dual education). The country must consider a wide range of options for agricultural production with a view toward ensuring food and nutrition for its inhabitants. This framework must consider all the (bio)technological options, provided they do not conflict with the environment and health. It is also essential to continue and intensify programs that seek to promote healthy eating habits and encourage physical activity among the population.

I. Features of the country

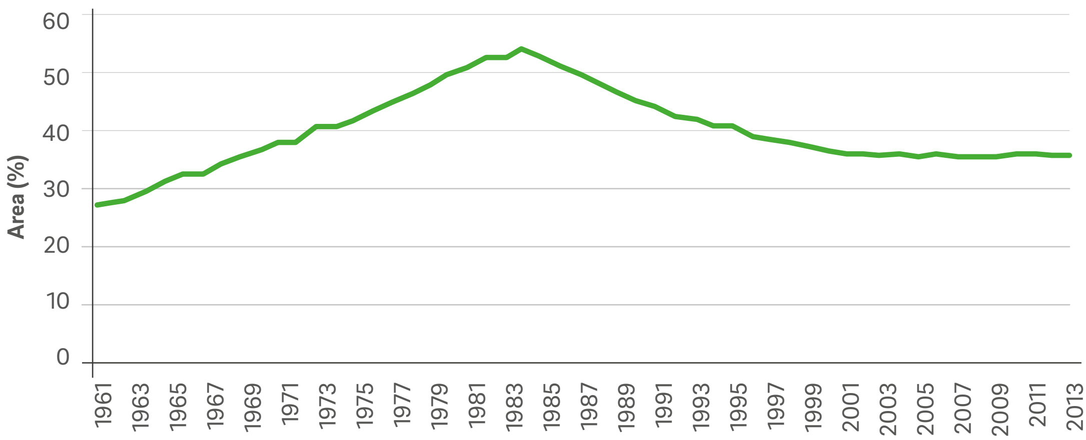
a. Physical dimensions, inventory of cropland, landscape and environmental diversity

Costa Rica, which has not had an army since 1948, is the third smallest country in Central America, with an area of 51,100 km^2. In the past 50 years the largest area devoted to agricultural activities was achieved in 1984, with 53.8% of the national territory. This figure gradually declined year after year until 2000, and thereafter remained fairly stable until it reached 35.6% in 2013 (**Figure 1**). Forest cover has increased since 2000, reaching 51% in 2010. That same year, 1.54% of the land under cultivation was irrigated.

Despite its small size, the country boasts a diversity of landscapes ranging from those at sea

[1] Víctor M. Jiménez, Coordinator: Center for Grain and Seed Research (CIGRAS) and Institute for Agricultural Research (IIA), University of Costa Rica, 2060 San Pedro, Costa Rica; Food Security Center, University of Hohenheim, 70599 Stuttgart, Germany, victor.jimenez@ucr.ac.cr **[2] Catalina Acuña-Gutiérrez,** Center for Grain and Seed Research (CIGRAS), University of Costa Rica, catalina.acuna@ucr.ac.cr **[3] Marilín Agüero,** Institute of Agricultural Research (IIA), University of Costa Rica, marilin.aguero@ucr.ac.cr **[4] Alfredo Alvarado,** Center for Agronomic Research, University of Costa Rica, alfredo.alvarado@ucr.ac.cr **[5] María L. Ávila-Agüero,** Head of Infectology Service, National Children's Hospital, San José, Costa Rica, avilaaguero@gmail.com **[6] Marialis Blanco,** Mayca/Sysco, Alajuela, Costa Rica, marialis55@gmail.com **[7] Marcela Dumani,** School of Nutrition, University of Costa Rica, marcela.dumani@ucr.ac.cr **[8] Patricia Esquivel,** School of Food Technology, University of Costa Rica, patricia.esquivel@ucr.ac.cr **[9] Andrés Gatica-Arias,** School of Biology, University of Costa Rica, andres.gatica@ucr.ac.cr **[10] Eric Guevara,** Center for Grain and Seed Research (CIGRAS), and School of Agronomy, University of Costa Rica, eric.guevara@ucr.ac.cr **[11] Andrés Hernández-Pridybailo,** Center for Grain and Seed Research (CIGRAS), and School of Agronomy, University of Costa Rica, andres.hernandezpridybailo@ucr.ac.cr **[12] Raquel Hernández,** School of Nutrition, University of Costa Rica, and Municipality of Santa Ana, San José, Costa Rica, hernandezcor@hotmail.com **[13] Andrea Holst,** Center for Grain and Seed Research (CIGRAS), University of Costa Rica, andrea.holst@ucr.ac.cr **[14] Karol Madriz,** Ministry of Health, San José, Costa Rica, kmadrizmo@gmail.com **[15] Julio F. Mata-Segreda,** School of Chemistry, University of Costa Rica. julio.mata@ucr.ac.cr **[16] Olman Quirós-Madrigal,** School of Agricultural Economics and Agribusiness, University of Costa Rica, olman.quiros@ucr.ac.cr **[17] Ricardo Radulovich,** School of Agricultural Engineering and Biosystems, University of Costa Rica, ricardo.radulovich@ucr.ac.cr **[18] Álvaro Salas-Chaves,** Medical Specialist in Health Service Administration, Member of the Board of Directors of the Central America Health Care Initiative (CAHI), alvarosalas158@gmail.com **[19] Paúl Solórzano-Cascante,** Center for Grain and Seed Research (CIGRAS), and School of Agronomy, University of Costa Rica, 2060, San Pedro CR, paul.solorzanocascante@ucr.ac.cr

Figure 1. Area of country used for agricultural activities (%)



Source: The World Bank

level, through medium-sized mountains and the Central Valley (900-1,200 meters above sea level [masl]), where most of the population lives, to the high mountains - located mainly in the Central Volcanic Cordillera and the Cordillera de Talamanca (where Cerro Chirripó is located, its 3,819 meters making it the highest one in the country). The diversity of microclimates generated by such heterogeneous landscapes, as well as its geographic position, means that, despite its small area (0.03% of the earth's total), the country is home to nearly 4% of the species thought to exist worldwide, making it one of the 20 countries with the greatest biodiversity. All this is protected by an extensive system of conservation areas, which guarantees the protection of more than 25% of the country's territory.

b. Demographic features and future trends

On June 30, 2016, according to the Instituto Nacional de Estadística y Censos (INEC), the estimated population of Costa Rica was 4,890,379, with 22% of the population under 14, 17% ages 15 to 24, 44% between 25 and 54, 9% between 55 and 64, and 8% ages 65 and over. By 2013 the overall fertility rate was 1.76 children per woman, which is much lower than the replacement level (2.1 children per woman) and also 5.3% lower than it was two years earlier, reflecting the tendency to have fewer children. The low birth rate, coupled with high life expectancy at birth (78.8 years in 2015), mean that Costa Rica's population is aging. It is estimated that by 2025, 11.5% of the population will be 65 or older (600,000 people).

In assessing these numbers it is important to consider the situation of immigration in Costa Rica. In 2011, 9% of the country's population was born abroad. Nearly 75%, or 386,000, were from Nicaragua, 4.3% from Colombia, 4.1% from the US, 2.9% from Panama and 2.4% from El Salvador. Here it is important to note, for example, that the overall fertility rate of women of childbearing age of certain other nationalities is higher than that of Costa Ricans.

By 2030, Costa Rica is likely to have a population of 5.6 million, a 15% increase over 2015. This will confirm the decline in the population growth rate due to a decrease in the birth rate and probably a reduction in immigration.

c. Status of Food and Nutrition Security

FAO data show that undernourishment levels in Costa Rica are below 5% and have remained stable over the past 25 years (FAO, 2015a). Global malnutrition (proportion of children under 5 with low weight for their age) for the 2005-2012 period in Costa Rica was 1.1%, the second lowest in Latin America after Chile. By 2015, food availability was 2,960 calories per day per person, which is more than enough to meet the population's minimal requirements.

Most indicators show a clear trend toward a decline in the proportion of the population at risk of food insecurity, particularly of malnutrition in children under 5 and chronic malnutrition (FAO, 2015b). However, the latest report of the State of the Nation (Estado de la Nación), delivered in November 2015, indicates that the country does not have statistics that allow it to "accurately estimate its degree of food and nutrition security or insecurity", coupled with a situation of dependency and vulnerability in its food availability, as well as socioeconomic asymmetries affecting food access (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2015). Accordingly, a sector of the population does not have its right to food guaranteed, since it faces difficulties in relation to food access and availability.

d. Farming Modalities

Data from the 2014 Agricultural Census show that Costa Rica has a total of 557,888.6 hectares (ha) under perennial agricultural crop cultivation (excluding forest plantations) and 133,249.8 ha planted with annual crops (**Table 1**) (INEC, 2015a). Smaller productive units (farms) tend to grow crops such as maize, beans, vegetables, palm trees, fruit trees, coffee and some livestock (mainly dual-purpose), whereas larger farms produce banana, sugar cane, rice, pineapple, orange, tilapia and milk. Compared with the situation in the rest of Central America, subsistence agriculture is extremely limited in Costa Rica (IICA, 2011).

Table 1. Main agricultural crops in Costa Rica according to the planted area, 2014

	Crop	Area (% of total area for this type of crop)
Perennial (557 888 ha)	Coffee	23.8
	Oil palm	18.8
	Sugar cane	18.4
	Banana	14.6
	Pineapple	10.6
Yearly (133 249 ha)	Rice	43.9
	Bean	14.6
	Corn	11.8
	Cassava	11.3
	Cantaloupe	4.4

e. Self-sufficiency in agricultural production

Costa Rica is not self-sufficient in terms of the production of the food consumed by its population. In basic grains, particularly rice, beans and corn, there is a clear trend toward a decrease in local production and an increase in the amount imported. A similar pattern can be observed in vegetable production. Conversely, from 2005 to 2011 there was a 65% increase in fresh fruit production, with a 20% increase in the area planted. Livestock production also saw an increase in the period 2003-2007 (Ministerio de Salud, 2011).

f. Main export/import crops and markets

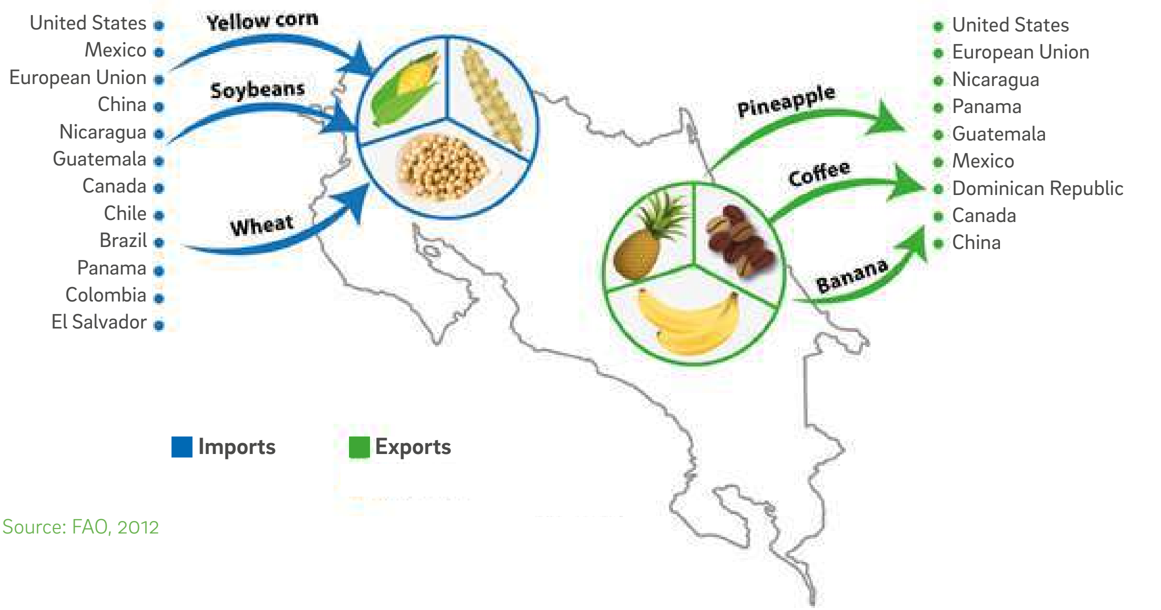
In 2014, the Costa Rican agricultural sector accounted for 22.8% of the value of the country's exports ($2,574.4 million USD), while the livestock and fishing sectors contributed 3.2% ($366.5 million USD) (PROCOMER, 2014). 2012 Statistics show that the country's main agricultural products are bananas, pineapples and coffee and that it imports yellow corn, soybeans and wheat (**Figure 2**), all essential to the country's food security.

g. Potential sources of instability in Food and Nutrition Security

Costa Rica is prone to natural disasters, such as volcanic eruptions, drought, floods, hurricanes and earthquakes, which, according to the GlobalRisksReport 2016, makes it the world's fifth country most exposed to natural disasters and eighth on the risk index. Although over 120 mostly extinct volcanic formations have been identified, there are five active volcanoes, three very close to major population centers, whose emanations not only have a direct effect on people's health, but may also affect crops.

Although since the time historical records began to be compiled, Costa Rica had not directly experienced a hurricane hit until Hurricane Otto in 2016, it has suffered their indirect impact, mainly in the form of heavy rains and floods, as well as the effects of El Niño and La Niña. Moreover, the country's location in a subduction zone where three

Figure 2. Main agricultural products that Costa Rica exported and imported in 2012



Source: FAO, 2012

large tectonic plates interact (Cocos, Caribbean and Nazca) means that earthquakes are very frequent, sometimes with magnitudes of between 7.0 and 7.7. These earthquakes, as well as major meteorological phenomena, have repeatedly caused severe damage to road infrastructure and communications. At the same time, it is estimated that anthropogenic climate change will cause a nationwide temperature rise, with an increase in rainfall in the Caribbean and southern regions of Costa Rica and a decrease in N and NE areas (CCAFS, 2014).

h. Main agricultural challenges

The greatest challenges for agriculture in Costa Rica, in terms of food security, are probably linked to its current agroexport model, which has forced the country to import a considerable percentage of its basic foodstuffs. It is also important to achieve more environmentally-friendly production, which involves a careful review of agrochemical use, waste management and residual biomass use. The use of state-of-the-art technologies and varieties adapted to local conditions is also crucial to raising yields, since in some crops, these are far below world standards. Water management, for both irrigation and drainage, must be examined in regard to climate change. Socioeconomic aspects must be considered, especially farmers' access to markets. This is crucial because farmers in Costa Rica are getting older, since young people do not wish to remain in the countryside.

II. Institutional environment

a. Universities and Research Institutes

Data from 1999 indicate that 60% of agricultural research in Central America was conducted in Costa Rica, with a very high percentage in the four public universities at that time - University of Costa Rica (UCR); National University (UNA); Technological Institute of Costa Rica (ITCR), and the State Distance University (UNED) – and mostly at UCR. Founded in 2008, the National Technical University (UTN) has also become increasingly involved in the agricultural sphere. Public universities usually have relatively highly qualified academic staff, a significant proportion of whom have completed postgraduate training abroad. These institutions have been growing their infrastructure as a result of which some centers and institutes have the latest technological advances in their respective fields. The country also has public non-state research centers focused on specific crops, financed by the producers themselves, such as the Sugarcane Research and Extension Division

(Departamento de Investigación y Extensión de la Caña de Azúcar - DIECA), the Center for Coffee Research (Centro de Investigaciones en Café - CICAFE) and The National Banana Corporation (Corporación Bananera Nacional - CORBANA). The National Biodiversity Institute (Instituto Nacional de Biodiversidad - INBio) is a non-governmental, non-profit organization focusing on research and management regarding the country's biodiversity. The recently founded National Biotechnology Innovation Center (Centro Nacional de Innovaciones Biotecnológicas - CENIBiot) seeks to link the country's business and academic sectors in order to scale-up agroindustrial research projects that will boost productivity. The Tropical Agricultural Research and Higher Education Center (Centro Agronómico Tropical de Investigación y Enseñanza - CATIE), the Inter-American Institute for Cooperation on Agriculture (Instituto Interamericano de Cooperación para la Agricultura - IICA), the EARTH University, the Tropical Science Center (Centro Científico Tropical - CCT) and the Organization for Tropical Studies (Organización para Estudios Tropicales - OTS) are international organizations located in Costa Rica, which have been important players in the country's agricultural research.

b. National Agricultural Research System

Although there were previous programs and initiatives, the current structure of the state regarding agricultural research dates back to 1996, when the Ministry of Agriculture and Livestock (Ministerio de Agricultura y Ganadería - MAG) set up the National System of Agricultural Research and Technology Transfer (Sistema Nacional de Investigación y Transferencia de Tecnología Agropecuaria - SNITTA) to promote technological changes in the sector, as well as the Foundation for the Development and Promotion of Research and Transfer of Agro-Technology (Fundación para el Fomento y Promoción de la Investigación y Transferencia de Tecnología Agropecuaria de Costa Rica - FITTACORI), as a private, non-profit entity for public utility that looks for resources from national agencies and international organizations to undertake projects in the agricultural sphere. In 2001, the National Institute for Innovation and Transfer of Agricultural Technology (Instituto Nacional de Innovación y Transferencia en Tecnología Agropecuaria - INTA) was created within MAG, which took over the functions of the Research Management (Chaves-Solera, 2011).

i. **Research Capacity Development.** The country has a limited number of trained personnel. Moreover, low investment in agricultural research is a serious handicap to implementing new technologies. There is also an urgent need to prioritize working lines of a multidisciplinary nature, particularly those that foster interaction between the private and public sectors, in a model that includes state universities and other centers. It is important to note that the existing infrastructure means that work is carried out on a limited scale. Investment is therefore required to enable research to be undertaken on a larger scale.
ii. **Local strengths.** In addition to the fundamental role of public universities in training qualified professionals, as well as the research they conduct on current issues of enormous importance for the agri-food sector, the country has a number of strengths worth highlighting. On the one hand, the production of basic research as a result of projects owned by state universities and/or in cooperation with institutions abroad has allowed the generation of knowledge which in many cases is used in practical applications that have a favorable impact on the sector. There is also the knowledge gained from perennial crops over time, resulting of many years of research, which made the country a leading producer of crops such as coffee, bananas and pineapple.
iii. **Scientific collaboration networks inside and outside the country.** RedCONARE is an advanced research and education network of the National Council of University Presidents (Consejo Nacional de Rectores - CONARE), in which the country's public universities participate. Through this network, the country is linked to RedCLARA, which develops and operates the only advanced Internet network in the Americas. The country also participates in several international networks linked to the agri-food field, such as: the Cooperative

Regional Potato Program (Programa Regional Cooperativo de Papa), organized and supported by the International Potato Center (CIP), the Regional Food Security and Nutrition Programme for Central America (Programa Regional en Seguridad Alimentaria y Nutricional para Centroamérica - PRESANCA II) and the Regional Programme for Food and Nutritional Security Information Systems (Programa Regional de Sistemas de Información en Seguridad Alimentaria y Nutricional - PRESISAN), both funded by the European Union (EU) and run by the General Secretariat of the Central American Integration System (Secretaría General del Sistema de la Integración Centroamericana - SG SICA). It is also important to consider the additional efforts that have allowed public higher-education institutions in Costa Rica to become involved in international networks. An example is the University of Costa Rica, which acts as regional coordinator for Latin America of the Food Security Center of the University of Hohenheim in Germany with the participation of partners in Thailand, the Philippines, Kenya and Benin.

iv. **Access to and maintenance of databases for monitoring farming systems.** As for databases related to the sector, MAG hosts the Costa Rican Agricultural Sector Information System (Sistema de Información del Sector Agropecuario Costarricense - InfoAgro), which provides updated statistics on the economy, trade and agricultural production (www.infoagro.go.cr). INEC tools to enable users to find useful information for the agricultural, trade and health sectors include the National Information System on Food and Nutrition Security (Sistema Nacional de Información en Seguridad Alimentaria y Nutricional - sistemas.inec.cr/snisan), which provides the most significant indicators on nutritional status, anthropometry, and access to and the availability of food and basic services. The Costa Rican Forest Resources Information System (Sistema de Información de los Recursos Forestales de Costa Rica - SIREFOR) is a national program that collects, processes, analyzes, systematizes and periodically publishes information concerning the condition of forest-related activities and resources in Costa Rica.

c. Development of skilled workforce and state of national education systems

In Costa Rica, both primary and secondary education (for a total of 11-12 years, depending on the modality) are compulsory and free in the public education system. In 2012, 91.1% of elementary students and 87.3% of middle school students attended public schools and high schools. By 2012, practically 100% of the population of the corresponding age had completed elementary education while 75% had finished middle school (Castro-Valverde 2013). For diversified education, which includes the last two to three years of high school, there are several options including scientific, humanistic, artistic, environmental, sports and other institutions. Professional technical education includes the following modalities: trade and services, industrial and agricultural. In addition to the five state universities mentioned earlier, the country has over 50 private universities approved by the National Council of Private Higher Education (Consejo Nacional de Enseñanza Superior Universitaria Privada- CONESUP). There are over 20 public and private higher education institutions that offer technical degrees (instituciones parauniversitarias) approved by the Higher Education Council (Consejo Superior de Educación). There is also the National Learning Institute (Instituto Nacional de Aprendizaje - INA), a free, public, autonomous entity, created in 1965 to promote and develop professional training and education for those ages 15 to 20 who have successfully completed at least sixth grade.

d. Relative contributions of the public and private sectors

In 2014, Costa Rica invested 0.58% of GDP in Research and Development, an increase of 0.02% over the previous year, yet still well below the average for Latin America and the Caribbean (0.82%). As for human resources, in 2014, the country had 1.1 researchers (equivalent to full days) per thousand inhabitants of the economically active population, above the regional average of 0.8, and surpassed only by Argentina and Brazil.

The contribution of public funds to research and development, provided mainly by state universities and the public sector, was 67% in 2013 ($184 million), more than twice that of the business sector (32%). The remaining 1% was provided by non-profit organizations.

e. Outlook for the future

The Costa Rican Government, through the Ministry of Science, Technology and Telecommunications (MICITT), expects to reach the leading country in the region in terms of the number of researchers equivalent to full days per thousand inhabitants of the economically active population: Brazil (1.2). Regarding technological innovation, it would be important to strengthen research with state and private funding. The Costa Rican Development Bank System (Banca para el Desarrollo) should establish a credit plan for innovation, and encourage the development of products that take advantage of the country's biodiversity, often underused and barely researched. In terms of human resource training, university education must be renewed by reviewing the curricula, which in many cases, have not been changed for years, and by identifying and establishing new, more interdisciplinary degree programs. It is also important to strengthen technical training in the country. The "Dual Education" proposal (currently supported by Germany) is an alternative worth pursuing.

III. Resource and Ecosystem Features

a. Water resources and challenges in the next 50 years

The country has experienced severe water shortages, mainly for human consumption in the Central and Central and North Pacific regions, with a seasonal regime of up to five months without rain between November and May. Because of the total amount of rainfall, there should not be any water shortage in any region. It is therefore essential to improve water management and expand the area under irrigation with the same water available. The problem of overexploited aquifers has also been exacerbated, not only by the extreme water demand for new housing and tourist developments and insufficient recharge, but also by saline intrusion in Pacific coastal aquifers. The high cost of developing new sources of water in the required amounts - especially in a context of the depletion of traditional sources - coupled with the lack of water in the dry season, pose a short-term challenge, which will probably require the enactment of new laws. However, despite all the planned and ongoing efforts, in the future it may be necessary to implement non-conventional measures such as geo-engineering. This will imply, at least, more mega- water collection works in areas with high precipitation and rain flow, probably in conjunction with the country's hydroelectric generation and with the ultimate goal of providing water to cities. On the Pacific coast, especially the North and Central parts, the situation will be extremely severe and it may become necessary to implement seawater desalination plants.

b. Soil resources and challenges over the next 50 years

The variety of Costa Rican soils is as great as that of the agroecosystems developed in the various ecological niches by domestic and international farmers and researchers who have encouraged the use of increasingly environmentally-friendly agricultural management practices. Past soil-management mistakes serve as lessons to prevent their repetition, although they still prevail in large-scale, industrial export crop plantations. Thus, new agricultural practices - such as the use of soil inoculants (*Rhizobium* and mycorrhiza) and compost, minimal tillage, planting associated crops and greenhouse operations - are common in the Costa Rican landscape. These new approaches are expected to improve soil conservation, both from the point of view of chemical contamination and that of physical erosion. It is therefore essential for studies in the next fifty years to continue exploring areas such as carbon sequestration, degraded land reclamation, organic/biological agriculture, inoculant use, nutrient use by plants and bioindicators development, all with the participation of a greater number of farmers in the generation of new knowledge.

c. Energy challenges

The electric power market in particular is a centralized system within the largest generator, buyer and state distributor: the Costa Rican Institute of Electricity (Instituto Costarricense de Electricidad - ICE). Energy availability in Costa Rica could soon be limited by its (in)efficient use, resulting from cultural, material and political peculiarities that are not unique to the country. The following considerations support the previously mentioned statements:

i. As for energy for transport, aspects related to poorly designed road infrastructure, as well as bad driving behavior and insufficient concience related to the use of public transportation, impose a high entropic cost on the use of thermomechanical energy and obviously the finances assigned for importing fossil fuels.
ii. In the agroindustrial field, the use of process heat generation and electric cogeneration is limited by significant thermodynamic inefficiencies. However, efforts are currently underway in the water-food-energy nexus, which suggest that agroindustrial waste as well as alternative forms of alternative energy in the rural sector will soon be used.
iii. Bad practices regarding electricity use at home and in businesses continue to exist. Although a number of state institutions have developed certain social communication initiatives in this regard, they have not been continuous.
iv. Public and institutional policies have a number of flaws. The 2015-2030 National Energy Plan presents some timid proposals to "reward" companies that demonstrate improvements in energy-use efficiency, especially when it comes to renewable sources such as biomass. However, there are no efficient legal mechanisms to sanction those who fail to comply with them.

d. Conflicts and challenges in relation to biodiversity

In Costa Rica, the main causes of biodiversity loss and deterioration have been found to be linked to the growth of urban centers, lack of good agricultural practices (increased use of mechanization, agrochemicals, loss of live fences, etc.), illegal logging and forest fires, and to a lesser extent, to the fragmentation of natural covered areas, hunting and the introduction of exotic species. In 2015, the country issued a National Biodiversity Policy for the next 15 years with four main pillars. The second one briefly mentions the agricultural field, indicating that "policies and/or measures that promote market access and the linkage of products or services to environmental characteristics (organic certification, sustainable tourism, coffee, cocoa, fishing, aquaculture and livestock under good environmental and social practices)" will be encouraged (CONAGEBIO/SINAC, 2015).

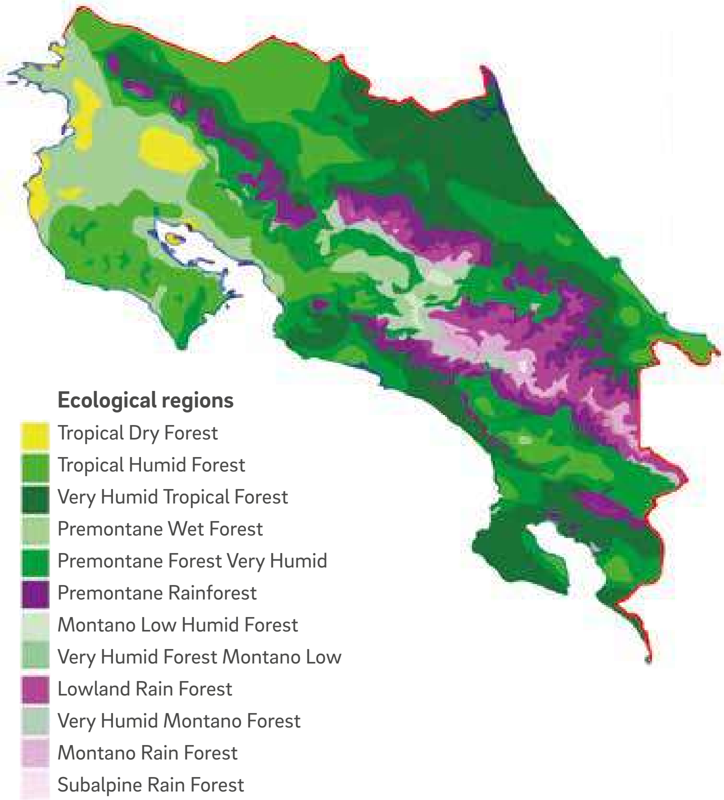
e. Forestry sector trends

The country's forest cover has doubled in the last three decades, from approximately 25% of the territory in the 1980s to 52.38% in 2013. This is thought to be a result of the prohibition of land-use change established by Forest Law 7575, passed in 1996, the implementation of the Environmental Services Payment Program (PPSA) in 1997 and a change in the national productive system due to the reduction in extensive livestock production, for example. However, pressure remains on the urban areas in the country's Greater Metropolitan Area to expand. It is also important to consider the ecological quality of forest cover since, outside large national parks, it is highly fragmented and secondary in nature.

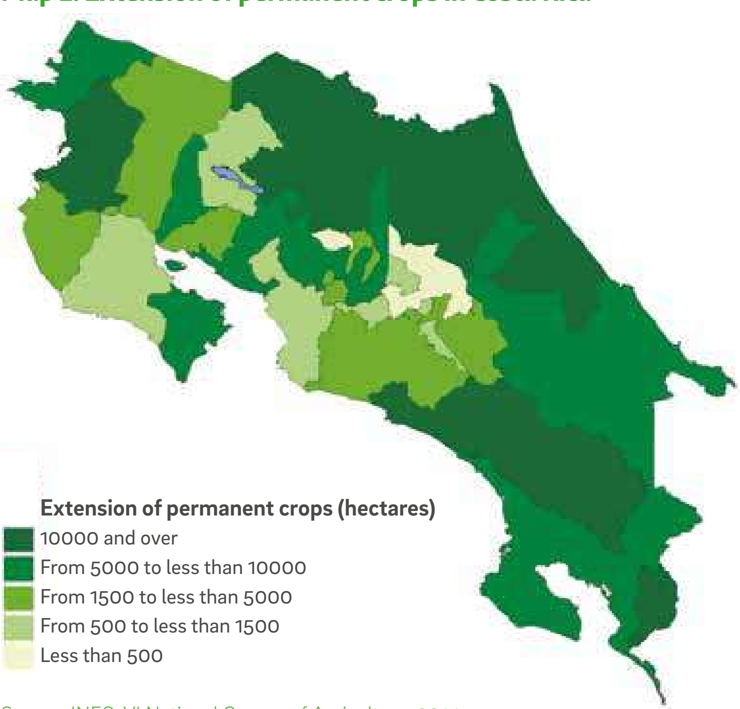
f. Potential impacts of climate change

Factors such as climate change and extreme weather events pose challenges which, if left unaddressed, could increase the likelihood of food and nutrition insecurity for the public. It is therefore useful to know the reality of the country in this respect and to identify specific challenges, in order to obtain information for the debate on the strategies required (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2015). The National Meteorological Institute (Instituto Meteorológico Nacional - IMN) has been studying the possible impacts of climate change on Costa Rican agricultural activities, first with the Central American Program on Climate Change (Programa Centroamericano sobre Cambio Climático - PCCC) and then through the Netherlands Climate Change Studies Assistance Programme. As a result of events related to climate change, many cantons

Map 1. Ecological Regions of Costa Rica



Map 2. Extension of permanent crops in Costa Rica



Source: INEC. VI National Census of Agriculture, 2014

will lose areas suitable for crops that are the basis of their economy, while the socioeconomic conditions prevailing in others will enable them to address the situation more effectively. It is important to consider the sensitivity of various crops to changes in climatic conditions. Of the main crops in Costa Rica, coffee and beans are probably among the most sensitive, while sugar cane, corn and cassava are the most tolerant. In order to encourage certain productive activities, the country established the first PPSA system in the region and subsequently passed Law 8408, in 2004, which recognizes environmental benefits in the agricultural sector (Bouroncle et al., 2015).

g. Developing resilience to extreme events

The Costa Rican agricultural sector has been working on the implementation of initiatives for over two decades with the aim of conserving natural resources and increasing agricultural production. In the early 1990s, technical principles were established to increase productivity, increase vegetation cover, conserve soil and improve conditions for water and carbon cycles. During the first decade of the 21st century, climate-smart agriculture was promoted through the Program Promoting Sustainable Agricultural Production (Programa de Fomento de la Producción Agropecuaria Sostenible - PFPAS), focusing mainly on coffee, sugar cane, vegetables and beef and dairy farming. Other programs designed to increase productivity and competitiveness, which consider aspects of mitigation, adaptation and resilience, are the National Organic Agriculture Program (Programa Nacional de Agricultura Orgánica), the Blue Flag Ecological Program (Programa Bandera Azul Ecológica), the National Plan for Sustainable and Healthy Gastronomy (Plan Nacional de Gastronomía Sostenible y Saludable), the Low Carbon Livestock Strategy (Estrategia para la Ganadería baja en Carbono), The Adaptation Fund (Fondo de Adaptación), Nationally Appropriate Mitigation Actions (NAMA) for coffee, cattle and sugar cane, the 2013-2030 Water Agenda and the BANACLIMA Program of CORBANA.

h. Outlook for the future

In the context of population growth and other uses for water, such as irrigation and industry, and given the uncertainty of the various climate-change scenarios, the next fifty years will probably see a change in the country's population distribution. The relatively sparsely populated region of the Caribbean, with far more rainfall than the Pacific, and without a defined dry season, could become more important and possibly a center of urban growth and industrial development, as well as increased crop and livestock farming. As for energy, a key challenge for its proper use is the achievement of optimal energy-efficiency levels. Moreover, in order to ensure high, efficient levels of agricultural productivity, it is essential for the country to consider environmental aspects. In the short term, food produced with good agricultural and social practices and the supporting certification will have a greater presence on the market.

IV. Technology and Innovation

a. The role of biotechnology

According to a CENIBiot study, in Costa Rica, agricultural biotechnology is the field in which most research activities are carried out at public R&D centers (46%) and companies (64%). Biotechnology applications in the agricultural field include *in vitro* culture for mass propagation and the development of plants with particular characteristics through genetic engineering. In Costa Rica, there are several plant tissue culture laboratories (both public and private) dedicated to micropropagation - mainly through meristems or nodal segments - of species such as banana, strawberry, roots and tubers (potato, taro, cocoyam), oil palm, bamboo and various ornamental plants (such as orchids, anthuriums and calla lilies). Moreover, particularly in public university laboratories, research is being conducted on other *in vitro* techniques, oriented mainly to genetic improvement, such as the culture and fusion of protoplasts –to produce new plant genotypes through the hybridization of somatic cells-, cultivating haploid cells - which could reduce the time required to obtain new genotypes - and somatic embryos - which could lead to the use of synthetic seeds. The cultivation of genetically modified organisms in Costa Rica began 22 years ago, for both research and seed reproduction. From 1991 to 2012, the release into the environment, for experimental purposes or seed reproduction, was authorized for taro, corn, soybean, cotton, banana, rice, pineapple and banana, with some of the following features: insect resistance; herbicide tolerance; resistance to diseases caused by fungi and viruses; slow maturation, and improvement of the nutritional quality of fruits. Thus, in 2012, a total of 283.63 ha of genetically modified crops were authorized to be planted. Costa Rica does not yet produce genetically modified organisms for human or livestock consumption. It only produces seeds for export, which are not sold on the domestic market. For pests and disease management through biotechnological strategies, Costa Rican companies have begun to commercialize biofungicides made from microorganisms with antagonistic action on microorganisms that affect crops.

b. New agricultural products

Novel agricultural products include plants that are currently underutilized, or new varieties resulting from genetic improvement. Public universities, particularly the UCR, are currently undertaking several projects designed to identify, evaluate and conserve tropical fruits that can make important contributions to human nutrition, such as anona, pitaya, peach palm, papaya and guava. This institution also undertakes projects for the plant breeding of rice, beans, guava, papaya, tomato and bell pepper. CATIE and CICAFE have genetic improvement programs for cacao and coffee, respectively. Last, the private sector has research initiatives for crops with economic and food importance such as the oil palm (ASD de Costa Rica) and rice (Semillas del Nuevo Milenio - FLAR). Many of the crops mentioned above provide the livelihood for many communities in Costa Rica, therefore, it is important to conduct research and develop them in order to guarantee the purchasing power of the producers.

c. Opportunities and obstacles to the use of new technologies

The country's particular conditions offer a series of opportunities which, at the same time, pose challenges to the sustainable use of resources such as soil, water, marine ecosystems, forests and biodiversity in general. Thus, the research undertaken – both now and in the future – should also offer options to small farms to reduce losses and achieve proper waste management, in addition to meeting increased demands. The doors should not be closed to new technological options, particularly those derived from agricultural biotechnology, provided efforts are made to minimize risk situations, particularly with respect to the country's biodiversity. Although agricultural irrigation has advanced considerably - with about 100,000 ha currently under this system -, the advance of an irrigation culture that uses water efficiently has been slow. An increase in the use of more efficient irrigation systems, such as dripping or micro-spraying, should be accompanied by intensification of production and diversification toward cash crops, as well as the use of advanced techniques such as precision agriculture and satellite monitoring. As for fertilization, opportunities include generalizing the use of more environmentally-friendly technologies (fertigation and foliar products with microelements), extending the use of fertilization in the forestry sector, employing precision agriculture to adjust the dose of agrochemicals applied, updating and using the management plans for the national territory, and strengthening rural education programs with curricula that incorporate new technologies.

There are a number of obstacles that could hamper the implementation of new technologies. Some have to do with opposition to varying farming practices, even among large companies, as well as the existence of cumbersome administrative and regulatory processes. It is also important to note that, regardless of the efforts made in recent years, there is a lack of economic support for research, as well as incentives to increase the number of professionals in science and engineering, especially with higher degrees (M.Sc. and Ph.D.).

d. Development of marine resources and aquaculture

Despite the upward trend in domestic demand for fish and other seafood with an annual per-capita fish consumption of 7.2 kg, the output of domestic marine fisheries for local consumption has declined considerably: 46% in just over a decade. This is due to a number of reasons, including legal restrictions and regulations, competition with imported aquaculture products, and declining fish stocks. At present, aquaculture in ponds - by far the main aquaculture activity with about 30,000 tons per year – has barely increased, either for freshwater - tilapia being the main species and trout the second - or for brackish water - with white shrimp being the sole species. Although it has developed slowly, aquaculture directly in the sea has advanced over the previous decade. Given the growing need for adaptation to climate change, marine aquaculture in the coming decades will be able to provide alternative food sources, particularly since it does not need freshwater. Moreover, implementing techniques to improve fish production, rather than merely restricting fishing - such as artificial repopulation with fast-growing species and the use of fish aggregation devices - together with marine aquaculture, will help turn the sea into a much more valuable resource, by promoting its conservation and proper management (Radulovich, 2008).

V. Efficiency of food systems

a. Perspectives of technological progress in agricultural production

It is only through the development of appropriate technologies that it will be possible in the future to increase agricultural production in harmony with nature. Thus, genetic improvement will allow the development of more nutritious varieties, with lower input requirements and greater resistance/tolerance to biotic and abiotic factors, which are better adapted to the conditions expected as a result of climate change. Increasing the use of productive systems that have not yet been implemented in the country on a large scale could also be an alternative means of boosting productivity. By 2012, only 5% of the country's farms had agricultural production units under protected environments (INEC, 2015a). The development and exploitation of protected tropicalized environments could increase vegetable production. The fact that Costa Rica is one of the countries with the highest use of agrochemicals per growing area provides an opportunity to modify agroecosystems in order to promote greater diversity of species and increase the biological interactions that facilitate biological pest and disease control. It is also important to register new agrochemicals that are more effective and environmentally-friendly so that farmers have new production tools, and to reinforce the use of good agricultural practices.

b. Infrastructure needs

Internal haulage in Costa Rica is largely undertaken by road. Costa Rica's road infrastructure is one of the densest in Latin America. However, its functionality has virtually collapsed (62% is classified as deficient or extremely deficient), it is largely concentrated in the Greater Metropolitan Area and has very little room to expand. As a complement to road transport, the Costa Rican Railway Institute (Instituto Costarricense de Ferrocarriles - INCOFER) must reactivate freight transport between San José and the Pacific and Caribbean ports (Puntarenas and Limón, respectively), and expand the rail network to other parts of the country, such as Guanacaste. The country has already achieved and continues to achieve significant progress in modernizing its ports, in both the Caribbean and the Pacific. However, work remains to be done on port infrastructure and nearby road traffic networks, since Costa Rica is one of the countries in the region ranked lowest in this respect. It is necessary to overhaul the storage and drying infrastructure for grains and seeds, particularly basic grains such as rice, beans and corn. It is also important to rehabilitate irrigation and drainage areas, and work on flood control and water transfer for irrigation. Laboratories must be set up to ensure that foods that are marketed, including basic grains, meet established quality and safety standards (SEPSA, 2008).

c. Food-use problems and waste minimization

In Costa Rica, 30% of the food produced is lost or wasted. Costa Rica's Food Bank (Banco de Alimentos de Costa Rica), created in 2012, is a private non-profit that seeks food donations to supply at-risk populations. Companies donate food and provide infrastructure, equipment, services and strategic capacities to operate the scheme. The Food Bank was declared an issue of public interest by the government. The Costa Rican Network for Food Loss and Waste Reduction (SaveFood Costa Rica) was set up in 2014. Studies have been carried out on dairy and tomato agrochains, while attempts have been made to reduce waste in business and institutional kitchens.

d. Conflicts between food production and energy and fiber production

Land use for the development of energy crops to the detriment of food crops has become a significant problem in some countries. Fortunately, Costa Rica is protected from this situation, since Article 18 of Decree 35091 on liquid biofuels states the priority of food production for human and animal consumption over biofuel production. This safeguard is also established in Article 23 of the draft of the new version of the decree, currently under development. Costa Rica looks forward to become a "carbon-neutral" country. In other words, net emissions of greenhouse gases into the atmosphere should be equivalent to zero by 2021. To this end, there are several programs and research projects on clean energy production to replace the use of fossil fuels and reduce their imports. An example of this is the Biofuel Development Program (Programa para el Desarrollo de Biocombustibles), which aims to develop research projects on this issue, to harness agroindustrial waste or use products or by-products to create biofuels (SEPSA, 2011). Suitable crops include oil palm, castorbean, jatropha, sugar cane, bitter cassava and sorghum. Other alternatives are also being explored, such as second-generation fuels, which are not part of the food chain (such as used oil waste, straw and wood), as well as microalgae to obtain oil.

VI. Health considerations

a. Foodborne diseases

For Costa Rica, food safety is a public health issue. In 2003, Executive Decree No. 30945-S established mandatory notification for 45 diseases, including some food- and waterborne ones, and classified these as salmonellosis, shigellosis, food and marine- products poisoning, as well as cholera. In 2015, approximately 312,000 cases of diarrhea were treated. Seventy-five people are estimated to die of diarrhea annually, mainly children under 5 and senior citizens. Since 2010, Costa Rica has had a National Food Safety Policy (Política Nacional de Inocuidad de Alimentos) designed to "define and establish the general guidelines to be followed regarding the safety of produced, processed, imported and marketed foods in order to ensure the protection of people's health and consumer rights" (Ministerio de Salud, 2011).

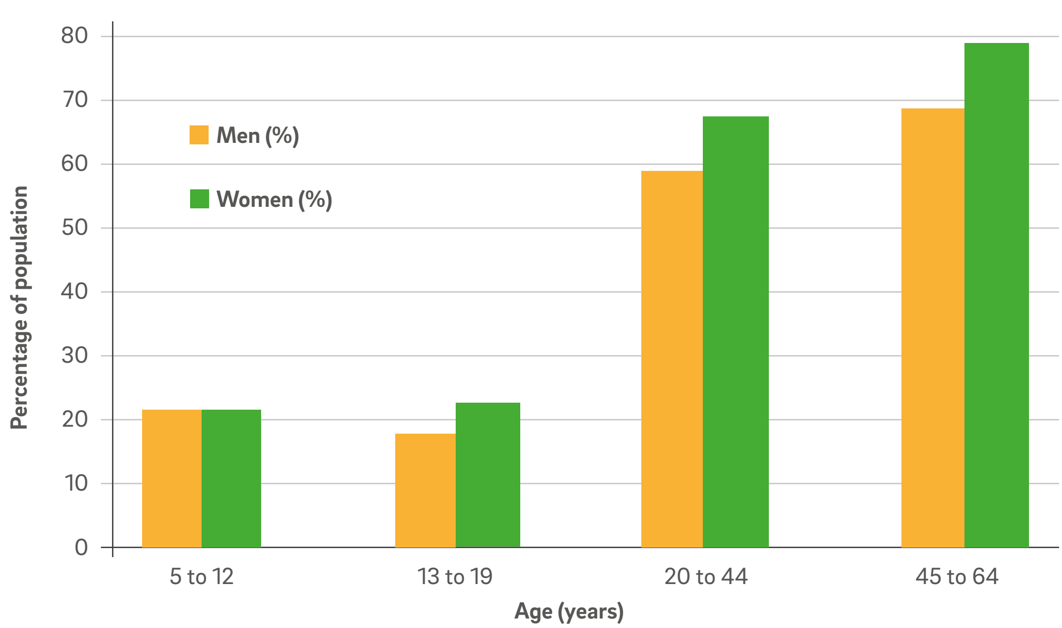
b. Overeating

Data from the 2008-2009 National Nutrition Survey indicate that a high percentage of the population is overweight (**Figure 3**), which increases with age and is generally higher in women than men. Among children under 5, 8.1% (height/weight indicator) are overweight. Studies by both the Ministry of Health (Ministerio de Salud - MS) and the Costa Rican Institute for Research and Education on Nutrition and Health (Instituto Costarricense de Investigación y Enseñanza en Nutrición y Salud - INCIENSA) and the Costa Rican Social Security Fund (Caja Costarricense del Seguro Social - CCSS) show alarming figures for the incidence and prevalence not only of obesity but also of type 2 diabetes, arterial hypertension, hypercholesterolemia, and triglyceride and uric-acid disorders. Accordingly, one of the areas of intervention described in the National Policy on Food and Nutrition Security 2011-2021 (Política Nacional de SeguridadAlimentaria y Nutricional 2011-2021) of the Costa Rican Ministry of Health addresses overweight and obesity.

c. Expected changes in eating patterns

Development strategies influence variations in eating patterns. In the case of Costa Rica, where the service sector has become a significant pillar of the national economy, tourism has led to a significant change in eating patterns driven precisely by the need to meet visitors' needs. The existence of better options for access to information (Internet, social networks, etc.) has also caused clear changes in the general population's eating patterns. New trends indicate that consumers are increasingly concerned about convenience foods (that have been canned, frozen, precooked or minimally processed), and keen to eat foods with direct health beneficial

Figure 3. Prevalence of overweight and obesity in population over 5 in Costa Rica, 2008-2009



Source: National Nutrition Survey, 2008-2009 effects (because of their nutritional and functional properties) or differentiated foods (organic, ethnic, solidarity and so on). These changes in eating patterns directly affect the various supply chains, whether they are wholesalers, supermarkets, retailers or even hotel chains. Food-supply strategies must change to meet these new trends.

d. Toward a change of behavior in food and nutrition

The efforts made by the Ministry of Public Education (MEP) and other state institutions, as well as non-profit organizations, which seek to instill a culture of healthy eating in schoolchildren, will have an effect in the medium and long terms and drive changes in behavior patterns related to eating. As will be mentioned later, Dietary Guidelines - an educational instrument developed in the country by the Intersectoral Commission on Dietary Guidelines (Comisión Intersectorial de Guías Alimentarias) - can also contribute to the acquisition of good eating habits by the population. Likewise, the College of Nutritionists, in collaboration with Costa Rica Institute of Technical Standards (Instituto de Normas Técnicas de Costa Rica - INTECO), has proposed an initiative to achieve a positive change in eating habits. This will improve the Costa Rican population's health by enabling them to eat according to their specific needs. This program, called ProNutri, proposes that nutritionists should be the drivers of change. The personalized nutritional prescription is made out in the CCSS' public hospitals, in private hospitals and clinics and in public and private universities, as well as private practices. Orthomolecular (personalized) nutrition is not yet available in the country.

VII. Political considerations

a. Subsidies and other agricultural policies

In Costa Rica, there are no direct subsidies for agricultural production. Agricultural inputs and equipment are imported tax-free. Tariffs are applied to the imports of certain agricultural products, as is the case of rice, to defend national production. In the case of beans, trading companies must first buy the national production and, once a declaration of shortages is issued, import permits are granted.

b. Nutrition-sensitive agriculture

In the quest for nutritionally sensitive agriculture - which facilitates the availability of and access to healthy and nutritious food - Costa Rica is now promoting the inclusion of sustainable diets that consider aspects with a low environmental impact and contribute to food and nutrition security, as well as healthy living. The country has contributed to nutrition education initiatives through strategies such as urban gardens, public spaces where crops are grown on a very small scale in order to educate consumers and promote agrochemical and pesticide-free agriculture for self-consumption. Initiatives, both public and private, have combined to create educational, equitable and productive spaces under the principles of fair trade and sustainable production, which result in differentiated products at farmers' markets. Costa Rica also has a National Plan for Sustainable and Healthy Gastronomy, led by the Costa Rican Chamber of Restaurants (Cámara Costarricense de Restaurantes y Afines), with the collaboration of institutions such as MS and MAG.

c. Policies that encourage technological innovation

In order to promote technological innovation in Costa Rica, MICITT, as the governing body, has established a set of policies and actions that seek to strengthen and diversify this field. Thus, the National Science and Technology Fair Program (Programa Nacional de Ferias de Ciencia y Tecnología - PRONAFRCYT) builds learning processes, in collaboration with MEP, the National Council for Scientific and Technological Research (Consejo Nacional para Investigaciones Científicas y Tecnológicas - CONICIT) and public universities, which encourage interest in science and technology, and the development of critical and creative thinking in students. There is also the National ExpoINGENERÍA Program, with the participation and collaboration of MICITT, MEP and Intel Corporation, designed to encourage interest and curiosity in engineering. MICITT Incentive Fund supports funding of innovation, science and technology development projects. The MICITT also has the PROPYME Fund to promote and improve the management and competitiveness of small- and medium-sized businesses.

d. Human resource generation policies

In terms of human capital formation, MEP's Department of Technical Education and Entrepreneurship (Dirección de Educación Técnica y Capacidades Emprendedoras - DETCE) seeks to continuously train and provide opportunities to improve skills for the student population in vocational technical education programs in the third cycle and diversified education. Specifically in the agri-food sector, there is a trend toward strengthening human resources. The strategy is geared toward technical careers and there is acceptance toward new degree programs and proposing new disciplines. Some of these, such as biotechnology and the development and use of precision farming equipment, are part of the new trends in this regard. Public universities, as well as other institutions mentioned earlier, participate in this human resource training, with a significant contribution from INA and technical colleges.

e. Policies that seek to redesign agricultural ecology

The goals of the Policies for the Agricultural Sector and the Development of Rural Territories 2015-2018 (Políticas para el Sector Agropecuario y el Desarrollo de los Territorios Rurales 2015-2018) include the redesign of agricultural ecology. The aim is to define joint strategies among the public, private and financial sectors, in order to incorporate the necessary financial resources for the promotion of green businesses and the payment of environmental services for environmentally-friendly products. Tax incentives, the responsible use of green seals and encouraging the use of biomass sources to generate clean energy, as well as promoting research on production systems that help reduce the carbon footprint, are also part of this policy. Last, a strategy has been developed for producers to increase the use of the C-neutral standard and encourage consumers to purchase products with this label (SEPSA, 2015).

f. Policies to promote the consumption of healthy foods

There are a number of organizations in Costa Rica whose goal is to promote healthy eating. On the one hand, there are intersectoral commissions that promote healthy eating, such as the Intersectoral Commission on Dietary Guidelines (Comisión Intersectorial de Guías Alimentarias - CIGA), which develops specific guidelines for the various age groups in the population, and the "Red 5 al Día", which develops strategies to promote the consumption of fruit and vegetables. The School Health and Nutrition Commission (Comisión de Salud y Nutrición Escolar) is responsible for coordinating the School Health and Nutrition Program (Programa de Salud y Nutrición Escolar). Institutions offering food service include the Centers of Education and Nutrition and the Centers for Child Nutrition and Integral Attention (Centros de Educación y Nutrición y Centros Infantiles de Nutrición y Atención Integral - CEN-CINAI), the National Network of Child Care and Development (Red Nacional de Cuido y Desarrollo Infantil - REDCUDI) and school cafeterias. One of the areas of intervention of the National Food and Nutrition Security Policy 2011-2021 (Política Nacional de Seguridad Alimentaria y Nutrición 2011-2021) of the MS deals with eating habits and healthy lifestyles. The MS itself, in coordination with the National Breastfeeding Commission (Comisión Nacional de Lactancia Materna), and national and international health guidelines and policies, passed the Public Policy on Breastfeeding for Costa Rica (Política Pública de Lactancia Materna para Costa Rica) (Ministerio de Salud, 2011). The MEP's School Child and Adolescent Food and Nutrition Programme (Programa de Alimentación y Nutrición del Escolar y del Adolescente - PANEA) provides supplementary meals for the student population. The program promotes healthy eating habits, hygiene and appropriate behaviors regarding a person's daily diet. The National Orchard Program (Programa Nacional de Huertas) operates under the Directorate of Equity Programs (Dirección de Programas de Equidad) within the MEP's Department of Food and Health. It is based on the principle of providing the country's educational centers with the necessary resources to launch agricultural projects that supply school cafeterias with fresh, healthy foods, and develop healthy eating habits in students and encourage them to eat balanced diets. In order to promote students' health by maintaining healthy eating habits, MEP defined the type of foods that could be sold at school cafeterias (Executive Decree 36910 of 11/22/2011). It stipulates that a daily supply of fresh fruits and vegetables must be provided, sets maximal sugar limits on the preparation of beverages and prohibits the sale of certain prepackaged products that fail to contribute to a healthy diet. Costa Rica joined the efforts of the Pan American Health Organization (PAHO) to formulate the 2011-2021 National Plan for Reducing Sodium and Salt Consumption in the Population (Plan Nacional de Reducción del Consumo de Sodio y Sal en la Población 2011-2021).

g. Comparative advantages of Costa Rica in agriculture

Costa Rica has high national Information and Communication Technologies (ICT); 94% of rural households have access to a mobile phone and 46% to the Internet (INEC, 2015b). This allows useful tools to be developed for farmers using ICT. Costa Rica's agricultural areas also have technical high schools, university campuses, centers dedicated to agricultural research and agricultural outreach agencies with trained professionals, which facilitates the assimilation and implementation of new technologies to improve production processes (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2014). The existence of a wide network of national parks contributes to the protection of watersheds and the conservation of biodiversity and water resources (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2015).

h. International Trade

The agri-food sector remains an extremely dynamic sector that contributes a great deal to the national economy. Of total exports, which amounted to $9.65 billion USD in 2015, US $2.45 billion were produced by the agricultural sector and US$ 335 million by the livestock/fisheries sector. Of all the goods exported in 2015, 22% corresponded to "medical devices", 9% to bananas, 8% to pineapple, 3% to gold coffee, 3% to syrups and concentrates for the preparation of soft drinks and 2% to fruit juices and concentrates. This accounts for 25% of the total exported goods.

i. Market challenges

Market challenges can be divided into those involving the domestic or national market and those for the export markets. Access to national markets is relatively simple. On the other hand, the international market involves higher costs regarding transportation and packaging, as well as the mandatory or voluntary certifications some destinations now require. Voluntary certifications are varied and may include ISO standards, organic production and good agricultural practices. Quality factors are another major challenge that must be met in accessing markets and ensuring the food supply. Both national and international markets are developing increasingly stringent standards that must be complied with. This is particularly important concerning nutrition, safety and even more tangible aspects such as packaging and preservation, not to mention the increasing concern with environmental protection.

VIII. Abstract

a. Some potential national agricultural scenarios for agricultural production in the next fifty years

If by 2030, there is a 1.3°C increase in the average annual temperature coupled with changes in rainfall distribution patterns, as some models suggest, this will lead to the redistribution of areas suitable for particular crops. As mentioned earlier, areas with most sensitive crops would be reduced, whereas others might benefit (Bouroncle et al., 2015). A potential scenario for the next fifty years would be one in which technological innovations and the value chain, as well as ICT, would determine agricultural production. The opening of markets (through free trade agreements) will probably continue to be a determining policy, meaning that production schemes must be clearly defined. Food security will continue to be a concern, since the needs of an increasingly large population will have to be met. On the other hand, agrobiodiversity requires a new paradigm for it to be exploited. Climate change is impacting all productive sectors and will continue to play a major role.

b. High-priority actions to achieve agricultural sustainability

Priority actions that will need to be considered to achieve agricultural sustainability are likely to be related to climate change. The impact of climate change at the national level should be monitored efficiently in order to feed mathematical models that will ensure more accurate forecasts and therefore make it possible to design long-term mitigation strategies for each of the country's agricultural regions (Bouroncle et al., 2015). The mitigation and adaptation strategies implemented will directly affect the agricultural sustainability not only of the country, but also at the global level. Moreover, local breeding programs should be strengthened and expanded, either conventionally or through genetic engineering, while new irrigation technologies should be implemented in traditional and new crops. The aim is to obtain a diversity of plants adapted to the new agricultural conditions and products with higher nutritional quality, to strengthen the country's food security and increase production without expanding the agricultural frontier. If the current production system (agroexport model) is maintained, agreements with countries interested in permanently supplying the demand for basic products should be signed, water collection and distribution projects should be substantially improved, agricultural production systems should be diversified to include other components that will enable producers to improve their incomes and remain in the countryside, internal transport (roads and railways) and transport to external markets (harbors and airports) should be upgraded to improve economies-of-scale, and strategic alliances should be promoted. It is also important to develop new productive opportunities in rural areas in order to reduce migration to cities. In this respect, ecotourism and agroecotourism would have activities that could have a more significant impact on rural families' economy in the future.

References

CCAFS (2014). Estado del arte en cambio climático, agricultura y seguridad alimentaria en Costa Rica. CGIAR, MAG, CAC, CIAT. https://cgspace.cgiar.org/rest/bitstreams/34613/retrieve on 15/01/17.

FAO (2015a). Perfil Nacional de Seguridad Alimentaria y Nutricional – Costa Rica. Plataforma de Seguridad Alimentaria y Nutricional. http://plataformacelac.org/storage/app/uploads/public/562/850/c13/562850c13b41e718065372.pdf Retrieved on 20/12/16.

INEC (2015a). *VI Censo Nacional Agropecuario. Resultados Generales.* San José, Costa Rica, INEC. 146 pp. http://www.mag.go.cr/bibliotecavirtual/a00338.pdf Retrieved on 20/12/16.

Ministerio de Salud (2011). *Política Nacional de Seguridad Alimentaria y Nutricional 2011-2021.* 1ª ed. San José, Costa Rica. 54 pp. https://www.ministeriodesalud.go.cr/index.php/biblioteca-de-archivos/sobre-el-ministerio/politcas-y-planes-en-salud/politicas-en-salud/1106-politica-nacional-de-seguridad-alimentaria-y-nutricional-2011-2021/file Retrieved on 31/01/17.

Programa Estado de la Nación en Desarrollo Humano Sostenible (Costa Rica) (2015). *Vigésimo primer Informe Estado de la Nación en Desarrollo Humano Sostenible.* San José, Costa Rica. 431 pp. http://www.estadonacion.or.cr/21/assets/pen-21-2015-baja.pdf Retrieved on 31/01/17.

SEPSA (2008). Plan Nacional de Alimentos. http://www.infoagro.go.cr/MarcoInstitucional/Documents/PNA.pdf Retrieved on 21/01/17.

SEPSA (2011). *Política de estado para el sector agroalimentario y el desarrollo rural costarricense 2010-2021.* San José, Costa Rica, SEPSA/MAG. 84 pp. http://www.mag.go.cr/bibliotecavirtual/a00289.pdf Retrieved on 31/01/17.

SEPSA (2015). *Políticas para el Sector Agropecuario y el Desarrollo de los Territorios Rurales 2015-2018.* San José, Costa Rica, SEPSA/MAG. 64 pp. http://www.mag.go.cr/bibliotecavirtual/a00333.pdf Retrieved on 31/01/17.

Additional references

Bouroncle C, Imbach P, Läderach P, Rodríguez B, Medellín C, Fung E, Martínez-Rodríguez MR, Donatti CI. (2015). La agricultura de Costa Rica y el cambio climático: ¿Dónde están las prioridades para la adaptación? En: Programa de Investigación de CGIAR en Cambio Climático, Agricultura y Seguridad Alimentaria. http://www.conservation.org/publications/Documents/La-Agriculture-de-Costa-Rica-y-el-Cambio-Climatico.pdf Retrieved on 20/01/17.

Castro-Valverde, C. (2013). Cuarto informe del estado de la educación. Desempeño de la educación general básica y el ciclo diversificado en Costa Rica. Estado de la Nación. 162 pp. http://estadonacion.or.cr/files/biblioteca_virtual/educacion/004/castro_desempeno-ed-basica-y-diversificado.pdf Retrieved on 31/01/17.

Chaves-Solera, M. (2011). Sistema Nacional de Investigación y Transferencia de Tecnología Agropecuaria (SNITTA): Importante y necesario instrumento institucional para mejorar la competitividad costarricense. https://www.laica.co.cr/biblioteca/servlet/DownloadServlet?c=443&s=2521&d=3348 Retrieved on 16/01/17.

CONAGEBIO/SINAC (2015). Política Nacional de Biodiversidad 2015-2030. San José, Costa Rica, GEF-PNUD. 72 pp. http://www.conagebio.go.cr/Conagebio/public/documentos/POLITICA-NACIONAL-DE-BIODIVERSIDAD-2015.pdf Retrieved on 31/01/17.

FAO (2015b). Panorama de la Inseguridad Alimentaria en América Latina y el Caribe. www.fao.org/3/a-i4636s.pdf Retrieved on 13/01/17.

IICA (2011). La Agricultura de Costa Rica: Situación al 2010, su Evolución y Prospectiva. http://orton.catie.ac.cr/REPDOC/A7612E/A7612E.PDF Retrieved on 20/12/16.

INEC (2015b). *Encuesta Nacional de Hogares julio 2015. Resultados generales.* San José, Costa Rica, INEC. 137 pp. http://www.inec.go.cr/wwwisis/documentos/INEC/ENAHO/ENAHO_2015/ENAHO_2015.pdf Retrieved on 31/01/17.

PROCOMER (2014). Estadísticas de comercio exterior de Costa Rica. http://www.procomer.com/uploads/downloads/anuario-estadistico-2014.pdf Consultado el 14/01/17.

Programa Estado de la Nación en Desarrollo Humano Sostenible (Costa Rica) (2014). *Estado de la Ciencia, la Tecnología y la Innovación.* San José, Costa Rica, EDISA. 396 pp. http://www.estrategia.cr/content/images/pdfs/ecti2014.pdf Retrieved on 31/01/17.

Radulovich, R. (2008). Maricultura en Costa Rica. *Ambientico*, 179:7-14.

Food and Nutrition Security: A Cuban Perspective

Panoramic view of "La Melba", an area that combines agriculture and nature conservation. It forms part of the Alejandro de Humboldt National Park. It is located in the Nipe-Sagua-Baracoa Orographic Group, in the northeast region of Cuba. Its complex relief and high ecological variability are reflected in its biodiversity (courtesy of Dr. Julio Larramendi).

Cuba

[1] María Teresa Cornide Hernández
[2] Walfredo Torres de la Noval
[3] Ramón Pichs Madruga
[4] René Pablo Capote López
[5] Amelia Capote Rodríguez

Agricultural and livestock production in **Cuba has been sustained for 20 years by the use of ITC results to achieve sustainability.** However, food import dependence continues to have negative consequences for food and nutrition security, which may be exacerbated in the future by the expected competition for water and land use, and the forecast of effects associated with climate change.

Summary

This report presents an integrated perspective of a group of specialists from the agri-food, environmental, economic and scientific management sectors, invited by the Cuban Academy of Sciences to take part in this survey on the country's food and nutrition security in the middle of this century, and outline the country's challenges, strengths and experiences.

Science, Technology and Innovation (STI) are indispensable for developing a sustainable, efficient and resource-based agriculture in Cuba to sustain and increase food production for the entire population. To this end, a state policy was formulated for the *National Economic and Social Development Plan Until 2030*, specifying the key objectives, supported by a Science and Technology system comprising over 200 entities in various ministries. It addresses the status of natural resources, the challenges and projections for their conservation, as well as the potential impacts of climate change and the actions required to increase the country's resilience to them.

It highlights the need to optimize food-production value chains so that potential yields are achieved in production; the importance of designing research with a "multidisciplinary and systemic approach" to complete the cycle "from the laboratory to the field" and to develop models that will incorporate climate risk indicators into the traditional agronomic variables used for these purposes.

By way of an example, this chapter describes successful programs currently underway, based on the principle of Local Development, so that STI can contribute to a high level of food self-sufficiency in the light of changing climatic conditions and the high proportion of new farmers. The municipal government brings together all of the factors which, through direct participation, implement actions for the benefit of its population. These include achieving a safe, stable market for farmers, a broader range of products at affordable prices for the population and job creation. Land use is improved by encouraging the development of non-state forms of family or cooperative agriculture, which account for 69.7% of the total agricultural area.

This chapter also describes health aspects and policy projections for contributing to food and nutrition security from the point of view of technological innovation, human resource training and various economic, trade and social aspects.

I. National Characteristics

Geographic characteristics, population and society

Cuba is an archipelago with an area of 109,884.01 km², 106, 757.60 km² of which correspond to the island of Cuba, and its capital is Havana. It is located in the Greater Antilles near the Tropic of Cancer, at the entrance to the Gulf of Mexico.

The predominant climate type is warm tropical, with seasonal distribution of rainfall in two periods (November-April and May-October), maritime influence and a number of continental features. The country has other localized types of climate, such as those in the highest mountainous areas and the southern coastal strip of the provinces of Santiago de Cuba and Guantánamo, which has a dry tropical climate with low rainfall (ONEI, 2016a).

Its urbanization rate is 76.8%, and it has a total resident population of 11,239,661 inhabitants, of whom 19.2% are aged 60 or over and 49.8% are men. The overall fertility rate is 1.72 (children/women) and its population density is 102.3 inhab./km². Life expectancy at birth is 78.45 years (ONEI, 2016a).

Food and nutrition security, education, health and environmental protection have been prioritized in the design of the country's socioeconomic and environmental policies since the beginning of the revolutionary process in 1959, to ensure the well-being and quality of life of the whole population, and these comprise the strategic objectives of the Cuban socioeconomic development model, currently being overhauled.

Cuba's integral approach to mother and child health has reduced morbidity, mortality and malnutrition rates, as well as moderately and extremely low birth weight rates in children under 5 as well as stunted growth (<5%). It has also promoted gender equity and women's autonomy. As a result of its public health, education and environment (GNI), Cuba is among the countries with sufficient human development indices to enable it to achieve the Millennium Development Goals (UNDP, 2015).

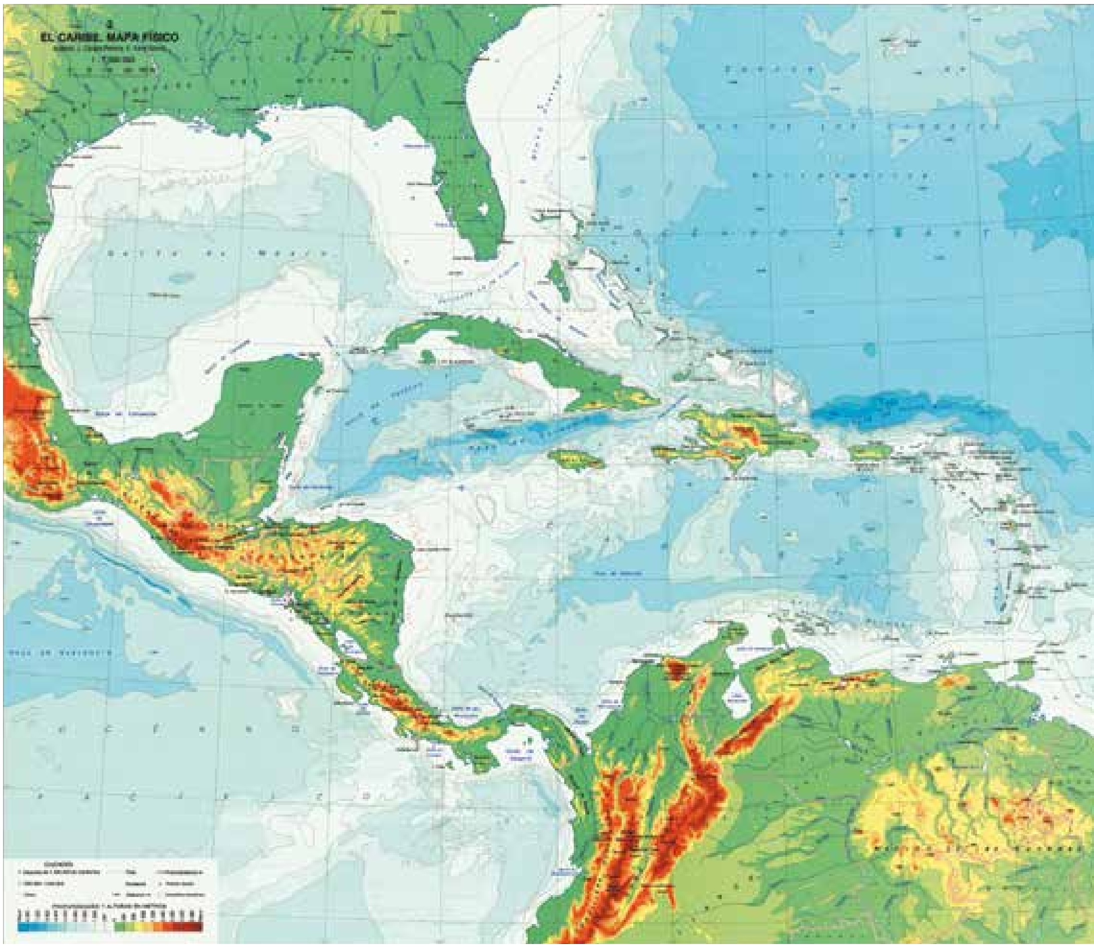
Agricultural systems. Food self-sufficiency and principal threats and challenges

Cuba's total land area (10,988.4 million ha) includes 6,2403 million ha for agricultural use, 2,7336 million of which are cultivated with a Utilization Index (UI) of 43.8%. A total of 3,371.6 million ha is occupied by forests while the remainder comprises aqueous surfaces and other land unsuitable for agriculture. Land ownership of the total agricultural area is distributed as follows: 30.3% belongs to the state sector (UI = 27.7%), 13.9% is owned by peasants (IA = 52.8%) and 21.4%, by usufructuaries (IA = 45.9%). There are three types of cooperativized ownership classified by land ownership and the ownership of communal means of production. Since 2009, 279,021 people have received land in usufruct in return for making them productive and profitable. Non-state forms of land ownership occupy 69.7% of the total agricultural area (UI = 50.8%) (ONEI, 2016c).

Despite the policies implemented since 1959 to achieve the population's food and nutrition security, significant challenges remain. Cuba is a developing state vulnerable to a number of factors such as global changes in the world

[1] María Teresa Cornide Hernández, Plant Genetics, Applied Molecular Genetics, Plant Breeding: BSc. in Biology, PhD. in Sciences (ScD.); Senior Researcher at the Sugarcane Research Institute; Full Professor at the Faculty of Biology, University of Havana (UH); Academician of Merit; Coordinator of the Agrarian Sciences and Fisheries Section, Cuban Academy of Sciences (ACC), mtch1646@gmail.com **[2] Walfredo Torres de la Noval,** Fisiología Vegetal en el tema de estreses abióticos: Degree in Chemistry, Doctor of Biological Sciences; Researcher at the National Institute of Agricultural Science (INCA); Academician of Merit, Agricultural Sciences and Fisheries Section, ACC, walfredo48@gmail.com **[3] Ramón Pichs Madruga,** World Economy, Environment and Development: BA. in Economics, PhD. in Economics; Senior Researcher; Full Professor, Faculty of Economics, UH; Director of the Center for Research on the World Economy (CIEM), Ministry of Science, Technology and Environment (CITMA); Head of the Section of Social and Humanistic Sciences, rpichs@ciem.cu **[4] René Pablo Capote López**, Ecología y Conservación de la Naturaleza: BSc. in Biology, PhD. in Biological Sciences; Senior Researcher at the Institute of Ecology and Systematics (IES); Environment Agency CITMA; Full Professor at the Faculty of Biology, UH; Academician of Merit, Section of Natural and Exact Sciences, rpcapote@ceniai.inf.cu **[5] Amelia Capote Rodríguez,** Agricultural Biotechnology. Management and Directorate of Science: Agronomist Engineer, PhD. in Biological Sciences; Principal Investigator of the Alejandro de Humboldt Institute of Basic Research on Tropical Agriculture (INIFAT), MINAG; Head of the National Program of Science and Technique of Human Food, dircientifica@inifat.co.cu

Map 1. Physical map of the Caribbean



economy. Examples include the dismemberment of the Socialist Bloc, which reduced the Gross Domestic Product (GDP) by 35% from 1989 to 1993 and the adverse impact of the US economic, financial and trade blockade, which persists to this day (MINREX,2016), severe constraints on underdeveloped countries in international markets, internal deficiencies and the effects of natural phenomena associated with the fact of Cuba's being an island and its geographical location.

One of the challenges is high dependence on food imports: Cuba imports 80% of the food it consumes and it is estimated that by 2017, this will amount to $1.7502 billion USD. Despite being a net food importer, the productive potential of Cuba's agricultural sector is expected to reduce import dependence by between 35% and 40% (Nova, 2016).

The socio-economic guidelines for the country's development are designed to meet the short-, medium- and long-term development needs of the agro-food sector (PCC, 2016). The goal of the *National Economic and Social Development Plan Until 2030* is to achieve agricultural production and marketing levels that will guarantee a high degree of food self-sufficiency.

To this end, the country has adopted a food security strategy based on a combination of increased agricultural productivity, greater policy predictability and trade liberalization through: (1) the reduction of the main food imports: potato, grains (rice, corn, beans), milk and meat; (2) an increase in the quantity and diversity of agricultural exports of traditional products (sugar, tobacco, coffee, cacao and fruit); (3) the search for new exportable items, and (4) the expansion of existing markets and buyer countries. In 2016, Cuban agriculture grew by 5.9%, well above the 2.5% in the previous year, although not sufficient to satisfy domestic demand or substitute food imports.

Development strategies have included the growth of new industries on the basis of science and technology, available natural resources and the country's economic possibilities. Mining, oil drilling and electricity generation have been intensified. The tourism industry has significantly expanded. The achievements of Cuba's medical-pharmaceutical industry, particularly biotechnological development, have been internationally acknowledged. The main export products and services are professional services, tourism, petroleum derivatives, nickel, biopharmaceuticals, sugar and tobacco products. New structural, functional and policy transformations and projections for the agricultural sector have recently been approved to boost agricultural activity through more decentralized management methods and the support of local production. The country has the political will, practical experience, acquired knowledge and the participation of Science, Technology and Innovation (STI) to achieve this goal.

II. Science, Technology and Higher Education Infrastructure in the Agricultural Sector

National agricultural research systems

In order to contribute to the strategic goal of achieving a high level of food self-sufficiency, the Cuban Ministry of Science, Technology and Environment (CITMA) has prioritized *Food Production from the Perspective of Science, Technology and Innovation*, together with the organization, improvement and implementation of new policies in the various ministries and business groups (linked to food production).

National agricultural research is undertaken by a network of research centers, scientific and technological services and development and innovation units attached to various ministries (such as CITMA, MINAG, the Ministry of Higher Education (MES) and the AZCUBA Business Group). These organizations focus on essential aspects within the National Programs and Projects System, directed by CITMA. Other programs include studies on Climate Change (CC), biodiversity, water resources, energy, meteorology, local development, computerization and socioeconomic problems.

By the end of 2016, 300 projects associated with these programs and 500 institutional and business projects were underway, together with innovation actions, derived from research-development and the application of knowledge, with practical, beneficial repercussions.

The Cuban Academy of Sciences

The Cuban Academy of Sciences (ACC), founded in 1861 as the Royal Academy of Medical, Physical and Natural Sciences of Havana, is the principal, independent scientific advisor to the government on science, attached to CITMA. It is an active member and founder of the main global and regional institutions bringing scientists together: The International Science Council (ICSU) since 1931; the InterAcademy Panel (IAP) Network since 1994; the Academic Network of the Americas (IANAS) since 2004, and the Caribbean Scientific Community (2000).

In addition to its advisory work, it promotes science and technology in society. It links this work to the mass media and organizations in the education sector through its electronic magazine *Anales ACC*, its historical records and liaising with Cuban scientific societies, including three of those with the largest membership in the agricultural sciences. It awards annual prizes in recognition of scientific results that contribute to knowledge and impact the economy, services and production.

The highest authority of the ACC is the Plenary, comprising 250 of the country's' scientists, grouped into five sections, one of which is Agrarian and Fishing Sciences, with 43 senior researchers and eight young research associates. The ACC is the main coordinator and independent organizer of the Cuban scientific community. It encourages debate and brings together the main trends in national development in STI matters.

Research Institutes and Universities

Research in the agricultural sector is undertaken at universities and within the network of 41 scientific organizations with over 11,000 employees, approximately 1,600 of whom are researchers and 600 hold a PhD. in science.

A system of scientific journals publishes the results of national research; 31 are related to agricultural research, certified by CITMA on the basis of their editorial quality and stored in various international databases (six in *Scopus* and two in the *Web of Science*). Efforts are being made to increase the international visibility of these results.

Development of specialized workforce and status of the country's educational systems

Last year, over 420,000 students graduated from various levels and types of education, 49.9% of these were women (ONEI, 2016b). Higher education in agricultural science courses and others where students graduate in similar fields is provided at 22 public universities in different modalities. The current aim is to strengthen distance education in agricultural degree programs to enable the greatest number of students to study from their workplaces or homes.

The country's education systems have established programs which, in the short and medium term, will focus on training skilled workers and mid-level technicians, under the aegis of the Ministry of Education (MINED). Since there is currently a shortage of this type of personnel in many of the productive units related to food production, these programs are designed to increase the trained labor force (non-university graduates) at the basic productive unit level.

Agricultural degree programs can be studied in face-to-face, semi-face-to-face or distance modalities. In order to graduate, students must conduct supervised research culminating in a thesis. Current enrollment in agricultural degree courses is over 5,000, 47% of whom are women.

Research that contributes to national food security involves professionals from natural sciences (biology, microbiology, biochemistry, chemistry, mathematics, food sciences and pharmaceutical sciences), economics (accounting, finance and economics), social sciences (sociology) and technical sciences (computer engineering).

Relative contributions of the public and private sectors

The greatest contribution to the STI activities of the scientific organizations related to the agro-food sector is provided by the Cuban state and government, regarding both financial aspects and material and human resources, and the political support and guidance to enable them to fulfill the missions and tasks with which they have been entrusted. Private sector contribution is still in its infancy with respect to the production of certain types of food. The current business system is contributing to the development of scientific centers in this area as part of the process of improving the system and reorganizing the science units.

III. Natural Resources and Ecosystems

Water resources and challenges for the next 50 years

In the mid-1960s, measures were taken to reduce the impact of the heavy rains and flooding caused by hurricanes and to ensure a sufficient supply of water in quantity and quality for human consumption, agriculture and industry and integrated water-resource management (Fontova et al., 2012).

According to one of the most optimistic forecasts, recent Climate Change models predict a reduction of water availability to 24 km^3 in 2100, equivalent to 38% of today's calculations (Planos, 2014). The current usable potential is 75% of surface water and

25% of groundwater, with a permanent risk of contamination by saline intrusion due to aquifer overexploitation.

For water storage and use, the country has a total reservoir capacity of 9,148.6 Mm^3 and 788.4 km of master channels connected to them. It has an additional 805 micro (>600 million m^3) and an extensive network of irrigation and drainage canals, dams and canals for flood protection and saltwater intrusion (ONEI, 2016). In order to ensure the population's water supply and irrigation in areas severely affected by periodic droughts, three transfers and a new dam with a capacity of 630 million m^3 (Mm^3) have been built (Fontova et al., 2014). In 2015, the water availability indicator was 1,231.7 m^3/inhabitant, with uneven distribution throughout the island (ONEI, 2016). In 2013, the National Water Policy, designed on the basis of contributions from all the users, was approved by the National Institute of Water Resources (INRH).

With regard to water availability, the greatest challenges the country will face over the next 50 years include:

- Implementing the geosystemic and ecosystemic approach to counteract the fragmentation of ecosystems caused by the construction of large, interprovincial transfers.
- Establish cooperation between the agricultural and forestry sectors to mitigate these impacts, and promote connectivity routes between the species and ecosystems affected by these public works.
- Use technology to increase water availability. Examples include sea water desalination, rain harvesting, recycled water use and more efficient irrigation systems.
- Design civil engineering works to mitigate the impact of rising sea levels, which requires technology transfer.

The main strengths lie in the development and stability of the aforementioned national water program and the human resources available to assess water from a multisectoral, interdisciplinary perspective.

Land resources and challenges for the next 50 years

The country's edaphic cover is extremely varied, due to its complex geological structure, divided into 14 categories based on the type of soil formation (Institute of Soils, 1999). The recent land evaluation study for soil degradation monitoring based on the agroproductive potential for 29 crops, using a 1:25,000 soil map, showed that 65% of these had a potential yield reduction to below 50% due to one or more limiting factors, such as erosion, low organic-matter content, compaction, poor drainage and salinity (ONEI, 2016c). Cuba's National Environmental Strategy cites land degradation as the main problem, compounded by the effects of climate change on over a million hectares that form part of fragile ecosystems, such as mountainous areas with a high risk of erosion and coastal areas or adjacent cumulative plains with a salinity risk.

State policies and institutional programs have been drawn up to ensure sustainable soil and water management, such as the National Program for the Management and Conservation of Soil in Agroecosystems (PNMCS), which has benefited 901,000 ha (ONEI, 2016). Six state-funded programs are underway to achieve soil conservation, improvement and sustainable management to mitigate its degradation. The gradual assimilation of 'Conservation Agriculture' methods is essential if its degradation is to be minimized in the coming years.

Renewable Energy Sources (RES)

Cuba is a small greenhouse gas emitter that has maintained its commitment to the Framework Convention on Climate Change to the reduce emissions in keeping with its national circumstances and available financial and technological resources. Since the energy sector is the main emitter, sustainable modernization and technological development have been proposed, together with capacity building in the various sectors.

Based on the potential use of available RES, plans are afoot to install 2,144 MegaWatts (MW) of power connected to the national electricity grid, which includes the construction of 19 bioelectrical plants attached to the sugar mills (755 MW) based on sugar cane and forest biomass, and 13 wind farms (633 MW), particularly in the eastern part of the country. Parks (with 700 Photovoltaic MW) will be built in areas with less than 5 MW of power to connect them to the national grid, together with 74 small hydroelectric plants in small waterfalls. These programs will make it possible to generate over 7,000 GigaWatts (GWh) a year from renewable energy sources, and prevent the release of 6 million tons of CO_2 into the atmosphere (ONEI, 2016).

Biodiversity, conflicts and challenges: problems associated with over-exploitation and the loss of genetic diversity

Cuba boasts the greatest biodiversity of flora and fauna in the Caribbean. It is one of the four islands with the largest number of plant species worldwide, as well as having the highest number of taxa/km². A total of 5,778 native taxa of plants with seeds (51.4% endemic), 11,954 invertebrate species and 655 vertebrate species have been registered in the country. Its faunal diversity includes genetic resources useful for biological control and the development of nature tourism (CITMA, 2014).

The country has laws supporting the policies established for the use and conservation of diversity (CITMA, 2014). It has a system of protected areas approved by the Council of Ministers, six of which are 'Biosphere Reserves' and nine of which have been recognized as the World's Natural Heritage. This system operates on 116,679.6 km² (49.4% of the total area of the national territory in addition to the marine platform) (ONEI, 2016a).

In the Cuban archipelago, biodiversity and terrestrial ecosystems generally comprise mountain ecosystems, with hills and plains, with a predominance of the latter. For conservation purposes, they are divided into inland and coastal wetlands and keys, with large areas of mangroves.

The main causes of biodiversity loss are: alterations, due to the fragmentation or loss of habitats/ecosystems/landscapes; overexploitation of resources; the introduction of invasive alien species, land and soil degradation, and soil, water and air pollution (CITMA, 2014).

Every year, variations in the national pollutant load are evaluated in the main hydrographic basins, mountainous massifs and main bays, to track their evolution from liquid waste of organic and biodegradable origin. Forest fires of varying size and frequency contribute to deforestation, soil degradation and loss of biological diversity.

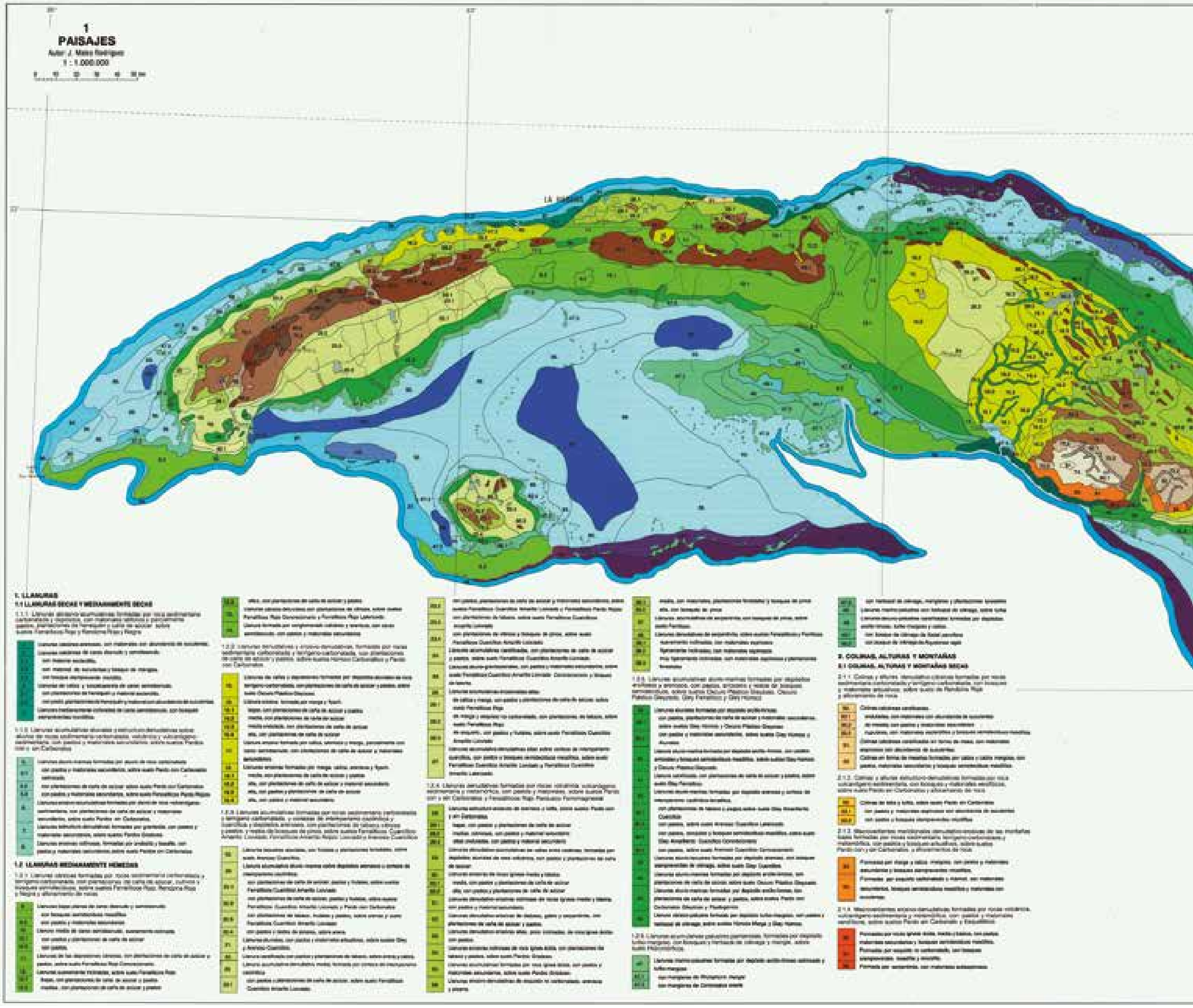
The challenge is to maintain ecosystem services for the country's human and socioeconomic well-being, such as the protection of agricultural lands and human settlements from CC and extreme weather events.

Forest resources

The genetic diversity of tree species has been affected since the 1990s by: resource constraints for monitoring and conservation; fossil-fuel restrictions that encouraged the use of firewood and charcoal, and increased levels of domestic sawn timber production. This was compounded by the decline in competent human resources and materials available for dealing with genetic resources, as well as the cumulative effects of the tropical hurricanes that have affected the country since 2000.

The combined action of these factors has had negative impacts on the genetic diversity of economically important tree species, both native (pine, cedar, mahogany and *Hibiscus*) and introduced. In order to reverse genetic erosion and stabilize forest production (timber and non-timber), the following priority objectives have been set for the forestry sector: maximal protection from the impacts of sea level rise in coastal areas and of the biodiversity of ecosystems in mountainous areas (>200 meters above sea level [masl]), by suspending the economic use of mangroves throughout the country and of several forestry products; expanding the area of artificial forests in flat and undulating areas, with specific productive objectives, increasing agroforestry systems and integrated management (intensive silviculture); intensifying enrichment and reforestation actions in natural forest areas classified as protected and conservation zones; achieving

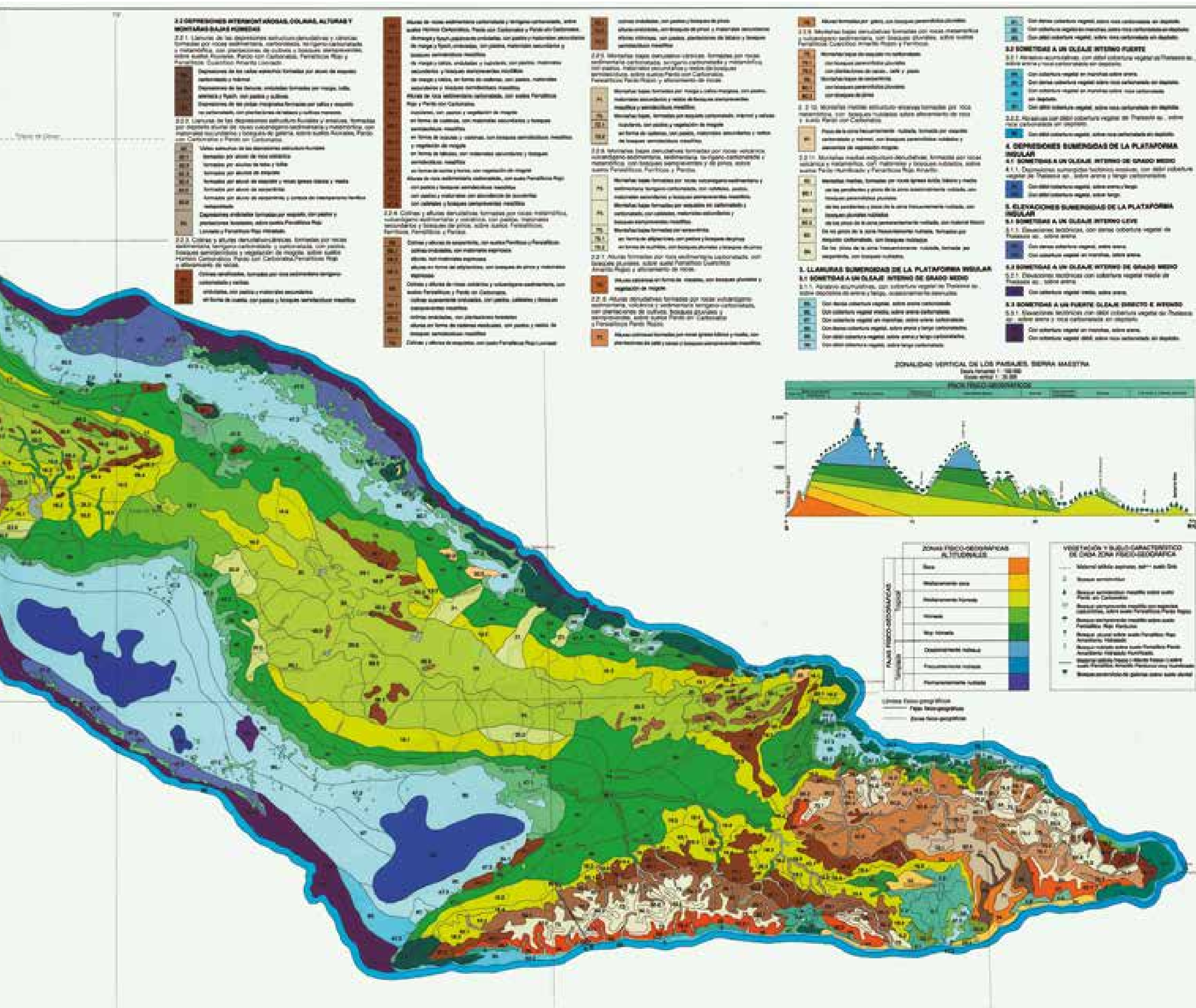
Map 2. Vegetation and soil characteristic of every physical-geographic zone of Cuba



33% of the forestry coverage planned for the country (currently ≥30%), and reactivating breeding programs with newly trained personnel.

Marine resources

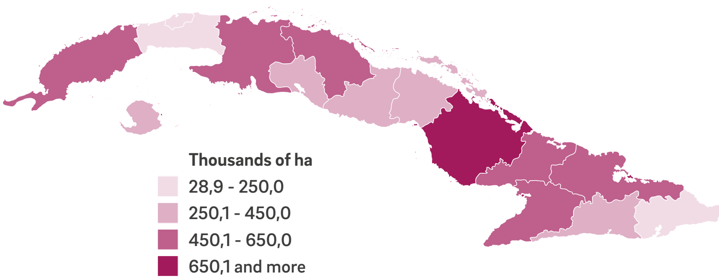
The insular shelf has the relief of a submerged plain, hence the value of coastal and marine ecosystems for the ecological stability of the biota. The greatest wealth of marine species is distributed among the nine ecozones of the Cuban shelf, mostly on the South coast, especially at the eastern and western extremes (CITMA, 2014). The close link between the land and the ocean, as well as the robust state of health of Cuba's marine and coastal ecosystems, supports some of the most important fishing activity in the Caribbean, such as thorny lobster fishing, accounting for 75% of the revenue in that sector.



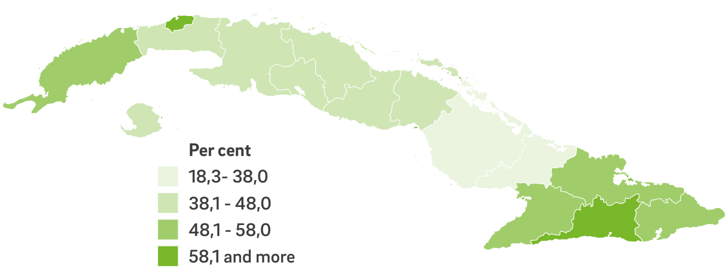
The high economic value of most of the fishing resources in the Exclusive Economic Zone (EEZ) and the fishing capacity created in the country since 1959 has led to the overexploitation of some of these resources. The statistics (1935-2014) for 25 species show that a steady increase in catches was followed by a steady decline in total catches and most individual species, with several cases of collapse. An analysis of their causes indicates that overexploitation is not the only factor responsible and that various human actions have affected certain habitats, such as fishing, the damming of major rivers, industrial waste pollution and the drastic reduction in the use of synthetic fertilizers since the late 1980s (Baisre and Arboleya, 2007). On the other hand, in the past two decades, the intensity of the cyclonic organisms have been the CC-related events that have most affected marine and coastal biodiversity.

Map 3. Land use in Cuba

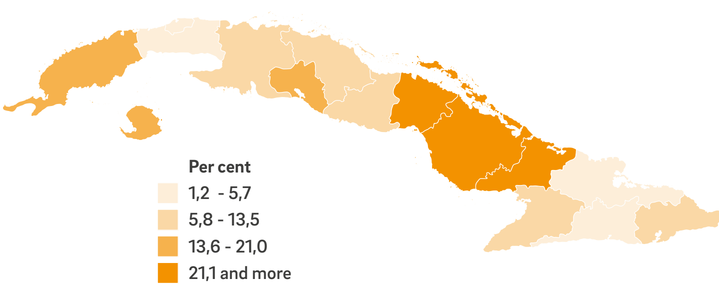
Total agricultural area



Account of utilization



Index of idleness



Source: National Office of Statistics and Information.

Under these circumstances, the strategy for projecting these resources over the next few years should begin with a program to restore damaged coastal zone habitats, reduce fishing efforts and restore strict control of compliance with the fishing regulations established to prevent illegal fishing and catching specimens below the legal minimal size.

Potential impacts of climate change. Building resilience to extreme events

The country has national and territorial strategies (provinces, municipalities, basins) for managing the reduction of CC impacts (adaptation-mitigation), which it periodically renews, based on the studies on the danger, vulnerability and risk of occurrence of disasters directed and coordinated by the Environment Agency (AMA-CITMA) with the National Civil Defense General Staff (EMNDC) and the participation of various institutions. Cuba's efforts in this field have been recognized: in 2001, it shared with Italy the world venue for "World Environment Day" and in 2006, in the "Living Planet 2006" Report (WWF, *World Wide Fund for Nature*) Report, it was declared the only country to have advanced sustainable development, with a sustainable ecological footprint (ONEI, 2016).

Studies in Cuba indicate that agriculture will develop in an adverse climate environment (Planos, 2014). Net primary productivity and the potential density of biomass will decline; the duration (in days) of phenological phases will be progressively shortened, while the total duration of the life cycles of major crops, including those of animal feed and their potential yields, will decrease. Phenomena associated with CC already influence the development and exacerbation of diseases and pests by acting on host-pathogen-vector-biological controller interactions, and there will be changes in the distribution, seasonality and severity of vector-borne diseases and pests.

The direct impact of rising temperatures and reduced rainfall will affect the productivity of major crops such as potato, soybean, beans, rice, cassava, maize and sugarcane, and animal husbandry. Research will be required on their adaptive response mechanisms to obtain improved materials with higher nutritional value, as well as on the type of management that encourages them. There is also a need to find new genetic sources, preferably native ones or through the introduction of new crops. These CC phenomena will hasten the degradation of agricultural soils, while the salinization of coastal aquifers will affect fishing and aquaculture activities. This, together with the reduction of agricultural areas, will lead to impacts on food production and changes in the population's food culture.

The synergy between the increase in the surface temperature of the oceans and their acidification, the intensity of coastal meteorological events - especially cyclonic organisms - and the gradual rise in the sea level increases the risk of the loss of biodiversity, together with its goods and services, which is already extremely threatened in the coastal areas transformed by man.

Research on the marine and coastal ecosystems comprising the natural barrier of the Cuban archipelago to strong winds, tidal waves and intense waves, and rigorous compliance with conservation measures will contribute to reducing these foreseeable impacts and should be prioritized.

IV. Technology and Innovation to Achieve Food and Nutrition Security

The current infrastructure of agricultural research, with few exceptions, emerged in the 1960s as a result of the political will to develop science and technology because of their intrinsic connection with the country's social progress. In the agrarian sciences, this coincided with the start of the "Green Revolution" and its concepts. Over the next two decades, the human capital and resources of these centers grew considerably. The first results were obtained, and their priorities were defined and refined through planning (Cornide et al., 2006). The period from 1980 to 2010 was particularly important for the agricultural sector:

- The development of new biotechnologies in the medical-pharmaceutical sector was promoted, which was extended to the agricultural field, where the applications of "first-generation biotechnologies" were gradually incorporated into research programs that constituted a methodological advance in research. The most promising ones were incorporated into development programs and services, and included in curricula. The year 1986 saw the creation of a Center for the development of Genetic Engineering and Biotechnology (CIGB), with a division devoted to agricultural objectives.
- As a result of the collapse of the Socialist Bloc, food security became a strategic objective for the population's survival.
  Within the framework of the socioeconomic guidelines approved for the country, specific research objectives were formulated with a "systemic, multidisciplinary approach" to close the cycle "from laboratory to field". To boost local use of new technologies, two centers were set up in the provinces of Villa Clara and Ciego de Ávila, together with several facilities for the multiplication of high-quality propagules ('biofactories'), the production of bioproducts and Centers for Entomophage and Entomopathogen Reproduction (CREE) employed in integrated pest control (Borroto Leal et al., 2011).

The change in unsustainable production and consumption patterns in Cuban agriculture, begun for economic reasons and encouraged by new biotechnologies for raising yields, was a success that was confirmed by its coincidence with the Agenda 21 of the *United Nations Conference on Environment and Development* (Rio de Janeiro, Brazil, 1992) and the agreements of the *Summit on Sustainable Development* (Johannesburg, South Africa, 2002). Among other measures, the priority of this strategy was supported by the creation, in 1994, of CITMA as the Central State Administration Authority responsible for proposing STI and Environment policies and controlling their implementation on the basis of management coordination and control by the agencies responsible for their implementation.

Out of the necessary multidisciplinary and systemic conception of work and in order to optimize available resources, organizations were created to bring together several institutions from different sectors, fostering the multisectoral and transdisciplinary discussion of common issues and cooperation links. ISO (*International Standards Organization*) standards and various systems to accredit the facilities were assimilated. The development of a culture of patenting, registration and protection of plant varieties was reinforced, with emphasis being placed on the need for new economic indicators and methods to forecast and impact the measurements applied to the planning and execution of research projects, scientific and technical services and production.

Food production for human and animal consumption

Agricultural research yielded the following benefits for agriculture: new varieties, animal breeds and technologies for their management; recommendations for differentiated fertilization with the available mineral fertilizers and their national alternatives including registered biopreparations; livestock feed; methods of diagnosis and epidemiological surveillance, and vaccines (Borroto Leal et al., 2011). These have also been used in technical collaboration with other countries, some of which have received international awards.

At present, lines of work are being implemented to continue practices that have proved successful, and incorporate new technologies and the sustainability approach. Priorities for the period-in-development (2013-ca. 2025) (CITMA, 2015) include:

Genetic improvement and plants and livestock management

- Introduction of new methods and technologies to improve the evaluation and conservation of genetic resources.
- Traditional and biotechnological improvement of cultivars (sugarcane, rice, potatoes, vegetables, tropical meats and grains, and others for animal feed), and elite livestock breeds and species (dairy and beef cattle, pork, buffalo, rabbit, poultry, sheep and goats), to boost their productive potential and nutritional quality, as well as tolerance to abiotic stresses derived from CC, improved water use and resistance to emerging or high-risk diseases, together with the technological package for their exploitation.
- Development of new biopreparations and means of biological control and technological transferences to adapt them to the new production scenarios.
- Design of databases from agricultural research, historical series of programs for development and the productive behavior of results, using advanced computer methods and interactive computer tools to aid decision making.
- Studies of the horizontal and vertical models of extensionism and their coexistence and mutual empowerment, to achieve adaptation to local systems and the participation of decision makers and actors in each territory.

New foods for human and livestock consumption

- Diversification of food fortified for human consumption; formulation of new foods; manufacturing technologies with a predominance of local raw materials; products to preserve quality; and new methods for the analysis of the chemical, microbiological and toxicological safety of these foods.
- Formulation of grasses and fodder based on gramineae and legumes to increase their productivity under unfavorable conditions (low rainfall period, salinity, degraded soils, biotic stresses) and the nutritional balance of livestock; technologies for their management and rehabilitation; study of the nutrient recycling in the soil-plant-animal system and the development of silvopastoral systems, and technologies to increase hay and silage production.
- Microbiological studies for the management of legumes and to obtain activators of ruminal fermentation and food supplements and additives based on by-products or agroindustrial residues available in the country; and the use of physical, chemical and biological options to increase their nutritional value, conservation and form of presentation.

Agricultural health

Agricultural health research supports the Agricultural Health System and, because of its strategic importance, Cuban institutions work in collaboration with networks both inside and outside the country. Researchers participate in research projects on disaster prevention and mitigation and in training projects with various international organizations. The highest priority topics are:

- Identification, characterization and diagnosis of pests and diseases; molecular charac-

terization of phytopathogen populations and etiological agents of emerging and re-emerging diseases to determine their origin and predict their evolution.
- Development of integrated pest management systems; design of bioproducts that support other methods of control.
- Studies of host-pathogen interactions and participation in genetic improvement programs to obtain pest- and disease-resistant materials and in livestock programs through the characterization of various populations of veterinary interest affecting species prioritized for human consumption (cattle, pigs, buffaloes and goats).
- Development of vaccines of veterinary interest; design and optimization of systems to produce diagnostic tools and vaccines.
- Toxicosis studies for diagnosis, control and treatment.
- Study of the danger, vulnerability and risk of the occurrence of health disasters; assessment of the effectiveness of management programs, and issuance of early warnings for decision making.

New biotechnologies: Genetic Engineering and Functional Genomics

In Cuba, obtaining Genetically Modified Organisms (GMO) using Genetic Engineering (GI), molecular biology and *in vitro* culture techniques, has made it possible to obtain biological models to determine the structure and function of hereditary material. These models are used for gene isolation, marker-assisted selection in traditional genetic improvement programs, the development of methods for the molecular diagnosis of pathogens and vaccines for veterinary use on the basis of immunogens, and the study of gene regulation in plants and animals (Borroto Leal et al., 2011). The goals of biotechnological work include:

- The introduction of new biotechnologies to produce high-quality seed and bioproducts, *in vitro* and in vivo production technologies of substances of pharmaceutical and industrial interest, and obtaining genetically improved materials and research tools that generate new knowledge and genes.

New generation biotech products. (A): 'GAVAC' is an immunogen against ticks (*Boophilos microplus*) obtained recombinantly, after a peptide from the PO ribosomal has been identified as a vaccine antigen. 'Hebernem', a nematicide of biological origin. Both products are marketed in Cuba and several Latin-American countries (courtesy of Bio-CubaPharma).

- Obtaining transgenic soybean lines and transgenic dry maize hybrids for animal feed, significant areas for these imports.
- Use of new genome sequencing technologies and their products (transcriptome, proteome and metabolome) to predict the genetic value of improved individuals and populations, contribute to animal feeding and obtain new genetic modification tools such as specific genome editing without gene transfer between species.
- Production of new-generation veterinary vaccines for bird and livestock species.
- Obtain veterinary vaccines and growth and immune system stimulators from organisms used in aquaculture to eliminate or reduce antibiotics and chemicals in animal protein production.

The use of transgenic plants is legally regulated in Cuba under the principles of the Cartagena Protocol to which it is a signatory. In the 1980s, legislation was established to regulate research and the commercial use of GMO and, in particular, transgenic plants in terms of food safety, by the National Institute of Hygiene, Epidemiology and Microbiology (INHEM,MINSAP); (CNSB,CITMA), and biodiversity (novelty) and its technological usefulness in order to be registered as a seed by the National Plant Health Center (CNSV,MINAG) in each of the transgenic events that can be produced and marketed in Cuba, establishing a mechanism of evaluation and approval on a case-by-case basis.

Medium- and long-term projections

In today's world, species of economic interest and technologies and inputs for their management are protected by various types of intellectual property and are often marketed together (technology package). The growing privatization of this activity at the global level coupled with the trend toward the industrialization of improvement programs herald the risk of the food sovereignty that developing countries will experience by the middle of this century unless they have traditional and biotechnological improvement programs for plants and animals that should guarantee food sufficiency with majority control by the public sector.

The following measures are proposed for STI to contribute to the achievement of a high level of food self-sufficiency in 2050:

Technology development and transfer

- Optimization of the value chains of the main crops, meat, milk and egg.
- Optimization of biotechnological processes based on *in vitro* cultures, controlled conditions and field transfer in anticipation of temperature changes; implement a level of automation and low-cost quality-control methods; develop management schemes to improve the use of facilities under controlled conditions, and enhance the efficiency and stability of the processes involved.
- Genetic and economic optimization of genetic improvement programs for priority species, with a strong state-sector component.
- Development of modeling and computerized simulation for data analysis, studies of environmental impacts (abiotic, biotic and management) and comparison of recommended alternatives and their prognosis.
- Adaptation of technologies based on "Conservation Agriculture" for soils and crops, regarding the farm as a basic management unit, and the river basin as a geographic physical space to be protected.
- Transfer of irrigation technologies adapted to the new agrotechnical packages; design or innovate equipment, machinery and implements in food production systems in keeping with current energy and environmental policies.
- Build human capacities for bioinformatics support and improve training in the management of economic and market indicators in personnel associated with agricultural research and services.
- Implementation of means for data mining, storage and processing (meta-analysis, robotics) ("Big Data" challenge).

- Develop computer infrastructure and remote access communication to scientific-technical services to provide information for decision makers, technical staff and farmers regarding risks, biosecurity, production records, the market, and computer tools to use them in decision making in real time.

Proposed future objectives for research and development programs

- Expansion of genetic basis: Obtain and introduce new genotypes and crops tolerant to unfavorable environments; livestock breeds resistant to high temperatures and water deficit; and microorganisms for new biopreparations.
- Prioritize studies on the physiological bases of the adaptation of main crops to biotic and abiotic impacts with a local, sustainable approach.
- Seek efficient physiological indicators for selection; introduction of high-non-invasive, high-precision evaluation methods based on physical sensors and image processing.
- Gradual implementation of Genomic Selection for dairy cattle and prioritized crops.
- Use of new technologies to obtain improved genotypes and recombinant products with proven safety. Provide the scientific bases for improving the provisions of regulatory bodies.
- Functional genomics research for a better understanding of the genetic basis of productivity and adaptation to stress (oxidative, antioxidant and tolerance to abiotic factors) at the molecular level. Develop new products to be used within the framework of the "Precision Agriculture" approach.
- Establish an STI Program for the sustainable development of fisheries and aquaculture as food sources for human and animal consumption, restore damaged coastal-zone habitats and recommend measures for their exploitation and control, based on the biological and ecological aspects of species and ecosystems and the sources and scope of the impacts that affect them.
- Extend and improve feasibility studies, forecasts and estimates of the impact of STI work.

Constraints

In order to contribute to the solution of the main constraints, physical and human infrastructure of the following should be strengthened:

- Research centers and service laboratories essential to sustaining and developing the agro-food sector. Encourage personnel, especially young people who will be the generational replacement.
- The system of diagnosis and monitoring of the main agricultural pathologies and their associated productions and the reproduction of biopesticides in CREE.

V. Increasing the Efficiency of Food Production Systems

Despite CC-related effects, the production potential of crops and livestock species is expected to continue to increase in the coming decades as a result of STI contributions to improvement, management and sanitation. Their practical contribution is expected to be limited by competition for water and land between the two food sources and between the sector involved in agricultural production and other human activities. At the same time, the role of socioeconomic factors such as local priorities, human health and sociocultural values will determine the balance of these resources in terms of food security (FAO, 2006). This points to the importance of having an efficient, flexible management throughout the value chain of the activity.

In Cuba, local development strategies are conceived of as participatory processes in which participants are summoned by the municipal government, which organizes and implements actions that mobilize local factors that will directly benefit its population in order to achieve a safe, stable market for producers, a broader supply of products at affordable prices for the population and job creation, by encouraging family or cooperative farming.

The National Program for Local Development is linked to three national priorities associated with food security: food production for human and animal consumption, combating CC and water. It seeks to achieve municipal self-sufficiency by leveraging the participation of the non-state sector and facilitating mechanisms for its direct insertion into the management of local development. The participatory and local nature of this scenario will help to reduce territorial imbalances; technological change induced by innovation and technological diffusion for the benefit of business development; change food consumption habits, and establish a quality-price balance in order to improve the population's quality of life.

Agricultural companies work until the cycle ends with the commercialization of fresh products, which are processed by various industries. Waste is processed to obtain organic matter, biogas and other forms of energy. Grains and seeds are preserved and dried. Materials are transported by highway and railroad.

Several successful examples of this strategy are already underway: (1) The program for the **Optimization of the value chains of milk**, meats and various crops; (2) the **Urban, Suburban and Family Agriculture Program**; (3) the **Local Agricultural Innovation Project** (PIAL), and (4) **Territorial Environmental Strategies**. These programs focus on local action to preserve the environmental achievements attained and undertake new actions for sustainable development. They have contributed to building local human capacities, reforestation, the recovery of abandoned agricultural land and promoting local food security.

VI. Health Considerations

At the end of last year, health indicators showed a birth rate of 11.1/1,000 inhabitants and 99.9% of live births in health institutions. The total mortality rate of the population is 8.9/1,000 inhabitants, while the number of children <1 year is 4.3/1,000 live births. The two main causes of death at all ages are heart disease (218.3/1,000 inhabitants) and malignant tumors (215/100,000 inhabitants), followed by cerebrovascular diseases (82.6/100,000 inhabitants) (MINSAP, 2015).

Over the past 50 years, Cuba has established one of the world's most comprehensive social protection programs, which has made it possible to draw up action plans to eradicate or minimize the most important food and nutritional problems identified by the Food and Nutrition Surveillance System and national health and food consumption surveys: (1) high prevalence of iron deficiency anemia in pregnant women and children under five; (2) upward trend in overweight and obesity; (3) low prevalence of exclusive breastfeeding; (4) problems of food availability during disasters (hurricanes and drought); (5) poor food culture, and (6) dietary and nutritional problems associated with aging.

The Surveillance System detects and controls outbreaks of food poisoning and investigates the evaluation of microbiological hazards in food of animal origin with recommendations to improve production processes; diagnosis of pathogens in food for animal and human consumption; hazards, vulnerabilities and risks for pests and diseases with an impact on the health, social, environmental and economic orders, and toxicological and ecotoxicological methodologies for preclinical testing of new products.

VII. Policies to Contribute to Food and Nutrition Security

The projections of policies related to the goal of achieving agricultural production and marketing levels to increase the food and nutritional security of the population and the quality of life are found in the *National Economic and Social Development Plan Until 2030* (PCC, 2016).

Projection of policies in this area

One of these challenges is the high dependence on food imports, meaning that their purchase represents an important part of the expenditure of most Cuban families (Anaya and García, 2016).

Moreover, prices not regulated by the State are high for foods such as fruits, vegetables, beans and sources of animal protein, which encourages the consumption of products that lead to obesity and other associated health problems. Treatment of this problem is a high priority and requires a systemic approach in the midst of ongoing socioeconomic transformations aimed at: 1) increasing the production, productivity, competitiveness, marketing and environmental and financial sustainability of the agri-food production chains of prioritized non-sugarcane crops, and the sugar agroindustry and its derivatives; 2) developing a sustainable agriculture, based on the integrated management of STI and a new business management model to guarantee the productive use of the results, as well as the optimization of available capacities and the various productive scales that would increase this activity and create jobs among the local population; 3) prioritizing the conservation, protection and improvement of natural resources; 4) restoring the production of quality cultivars and species; 5) promoting the use of national bioproducts; 6) developing a comprehensive program for the maintenance, protection, conservation and development of watersheds, dams, hydro-regulatory strips, mountains and coasts; (7) increasing the efficiency of fisheries by complying with the quality of catches and preserving the marine and coastal environment, and 8) developing aquaculture with modern farming techniques.

Issues related to international trade and market challenges

Due to a myriad of factors, the country has very few comparative advantages in food products. Except for sugar exports, in most other products, the volume is small or very small and concentrated in very few countries and markets.

At the international level, policies are required to expand and consolidate price-protection mechanisms for the agricultural and food products Cuba sells, such as sugar and coffee. In the current and foreseeable context, in which the price of commodities (including food) has dropped, exports and income generation must be boosted, and the high dependence on financing that is now covered by revenue from other sectors should be reduced. It is essential to use quality systems with established standards and market demands to ensure food safety and healthy nutrition, and to systematize the identification of new production scenarios, taking into account customs, food habits and other conditions, such as agroecological foods.

Internally, policies must tailor agri-food production to demand and transform marketing, restructure the current system of marketing inputs and equipment for agriculture, in line with the new scenario of the agri-food activity and financial mechanisms implemented.

On the distortions caused by subsidies and other agricultural policy instruments

Cuba must weigh up the challenges and opportunities arising from the international commercial context in order to make responsible, careful choices. It is important to capitalize on the benefits of the principle of Special and Differential Treatment (SDT), whereby developing countries obtain privileges and are able to undertake reforms according to their capacity and development needs.

As imports of subsidized food increase, support should be provided to make farmers aware of new policies and forms of trade, to avoid their being affected, and to encourage the production that has been displaced by subsidized trade.

The product subsidy policy should be replaced by subsidies targeting people with specific needs.

Technological innovation policies and human resource training

Technical change driven by innovation and technological dissemination is seen as the most important driving force in food and nutrition security and in reducing poverty in developing countries. The country should implement policies and programs that foster constructive interactions between researchers and companies (state and non-state forms of production). A broad, sustained process of technological dissemination is required throughout society.

There should be an awareness that all the sectoral and global policies implemented, involving either health, education, employment, agriculture or taxes, have a positive impact on national scientific and technological performance.

Beyond a narrow vision of economic development, Cuba must employ STI personnel and results to address social problems.

In addition to focusing on high-level skills, professional technical careers must be strengthened in areas such as design, logistics and management, which will require changes in funding priorities within higher education. Raising the level of business innovation will require greater investment in human capital and the incorporation of qualified personnel into business activities together with the high knowledge component required by innovative solutions. Policies should encourage mobility between companies and public research organizations, facilitate student practices in industry and promote more investment in human resources by companies.

Policy design for the Cuban agri-food sector, which is highly sensitive to the effects of applied fiscal and monetary policies, should consider the impact of macroeconomic policies. For example, in monetary terms, a more objective exchange rate could create incentives to substitute imports and promote exports, which would have a positive influence on the sector's profitability.

VIII. Conclusions

Cuba is a developing state which, because of its insularity and geographical location, is vulnerable to the impact of climate change and certain natural disasters, as well as to global changes in the world economy. This chapter outlines Cuba's strengths and challenges in terms of food and nutrition security for the middle of this century (Epigraph I). It describes the Science, Technology and Innovation (STI) infrastructure the country has for its socioeconomic development and its measures-in-place for its management (Epigraph II). It analyzes the current status of natural resources, the main causes that threaten their conservation, the foreseeable trends of their evolution and the main institutional and legal measures-in-place to curb their deterioration (Section III). It also explores the role of STI in the present, the near future (2017-2030) and in the longer term, until the middle of this century (2030-2050) (sections IV-VI).

Agricultural production has been maintained for two decades with the application of STI results such as seeds and breeds, inputs and agricultural management systems and health and veterinary control methods. The acute economic crisis of the 1990s triggered a shift toward sustainability, driven by the new biotechnologies used in the agricultural sector. Nonetheless, food import dependence persists, with negative consequences for food and nutrition security, which could be exacerbated in the future due to the expected competition over water and land use, and the forecast of the effects due to climate change. New STI goals, currently underway, have been set to raise potential yields and other programs such as local development in order to optimize the value chains of the main agricultural products and lay the foundations for a new business-management model, which will strengthen the capacities available in the country, recognize the various production scales and contribute to promoting innovation and technological dissemination.

There is a need to prioritize knowledge of the physiological mechanisms of adaptation to the changing effects in space and time associated with climate change, and to hasten the obtainment of new genetic materials and bioproducts through the application of new technologies.

This chapter outlines the main policies supporting the agri-food sector, the challenges of the international market to expanding trade and recommended policies for promoting technological innovation, providing human resources with better business training and strengthening the current STI infrastructure.

Since today's solutions may not suffice to meet the challenges of tomorrow, it is suggested that the impact of all the sectoral and global policies implemented in the agricultural sector be evaluated in a timely manner, especially regarding their scientific and technological development.

The match between current and future STI objectives in terms of environmental conservation and food security, and those of the latter and the policies developed to support them, is neither a coincidence nor forced. On the contrary, it is the result of the joint, integrated design of three basic sectors: the environment, agri-food and the economy, based on the experience acquired in the sustainable development of Cuban society during the 2011-2016 period.

References

Aguilar, Y., Calero, B., Rodríguez, D. and Muñiz, O. (2015). Cuba's polygon program agricultural land rehabilitation. Current Opinion in Environmental Sustainability. 15: 72-78.

Anaya, B. and García A. (2016). El sector agropecuario cubano en la actualización. Boletín Semestral. Centro de Estudios de la Economía Cubana, January-June. Havana.

Baisre, J.A. and Arboleya, Z. (2007). Going against the flow: Effects of river damming in Cuban fisheries. Fisheries Research 81: 283-292.

CITMA (Ministry of Science, Technology and Environment) (2012). Cuba Report to the United Nations Conference on Sustainable Development 'Río +20'. Prepared by 9 CITMA entities in collaboration with the Directorate of Multilateral Affairs of the Ministry of Foreign Affairs, the Ministry of Foreign Trade and the Cuban Association of the United Nations. Havana, 2012.

CITMA (Ministerio de Ciencia, Tecnología y Medio Ambiente de la República de Cuba) (2014). V Informe Nacional al Convenio sobre la Diversidad Biológica. Havana, Cuba. ISBN: 978-959-270-340-7

CITMA (Ministerio de Ciencia, Tecnología y Medio Ambiente de la República de Cuba) (2015). Programas de Ciencia, Tecnología e Innovación. Ciudad de La Habana, septiembre de 2015, 123 pp.

Cornide, M.T. et al. (2006). Las Investigaciones Agropecuarias en Cuba, Cien años después. M.T. Cornide (Ed.). Editorial Científico-Técnica, Instituto del Libro, La Habana, 2006, 323 pp. (ISBN959-05-0394-2).

Borroto Leal, O. et al. (2011). Análisis de los Premios de la Academia de Ciencias de Cuba. Sección de Ciencias Agrarias y de la Pesca (1996-2010). [Electronic publication] Anales ACC, 1: (1), 30 pp.

Fontova de los Reyes et al. (2012). Recursos hídricos en Cuba. Una visión. In: P. L. Dorticós, M. Arellano and J. M. García Fernández (Eds.), Diagnóstico del Agua en las Américas (pp. 245-265). Coordinators: Blanca Jiménez Cisneros and José Galizia Tundisi, Red Interamericana de Academias de Ciencias (IANAS). Foro Consultivo Científico y Tecnológico, AC. ISBN: 978-607-9217-04-4.

Instituto de Suelos de Cuba (1999). Nueva Versión de Clasificación Genética de los Suelos de Cuba, MINAG, AGRINFOR, 64 pp. ISBN 959-246-022-1.

Ministerio de Relaciones Exteriores (MINREX) (2016). Informe de Cuba. Sobre la resolución 70/5 de la Asamblea General de las Naciones Unidas, titulada "Necesidad de poner fin al bloqueo económico, comercial y financiero impuesto por los Estados Unidos de América contra Cuba". June 2016, MINREX, 45 pp.

Ministerio de Salud Pública (MINSAP) (2015). Anuario Estadístico de Salud. Dirección de Registros Médicos y Estadísticas de Salud. La Habana, 2016. ISSN printed version 1561-4425.

Nova, A. (2016). El mercado agropecuario: Políticas e impactos. Cubadebate. Online Publication, July 2016.

Rodríguez, J.L. (2016). Una primera mirada a la economía cubana: resultados de 2015 y perspectivas de 2016 (I, II, III, IV). Cubadebate, January-April. Online publication. La Habana.

Oficina Nacional de Estadística e Información de la República de Cuba (ONEI) (2016): (a) Panorama Ambiental. Cuba 2015. July 2016 edition; (b) Educación: Resumen del curso escolar 2014/2015 e inicio del curso escolar 2015/2016. May 2016 edition; (c) Panorama Uso de la Tierra. Cuba. 2015. May 2016 edition.

Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO) (2006). World Agriculture: Towards 2030/2050. Interim report, Global Perspective Studies Unit. Rome, Italy: Food and Agriculture Organization of the United Nations.

Partido Comunista de Cuba (PCC) (2016). Proyecto de Conceptualización del Modelo Económico y Social Cubano de Desarrollo Socialista; Proyecto de Plan Nacional de Desarrollo Económico y Social hasta 2030: Propuesta de visión de la nación, ejes y sectores estratégicos; Lineamientos de la política económica y social del Partido y la Revolución para el período 2016-2021 (passed by the Asamblea Nacional del Poder Popular, in July 2016). Séptimo Congreso del Partido Comunista de Cuba, La Habana, April, 2016.

Planos G.E. (2014). Síntesis informativa sobre impactos del cambio climático y medidas de adaptación en Cuba. Basal (Bases Ambientales para Sostenibilidad Alimentaria Local) 26 pp. ISBN: 978-959-300-044-4; 2014.

Programa de las Naciones Unidas para el Desarrollo (PNUD). 2015. Panorama general Informe sobre Desarrollo Humano. 2015. Trabajo al servicio del desarrollo humano. http://hdr.undp.org/sites/default/files/2015_human_development_report_overview_-_es.pdf]

Acknowledgments

Academics **Arnaldo Álvarez,** Institute for Forestry Research, Ministry of Agriculture (MINAG). **Mario P. Estrada,** Center for Genetic Engineering and Biotechnology (CIGB). **Sergio Jorge Pastrana,** Academy of Science of Cuba (ACC). **Olegario Muñiz,** Soils Institute, MINAG.

The following experts played an active role in the elaboration and discussion of the contents of this consultation, as co-authors: **Julio A. Baisre,** Institute de Oceanology, CITMA. **Faustino Cobarrubia,** Center for Research on the World Economy (CIEM), CITMA. **María Felicia Díaz,** Institute of Animal Science (ICA). **Lianne Fernández,** Alejandro de Humboldt Institute of Basic Research on Tropical Agriculture (INIFAT), MINAG. **Marisol González,** STI Directorate, Ministry of Higher Education (MES). **Abel Hernández,** Center for Genetic Engineering and Biotechnology (CIGB). **Julián Herrera,** Institute of Agricultural Research, MINAG. **Mayuly Martínez,** Institute of Animal Science (ICA). **Rodobaldo Ortiz,** National Institute of Agricultural Science (INCA). MES. **Luis Paz** and **Eduardo Planos,** Institute of Meteorology (INSMET), CITMA. **Jonathan Quirós,** Center for Research on the World Economy (CIEM), CITMA. **Iván Relova,** CUBAENERGÍA, CITMA. **Armando Rodríguez,** Nutrition Center, National Institute of Hygiene and Medical Epidemiology, Ministry of Public Health. **Odalys Uffo,** National Center for Agricultural Health (CENSA), MES. **Antonio Vantour,** STI Directorate. CITMA. and **Daysi Vilamajó,** Environmental Agency (AMA). CITMA.

The following academic doctors made valuable observations on the document in their capacity as consultants: **Gisela Alonso,** Environmental Agency (AMA). CITMA. **Ondina León,** National Center for Agricultural Health (CENSA), MES. **María del Carmen Pérez,** National Institute of Agricultural Science (INCA). MES. **Adolfo Rodríguez,** Alejandro de Humboldt Institute of Basic Research on Tropical Agriculture (INIFAT), MINAG. **José Luis Rodríguez,** Faculty of Economics, University of Havana (UH). MES. And Drs: **Mercedes Arellano,** Environmental Agency (AMA). CITMA. **Olimpia Carrillo,** Faculty of Biology, UH. MES. **René Florido,** National Institute of Agricultural Science (INCA). MES. **Anicia García,** Faculty of Economics, University of Havana (UH). MES. **Alexander Miranda,** National Institute of Agricultural Science (INCA). MES. **Armando Nova,** Center for Research on International Economics, UH. MES. and **Aida Ramírez,** Institute for Research on Grass and Fodder, MINAG.

Dr. **Julio A. Larramendi,** Editorial Director, Ediciones Polymita, Cuba, authorized the use of two of his wonderful landscape paintings of the country.

We are grateful to all of them, because without their valuable and disinterested collaboration, this task would have been even more difficult.

Food and Nutrition Security in the Dominican Republic

A vision for the next 50 years

Cattle grazing among the palm trees in the Dominican Republic © Shutterstock

Dominican Republic

[1] Helmut Bethancourt
[2] Jorge A. Tallaj A.
[3] Lourdes Tapia Benoit
[4] Pedro Pablo Peña
[5] Angel Roberto Sánchez
[6] Elpidio Avilés
[7] Rafael Pérez Duvergé
[8] Anabel Kunhardt
[9] Miguel J. Henríquez
[10] Lidio Martínez

Every Dominican has the right to proper food. **Although the country achieved one of the Millennium Development Goals by reducing hunger,** 1.3 million citizens still suffer from this while many others are affected by nutrition. A great deal remains to be done to eradicate these problems

Summary

The Dominican Republic is an island state with an area of 48,308 km², with 1.9 million hectares dedicated to agricultural production. The country's main agricultural products are rice, maize, sugar cane, coffee, cacao, tobacco, coconut, beans, pigeon peas, yucca, taro, sweet potato, yam, potato, plantain, banana, onion, eggplant, squash, tomato, avocado, papaya, pineapple, sweet orange, passion fruit, cucumber and chayote. Beef cattle, pig, poultry and egg production are also very important.

The country's research policies are formulated by the National Council for Agricultural and Forestry Research (CONIAF) and implemented by the Dominican Institute of Agricultural and Forest Research (IDIAF). Funding is received from national (MESCyT and CONIAF) and international organizations, and research is conducted by the state university (UASD) and several private universities. A current problem in the country is the high average age of agricultural researchers and the lack of a clear generational change policy. At the same time, Dominican public expenditure on agricultural research was 0.30% in relation to its GDP, much lower than the 1% recommended by the UN.

The Dominican Republic also faces a major freshwater crisis as a result of climate change, due to a 20% reduction in annual rainfall, increased evapotranspiration and population growth. Freshwater resources per capita are expected to decline from 2,200 m³ in 2008 to less than 400 m³ by 2100.

Twenty-three percent of Dominican soils are considered suitable for agricultural crops, with specific use and management practices, while another 16% can be used for grazing and rice with modern mechanization methods and intensive management methods. However, they are undergoing degradation, the main causes of which are: deforestation, construction of the road network, mining activity, climate phenomena, agrochemical use and unsustainable water management. Moreover, many soils with agricultural vocation are being urbanized.

Dominican biodiversity is threatened by the fact that a number of species of endemic and native flora and fauna are in danger of extinction. This is mainly caused by the destruction and fragmentation of habitats for changes in land use, expansion of the agricultural and livestock frontier, urban growth, infrastructure construction, mining, deforestation, the capture and extraction of wild species, forest fires, the introduction of invasive species, the emergence of new diseases and climate change (extreme hydrological events and drought).

It is estimated that forest cover has been reduced from 83% of the total area at the beginning of the 20th century to 28.5% in 2005, partly as a result of agricultural activity. Moreover, the use of forest materials in industry for energy generation and construction, the use

of slash-and-burn agriculture and the abuse of agrochemicals are practices that severely damage forests. It is essential to design and implement a Land-Use Plan to identify the potential uses of the soil in accordance with specific local conditions.

Regarding technological research, the country has been working on the use of enzymatic technologies to produce extracts, fermentations of industrial interest, bioprospecting, tissue culture and molecular characterization. Some universities, as well as a number of private companies, have developed proprietary protocols for plant production through *in vitro* tissue culture. Success stories resulting from this upsurge of interest include the massive introduction of crop varieties such as plantain, pineapple, potato and strawberry. Animal biotechnology, however, has not elicited the same interest. The incorporation of genetically modified organisms has been slow, since there was no legal framework in place until 2015.

The Dominican Republic has not escaped FoodBborne Diseases (FBD), several outbreaks of which have been reported, with seafood being the main culprit. A key problem in terms of food is the high overweight and obesity rate among the population, which may be due to unhealthy eating patterns, both traditional (Dominican cuisine is rich in carbohydrates and fried foods) and as a result of globalization (such as fast food and eating out). A small segment of society is concerned about healthy changes in food, although not necessarily on the basis of sound scientific foundations.

As for the legal framework, the passage of the Sovereignty and Food Security Law in 2016, which stipulates the right to adequate food for all people, and implies access to sufficient, healthy food, was a key event

A detailed reflection is required to meet the challenges and perspectives of the agricultural sector. The entire livestock sector will be within the Dominican Republic-Central America Free Trade Agreement (DR-CAFTA) in 2020, meaning that it will have to compete with quota- and tariff-free imports. Current competitiveness of Dominican agricultural exports is relatively low. DR-CAFTA provides possibilities, rules and predictability for the agricultural sector, yet also poses two known challenges. The first is to take advantage of expanded access to the US market and the second is to protect producers of sensitive goods.

I. National characteristics

The Dominican Republic is an island state occupying the eastern part of the island of Hispaniola, with an area of 48,308 km². A total of 1.9 million hectares (ha) are dedicated to

[1] **Helmut Bethancourt,** Chapter Coordinator. Researcher, National Evangelical University (UNEV); Professor, Faculty of Agronomic and Veterinary Sciences, Autonomous University of Santo Domingo (UASD), helmutbio@yahoo.com [2] **Jorge A. Tallaj A.,** Dean of Post-Graduate, Pontifical Mother and Teacher Catholic University (PUCMM). Expert in Food Science and Technology, jtallaj@pucmm.edu.do [3] **Lourdes Tapia Benoit,** Natural Resources and Environmental Impact Assessments, ltapia@pucmm.edu.do [4] **Pedro Pablo Peña,** Agronomist and Agricultural Economist, Executive Director of the Center for Agricultural and Forest Development, Inc. (CEDAF), ppena@cedaf.org.do [5] **Angel Roberto Sánchez,** Professor and Acting Director of Directorate of Scientific Research of the Faculty of Agronomic and Veterinary Sciences, Autonomous University of Santo Domingo (UASD), robertosanche66@hotmail.com [6] **Elpidio Avilés,** Specialist in Tropical Soil Management and Conservation; Professor, Autonomous University of Santo Domingo (UASD); Researcher, Dominican Institute of Agricultural and Forest Research (IDIAF), avilesquezada@hotmail.com [7] **Rafael Pérez Duvergé,** Executive Director of the Dominican Institute of Agricultural and Forest Research (IDIAF), pduverge@idiaf.gov.do [8] **Anabel Kunhardt,** Nutrition and Dietetics. Departamento de Nutrición y Dietética de la Pontificia Universidad Católica Madre y Maestra, akunhardt@pucmm.edu.do [9] **Miguel J. Henríquez,** Nutrition and Dietetics. Departamento de Nutrición y Dietética de la Pontificia Universidad Católica Madre y Maestra, m.henriquez@ce.pucmm.edu.do [10] **Lidio Martínez,** Agronomist, Technical Coordinator of the Food Export Project (SAFE) implemented by the National Cooperative Business Association (NCBA CLUSA) and the Dominican Agribusiness Board (JAD), lidiomartinez@gmail.com

Table 1. Dominican Republic: Percentage distribution of agricultural productive units, by main type of crop planted

Main type of crop planted	Number of units	
	Absolute	Relative
Total	**251,916**	**100.0**
Cereals	70,638	28.0
Vegetables and melon	8,256	3.3
Fruit and nuts	61,892	24.6
Oilseed crops	3,292	1.3
Root vegetable/tuber crops with high starch or inulin content	23,654	9.4
Crops for beverages and spices	43,750	17.4
Pulse crops	19,035	7.6
Sugar crops	1,418	0.6
Other crops	19,981	7.9

Source: National Agricultural Pre-Census, 2015, p. 35

agricultural production, distributed as follows: over 0.69 million ha for agricultural use, 0.56 million ha for animal husbandry, 0.46 million ha for the cultivation of agricultural products combined with animal husbandry, 0.07 million ha for planting of forest and timber trees, 19,000 ha for a combination of tree planting and animal husbandry and 17,000 ha for growing flowers and/or ornamental plants (National Agricultural Precensus, 2015)

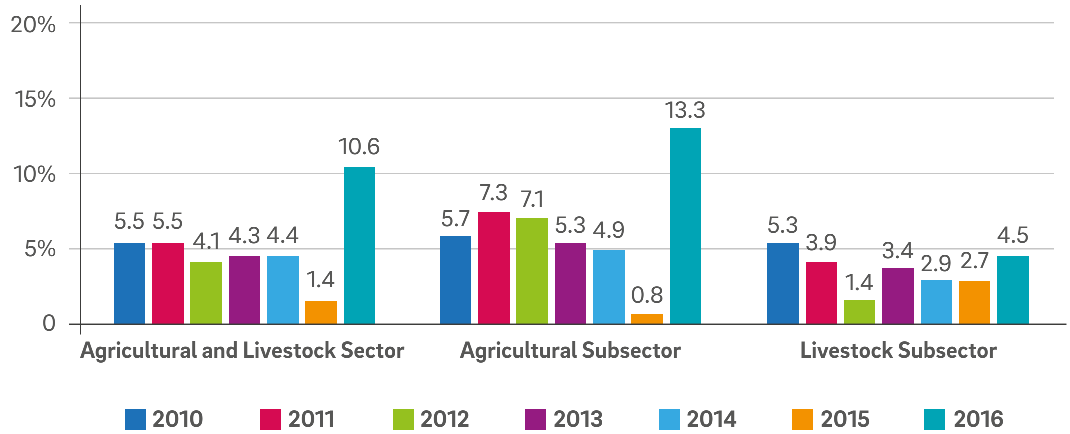
Land use at the national level shows a preponderance of agricultural activities. The majority of the country's productive units (251,916, or 62.6%) are dedicated to these activities. A fifth (20%) are devoted to animal husbandry, while 16.3% engage in both agricultural and livestock activities. Less than 1% are devoted to activities such as the planting of forest or timber trees, or cultivating flowers or ornamental plants (National Agricultural Precensus, 2015). The following table, taken from the National Agricultural Statistics Prediction Report, produced by the National Bureau of Statistics, shows the percentage distribution of agricultural production units by crop type.

The main agricultural products grown in the country are rice, corn, sugar cane, coffee, cacao, tobacco, coconut, red kidney bean, black beans, white beans, pigeon peas, cassava, taro, sweet potato, yam, potato, banana, plantain, onion, garlic, pepper, eggplant, squash, tomato, avocado, papaya, pineapple, sweet orange, passion fruit, cucumber and vegetable pear. There are currently about 300,000 ha under irrigation, equivalent to 55% of the country's potentially irrigable land, while 68.58% of cultivated land has irrigation infrastructure (National Bureau of Statistics, 2013).

The agricultural sector has enormous social importance for the country, since there are 319,676 agricultural production units (National Agricultural Precensus, 2015), and this sector accounts for 5.8% of the country's GDP. The following graph shows the variation of the GDP for the agricultural and livestock sector and the agricultural and livestock subsectors over the past seven years.

A third of the Dominican population is rural, earning its livelihood from agricultural and forestry activities. However, the rural population is increasingly linked to urban dynamics, in both economic and social issues. A large number of rural families have relatives abroad who send remittances that contribute to rural development and alleviate poverty. Nevertheless, analyses conducted on various crops show that limitations on access to financing for production and commercialization continue to constitute a major barrier to expansion (JAD, 2009).

Figure 1. Variation of GDP for the agricultural sector and the agricultural and livestock subsectors



According to statistics published by the Ministry of Agriculture (MA), products exported by the Dominican Republic are: rice, beans, pigeon peas, potato, yam, taro, yucca, garlic, red onion, eggplant, squash, pepper, cucumber, carrot, avocado, millet, pineapple, melon, banana, orange, plantain, banana, beef, chicken meat, pork and eggs. Of these, the main ones (≥ 100,000 quintals per year) are: plantain, avocado, rice, pepper, chicken meat, eggplant, beans, sweet potato, carrot, cucumber and pineapple (Dominican Ministry of Agriculture Statistical Base, 2017).

As for the livestock subsector, there are 115,578 productive units, which raise various types of livestock: cattle, pigs, goats, sheep, horses and farm and domestically reared poultry, the main ones being cattle (meat, milk and derivatives) and poultry (chickens and eggs). Other key livestock products include: rabbit, duck, guinea fowl, quail, turkey, fish and shrimp, honey and wax. Aquaculture and fishing activities have expanded in recent years, accounting for 11.3% of livestock production units (Precenso Nacional Agropecuario, 2015).

Research has shown that the growth of the agricultural sector is based on the development of the livestock subsector. According to data from the Central Bank, in the period between January and September 2016, annual growth in the added value of livestock, forestry and fisheries stood at 4.5%.

Exports of primary livestock products are limited, with only chicken meat, beef, pork and eggs and certain agroindustrial products being exported. In the case of imports, the situation is slightly different: nearly 5% of them correspond to this type of product. Conversely, a wide range of agricultural products are imported.

The main strengths of the agricultural sector include the attractive geographical position of the main markets, the fact that the country is an island, which creates a natural barrier against pests and diseases on the mainland and the efficient telecommunication system, which facilitates swift, easy access to international markets. There is also a basic road network in every region of the country, high consumption of traditional local gastronomical products by the diaspora, a technological innovation system(CONIAF, IDIAF and CEDAF) and programs to boost competitiveness (PATCA, PRODEVECO, CNC) (JAD, 2009).

According to a study undertaken by FAO to enable Caribbean countries to meet production needs, thereby guaranteeing their development and the food security of their inhabitants, it is essential to implement public policies and programs designed to promote family farming. These programs should include access to technologies to improve performance and productivity, information to support decision-making, outreach and training systems related to the sector, financing mechanisms, agricultural land, water resources and risk-management mechanisms to cope with potential natural disasters. Strategic alliances should also be created to improve small producers' insertion into markets (ECLAC, FAO, IICA, 2014).

These production systems would be a very important component for the small-scale production of food and thus continue to increase the proportion of the population with an adequate nutritional balance. During the 1990-1992 period, 34.35% of the population was undernourished. However, by the period from 2014 to 2016, this proportion had decreased by 20 percentage points, meeting the 1C objective of the Millennium Development Goals (FAO, 2015).

To illustrate the evolution of undernourishment in the Dominican Republic over the past 25 years, the following figure is included in the FAO report, "Overview of Food Insecurity in Latin America and the Caribbean: The region meets the international hunger goals," published in 2015.

This report states that: "*The positive situation of food and nutrition security in the country reflects the fact that the food availability of the Dominican Republic has increased in recent decades, reaching 2,619 calories per day per person in the triennium 2014-16, despite the fact that the country is a net importer of both goods and agrifood products*".

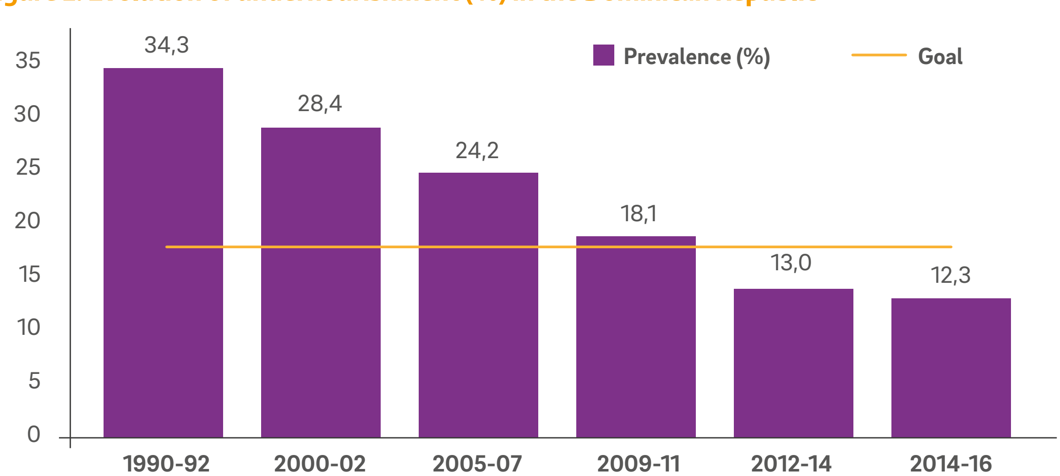
Other important aspects cited by this study as strengths are:

- Between 2004 and 2013, the country has managed to reduce poverty from 54.4% to 40.7% while extreme poverty fell by 8.8 percentage points during the same period, totaling 20.2% of the population (ECLAC, online).
- The country has been one of the regional pioneers in the institutionalization of food aid programs. Since the 1940s, State Economic Canteens have delivered food rations to the vulnerable population.
- The creation in 2008 of the Council for Food Security, responsible for implementing food and nutrition security actions, as well as consolidating and reinforcing the Dominican social protection system. (World Bank, online)" (FAO, 2015).

An important milestone for guaranteeing the fundamental right to adequate food and nutrition was the passage of Law No. 589-16, which created the National System for Sovereignty and Food and Nutrition Security of the Dominican Republic (SNSSAN), to establish the institutional framework for the creation of the SNSSAN.

However, all these actions and progress alone will not guarantee food security, since the Dominican Republic is a small island state located on one of the most active hurricane routes on the planet, extremely vulnerable to the impacts of climate change, with a high illiteracy rate, a

Figure 2. Evolution of undernourishment (%) in the Dominican Republic



Source: FAO, PMA, and FIDA. 2015.

deficient education system, where there is no political continuity when there is a change of government, or a public health system designed to meet the population's needs.

Another key aspect to be addressed is the growing migratory phenomenon of the rural population toward cities. In many parts of the Dominican countryside, there has been no generational replacement. Faced with the lack of incentives for agricultural production, young Dominicans set out for urban centers in search of opportunities, often living in overcrowded spaces with a lack of resources and services to guarantee their subsistence and quality of life.

II. Institutional climate

a. National Agricultural Research System

The Dominican Republic has a National System of Agricultural and Forest Research (SINIAF). Created in 2012, through Law 251-12, it comprises several institutions including the National Council for Agricultural and Forest Research (CONIAF), the organization responsible for formulating the country's agricultural research policy. Of particular importance is the Dominican Institute of Agricultural and Forest Research (IDIAF), the official body responsible for implementing research policy, as well as undertaking the various research projects approved by national (MESCyT and CONIAF) or international organizations (JICA-Japan, GIZ-Germany, KOPIA-Korea, USAID-USA, among others). It also includes public and private institutions and organizations that conduct research or technology-transfer actions in the agricultural and forestry sector, universities with faculties related to the sector, technological networks and any other agency directly or indirectly linked to agricultural or forestry research activities or (UASD, UCATECI, UNPHU, UISA, UNEV, UTECO) and the Institute of Innovations in Biotechnology and Industry.

b. Current status of SINIAF

The average age of the SINIAF researchers is currently estimated at 55 years. This is due to the difficulty of achieving effective generational replacement, which suggests that working conditions and salaries must be improved to make research more attractive as a profession (SODIAF, 2016). It is also necessary to further strengthen the training program through the granting of master and doctoral fellowships to current and potential researchers to increase the country's research capacity.

Research institutions in the Dominican Republic tend not to receive budget increases, and in some cases, these have been reduced by up to 30%. With adequate investment, necessary actions can be taken, such as improving the infrastructure for research on soil, phytopathology, entomology, virology and biotechnology laboratories. This includes purchasing up-to-date equipment and training laboratory technicians (SODIAF, 2016).

c. Universities and Research Institutes

The Dominican Republic boasts 50 higher education centers, according to the National Statistics Office (ONE), citing the administrative records of the Ministry of Higher Education, Science and Technology (MESCyT). In 2014, 443,555 were enrolled in higher education, 181,340 (41% of the total) at UASD, the public university. The remainder are distributed among private higher education institutions and seven specialized public institutes, with an enrolment of 262,215 (59% of the total).

These institutions are grouped under the Dominican Association of Universities, within whose framework the board of Agriculture and Livestock faculties operates. The association met in April 2016 to gather information on the research capacities of universities in the areas of agricultural and livestock sciences, in which UASD participated, together with ten other higher education institutions. Although research is undertaken at most of these centers, in many cases, its impact is actually marginal, even

Monocultures can have a long-term negative ecological impact.

though it is given considerable importance in the statutes of these organizations. Many of these universities have laboratories and experimental fields together with a limited number of researchers.

The creation of the Science and Technology Research Fund (FONDOCYT), which administers the MESCyT, has enabled research to be promoted at most universities and colleges. In recent years, through FONDOCYT, projects have been approved that have permitted the acquisition of equipment and the improvement of laboratories for university research. Although FONDOCYT is open to many areas of science that do not impact food and nutrition security, it is the largest local competitive fund currently in existence, and is expected to remain an opportunity for agricultural research capacity development at universities.

d. Strengths of SINIAF

- There are research capacities with experience, which could benefit young researchers in a process of generational replacement.
- SODIAF's *Revista Agropecuaria y Forestal* (APF) is published in both printed and digital versions as an important instrument for the dissemination of research results.
- SODIAF holds a Biannual Congress to facilitate the exchange of researchers from agricultural, livestock and forestry areas.
- Several proposals from SINIAF researchers have received funding from MESCyT through FONDOCyT.

e. Challenges and prospects for agricultural research

- Reorient research policy: emphasize the use of alternative local materials to reduce costs and improve crop quality.

Techniques that prevent soil erosion guarantee long-term production.

- Convince government authorities, as well as private-sector institutions, to invest more in research and development.
- Strengthen the Dominican Republic's outreach system.
- Encourage small producers to group together in cooperatives and clusters in order to leverage economies-of-scale.
- Add value to Dominican agricultural products through agroindustrial innovation.
- Create synergies between the public and private sector, and among state institutions to boost the country's research.
- Encourage young people to study agronomy and related degree courses, and to undertake specialization studies that will enable them to engage in research.

A key indicator, used internationally to determine the priority governments give to agricultural research, is intensity-of-investment. This is calculated as a percentage of Agricultural GDP (GDPAg). In 2012, Dominican public spending on agricultural research was 0.30% of its GDPAg. The UN recommends that this percentage be not less than 1% (Stads et al., 2016). According to a recent study by the International Food Policy Research Institute (IFPRI), in order for the Dominican Republic to narrow the investment gap, investment intensity in the agricultural sector will have to be raised to 2% of GNP (Nin, 2016).

III. Characteristics of Resources and Ecosystems

a. Water resources and challenges for the next fifty years

The Dominican Republic has an average annual rainfall of 1,410 mm, with a total volume of 68,620 million m³. Domestic renewable water resources have been estimated at 23.498 million m³/year, distributed among six hydrographic basins. Underground water resources have been evaluated at 4,161 million m³/year; although only 59.34% of this amount is recoverable for use (FAO-Aquastat, 2017).

National water extraction exceeds 7,000 million m³, 80% of which is used for agricultural and livestock production, 12% for municipalities and the remaining 8% for industrial activities. Only 80% of the population has access to improved sources of drinking water (FAO-Aquastat, 2017), which has serious quality and quantity limitations.

This resource faces several problems for its sustainability, including environmental degradation, together with production and distribution problems and climate variances due to the impact of climate change combined with inadequate planning, pollution of sources, lack of sanitation and inadequate infrastructure. This has resulted in the current shortage and the threat of a major crisis in the future (Dominican Political Observatory, 2014).

A study published by the University of Columbia, New York, in 2008, based on IPCC projections, shows that the Dominican Republic faces a major freshwater crisis as a result of climate change, due to a 20% reduction in annual rainfall, an increase in evapotranspiration of 2 km³ by the end of the century and a nearly 50% increase in the Dominican population by the middle of the century. The availability of freshwater per capita is expected to decline from 2,200 m³ in 2008 to less than 400 m³ by 2100.

The country has 13 state agencies devoted to water governance. In addition, there is a General Law on Environment and Natural Resources, with specific regulations for the management of both safe drinking water and water for other purposes, groundwater and discharges into the subsoil and wastewater. There is also a Law on the Domain of Terrestrial Waters and the Distribution of Public Waters; however, there is not yet a General Water Law or a Land Use Law that would permit integral, sustainable water management under a watershed approach.

b. Water resources and challenges for the next fifty years

The Dominican Republic shares the island of Hispaniola with the Republic of Haiti, occupying approximately three quarters of the territory (48,308 km²). Its physiography is determined by four mountain ranges running almost parallel from the NW to the SE. These elevations are interspersed with five depositional basins and plains containing the country's most fertile soils.

There are a number of state agencies responsible for soil use, the main ones being: The Ministry of Agriculture; the Ministry of Soils and Waters as part of the Ministry of Environment and Natural Resources (MIMARENA); the Dominican Agrarian Institute and the Agricultural Bank.

Modern methods with mechanization mean that Class V (15.75%) can also be used for grazing and rice cultivation, with extremely intensive management measures (Atlas Biodiversidad RD, 2012).

The Dominican Encyclopedic Dictionary of the Environment, based on data provided by MIMARENA, reports that 15% of the country's soils are overused while 40% are underused. This same source indicates that only 30% of Dominican soils, most of which are found in National Parks, have adequate use.

The main causes of soil degradation in the country are deforestation, construction of the road network, mining activity, the impact of climate phenomena, agrochemical use and unsustainable water management. The complexity of all these variables poses an enormous challenge for the population. Reversing the process of soil degradation will require a National Strategic Plan under the perspective of watershed management. A Land Use Law should also be enacted, strictly regulating the use of agrochemicals and integrating continuous conservation practices into agricultural culture, taking into account topography, soil type and potential use. Particular attention must be paid to the reforestation of critical areas and the incorporation of organic agriculture in order to advance sustainability in the medium term.

c. Energy Challenges

For over 30 years, the Dominican Republic has faced a severe energy crisis, reflected in constant brownouts lasting from 4 to 10 hours a day, which affects over 50% of the population (CDEEE, 2015), and the use of electricity through illegal connections - 25% of the population lacks a formal contract (CDEEE, 2015), which causes a minority to have to pay excessive tariffs to cover these inefficiencies and imposes a significant tax burden on the government for direct and indirect subsidies (*Diario Libre*, April 24, 2014). Over 85% of energy is obtained from fossil fuels, significant amounts of which are lost, mainly due to distribution failures (UNDP, 2017).

Electricity demand is rapidly increasing as a result of population growth. According to the National Energy Commission (CNE), energy demand will double by 2030.

In the search for solutions, in 2001, the National Energy Commission was created as a result of the passage of the General Electricity Law (Law 125-01). Another measure taken was the creation, through Law No. 100-13, of the Ministry of Energy and Mines. There is also a National Energy Plan that will not be in place until 2025.

The main challenge of the country's energy sector is the regularization of the service to make it accessible to the entire population on a regular basis at a fair price. This goal should become viable with the incorporation of energy production from alternative sources, taking advantage of the existence of the Law on Incentives for Renewable Energies and Special Incentives enacted in 2007.

d. Conflicts and challenges for biodiversity. Problems associated with overexploitation. Reduction of genetic diversity

According to historical records and lists compiled in recent decades, the island of Hispaniola is home to six thousand species of vascular plants, 5,500 of which grow in the Dominican Republic. In 2011, MIMARENA produced the first Red List of Threatened Plants based on criteria established by IUCN, comprising 547 species.

In 2016, as a result of meticulous research, the National Botanic Garden published the Red List of Vascular Flora in the Dominican Republic, listing 1,388 species, 831 of which are endemic and 557 native. According to this document, there are 813 species in Critical Danger, 249 in Danger, 249 that are vulnerable and 45 for which there is Minor Concern.

In terms of fauna, invertebrates constitute the largest group with approximately 7,030 species. Researchers agree that the local fauna has barely been studied and that there are also 74 species of amphibians, 71 of which are endemic

Cultures in a controlled environment have an enormous growth potential.

to the island; 166 reptile species, 87% of which are endemic; 306 bird species, 32 endemic, and 53 mammal species. The 2011 Red List of Endangered, Threatened or Protected Species in the Dominican Republic contains 223 animal species, many of which are Critically Endangered.

All the species included in the Red List of the Dominican Republic are protected by national laws and international conventions.

The main threats to the preservation and conservation of Dominican biodiversity are the destruction and fragmentation of habitats due to changes in land use, the expansion of the agricultural and livestock frontier, urban growth, infrastructure construction, mining, deforestation, the capture and extraction of wild species, forest fires, the introduction of invasive species, the emergence of new diseases and climate change (extreme hydrological events and drought).

An important element that negatively impacts native biodiversity is the introduction of invasive species, which is closely linked to productive activities in the Caribbean region.

In response to this situation, as part of the national biodiversity conservation policies, the Dominican Republic has joined the list of countries acting at a global, regional and private level to promote the conservation and sustainable use of natural resources, particular of biological diversity. It has ratified several conventions such as The Convention on Biological Diversity, the Convention on Climate Change, the Convention on Combating Desertification and Drought, the Convention on Wetlands (RAMSAR) and the Kyoto Protocol (MIMARENA, 2017).

e. Implications of forest trends

Agricultural activity has been practiced intensely since the 19th Century, which has led the decline of many plant species through the elimination of their habitats. Moreover, the use of forest materials in industry for energy generation and construction, the development of slash-and-burn agriculture and the over-use of agrochemicals are practices that severely affect forests. It is estimated that in the early

Detection of pesticide residue.

20th Century, forest cover in the Dominican Republic occupied 83% of its total area. By 2005, that percentage had fallen to 28.5%, according to a FAO assessment of global forest resources.

In order to offset this situation, a number of private- and public-sector initiatives have emerged with the aim of preserving and/or conserving species, ecosystems and environments of major importance for Dominican nature both in situ and ex situ.

The work of conserving species outside their natural area is mainly undertaken by the National Botanic Garden. This institution has undertaken essential work for several years now. Last year, the Red List of Vascular Flora was circulated in the Dominican Republic as a result of a meticulous research process and a few weeks ago, a Seed Bank was inaugurated on the garden's premises.

Since 1997, MIMARENA, through the Quisqueya Verde Project, has also undertaken reforestation work and recovered flower species. Over a period of nearly 20 years, millions of plants have been planted in degraded or vulnerable areas, encouraging the use of native and endemic species. This is the first government plan for massive reforestation on a nationwide scale.

This same agency contains a Vice-Ministry of Protected Areas and Biodiversity. There is also a National Law for the Management of Protected Areas, as a result of which Protected Areas now constitute 25% of national territory. There is also a Vice Ministry of Forest Resources.

Other institutions include the Dominican Forestry Chamber and a large number of non-profits working to recover, protect and/or preserve forest or species strongholds in areas with high endemism, water catchment areas, protected areas and degraded areas with Class VI, VII and VIII soil.

f. Potential impacts of climate change

The Dominican Republic is one of the ten most vulnerable states to the effects of climate change. Extreme climate-related phenomena - such as floods and droughts - are on the rise. Their frequency and magnitude are expected to increase, and are likely to affect agricultural and livestock production throughout the country (National Adaptation to Climate Change Strategy, 2014-2020).

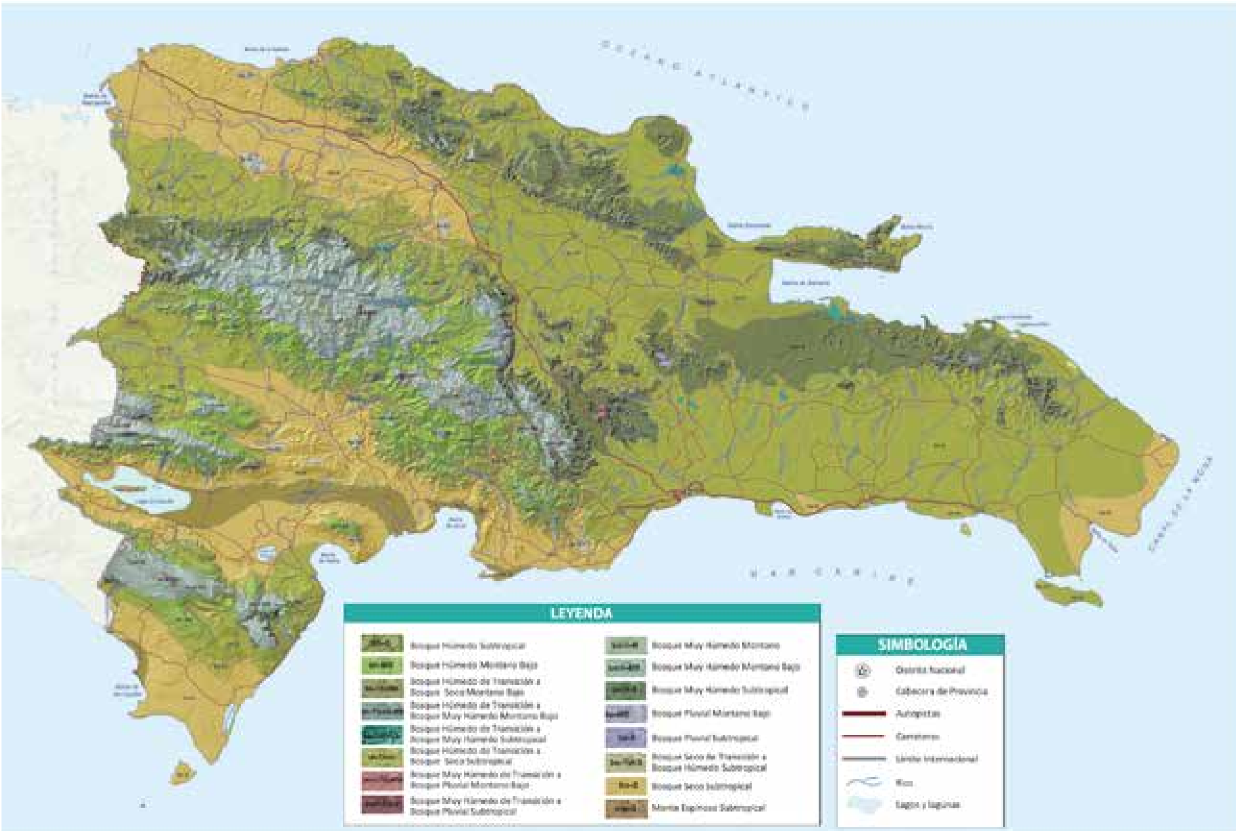
Sea level rise may result in salt water intrusion, through river mouths at high tide, or directly affect underground basins, which may impact water quality in aquifers that have hydrological continuity with the sea, making it unsuitable for human use or agriculture. Marine intrusion of groundwater is one of the most serious problems resulting from climate change.

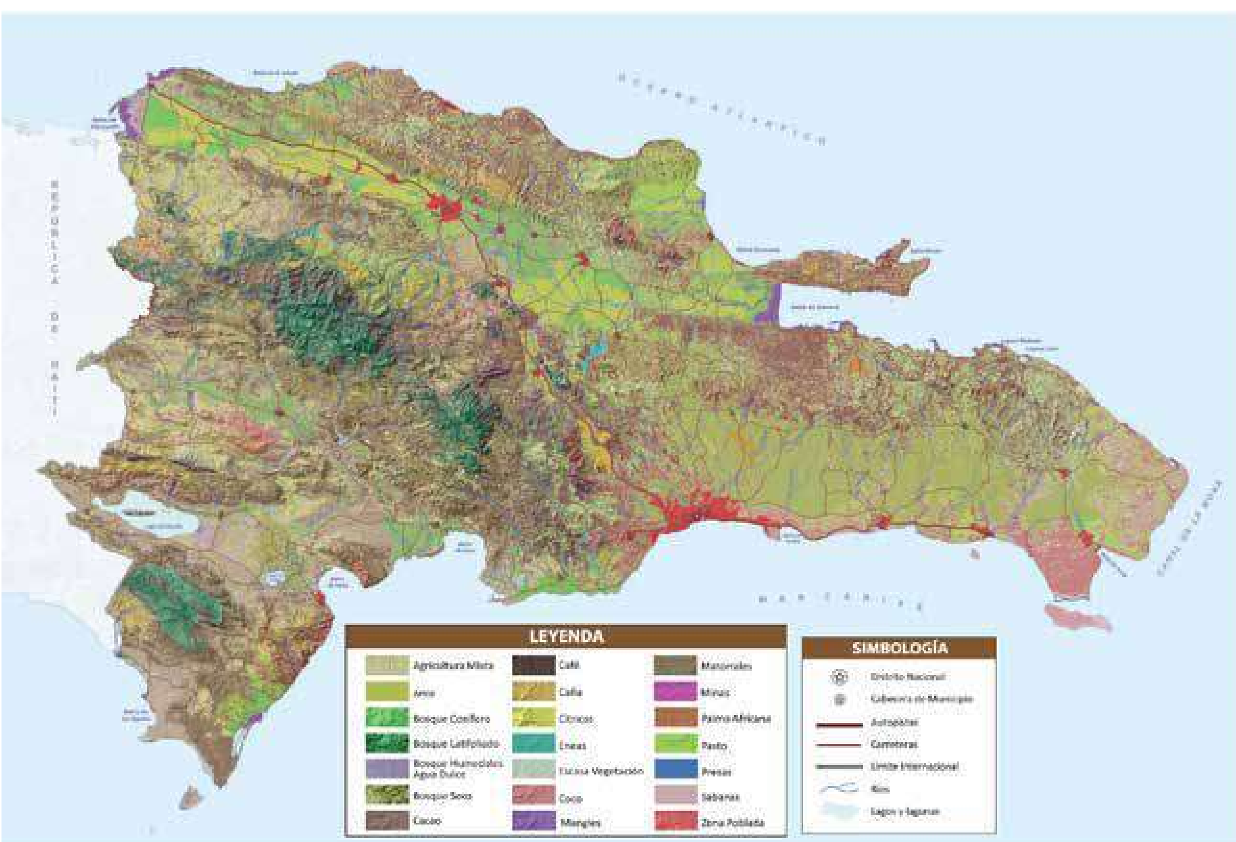
The country's groundwater reserves would be seriously affected by their physical-chemical deterioration and the reduction of water potential due to the rainfall deficit. The most likely hydrological scenarios would be characterized by a significant reduction of the country's water potential, both surface and underground, which would lead to the deterioration of the chemical and biological quality of water (National Adaptation Strategy to Climate Change, 2014-2020), therefore impacting biodiversity.

g. Building resilience to extreme events a eventos extremos

Significant progress has been made in the Dominican Republic to adapt to climate change with the aim of creating resilient citizens and communities. To this end, clearly defined public policies, laws and regulations have been implemented and national climate-change

Use of molecular techniques to certify agricultural production.


OCEANO ATLANTICO
MAR CARIBE
CANAL DE LA MONA
LEYENDA
Bosque Húmedo Subtropical
Bosque Húmedo Montano Bajo
Bosque Húmedo de Transición a Bosque Seco Montano Bajo
Bosque Húmedo de Transición a Bosque Muy Húmedo Montano Bajo
Bosque Húmedo de Transición a Bosque Muy Húmedo Subtropical
Bosque Húmedo de Transición a Bosque Seco Subtropical
Bosque Muy Húmedo de Transición a Bosque Pluvial Montano Bajo
Bosque Muy Húmedo de Transición a Bosque Pluvial Subtropical
Bosque Muy Húmedo Montano
Bosque Muy Húmedo Montano Bajo
Bosque Muy Húmedo Subtropical
Bosque Pluvial Montano Bajo
Bosque Pluvial Subtropical
Bosque Seco de Transición a Bosque Húmedo Subtropical
Bosque Seco Subtropical
Monte Espinoso Subtropical
SIMBOLOGÍA
Distrito Nacional
Cabecera de Provincia
Autopistas
Carreteras
Límite Internacional
Ríos
Lagos y lagunas


OCEANO ATLANTICO
REPUBLICA DE HAITI
MAR CARIBE
CANAL DE LA MONA
LEYENDA
Agricultura Mixta
Arroz
Bosque Conífero
Bosque Latifoliado
Bosque Humedales Agua Dulce
Bosque Seco
Cacao
Café
Caña
Cítricos
Eneas
Escasa Vegetación
Coco
Mangles
Matorrales
Minas
Palma Africana
Pasto
Presas
Sabanas
Zona Poblada
SIMBOLOGÍA
Distrito Nacional
Cabecera de Municipio
Autopistas
Carreteras
Límite Internacional
Ríos
Lagos y lagunas

education programs developed for teachers and students, impacting thousands of people.

Article 194 of the Dominican Constitution establishes as a State priority, the formulation and implementation of a land-use plan to ensure the efficient, sustainable use of the country's natural resources, in accordance with the need for adaptation to climate change. In the same vein, Axis 4 of the National Development Strategy 2030, "Seeks to achieve a society with a culture of sustainable production and consumption, which manages environmental risks and protection and natural resources with equity and efficacy and promotes adequate adaptation to climate change".

There is also a National Commission for Adaptation to Climate Change and a Clean Development Mechanism led by the President, through which important initiatives at the local and international level have been achieved. Strategic partners have been obtained for the implementation of projects and actions in order to build national capacities to address the impacts derived from this alteration of the climate. It is important to highlight the importance of the National Comprehensive Disaster Risk Management Plan in the Dominican Republic, based on Law 147-02.

h. Prospects and future outlook

The future of natural resources in the Dominican Republic is rather uncertain, mainly because their sustainability depends on a multiplicity of factors and variables. An effective solution will depend on the clear, precise understanding of the status of this environmental asset and the importance of achieving its sustainability, the availability of immeasurable resources, a strong State will, knowledge of the problem on the part of social sectors and above all, an integral approach to the problem to understand and address the various internal and external factors of a social, economic and environmental order.

As for agriculture in the Dominican Republic, projections indicate that there will be a temperature increase, and a decrease in total rainfall together with a decrease in the duration of the rainy season. Several models predict that there will be extreme events with more intense rains during the rainy season, in addition to intense droughts (National Strategy for Adaptation to Climate Change, 2014-2020).

In the valleys and plains where much of the agricultural sector is concentrated, resilience will be tested by several climate-change events, particularly increasing river flows, floods, high temperature, high relative humidity, increased incidence of pests and diseases, saline intrusion, high evaporation rates and greater stress on plants (crops) (National Strategy for Adaptation to Climate Change, 2014-2020).

It is essential to design and implement a Land Use Plan to determine the potential uses of the land in accordance with local conditions. It will also be necessary to identify the most vulnerable areas, establish flood control systems, ensure the integrated management of watersheds and crop diversification, promote access to credit and implement an Early Flood Warning System.

IV. Technology and Innovation

The use of biotechnologies to produce goods and services including more abundant foods or with interesting characteristics could make an enormous contribution to food and nutrition security. The Institute of Innovation in Biotechnology and Industry (IIBI) is an official institution that spearheads biotechnology efforts, with an emphasis on supporting agriculture and agribusiness. Its achievements to support agroindustry include the use of enzymatic technologies to produce extracts, fermentations of industrial interest, bioprospecting, tissue culture and molecular characterization.

A number of universities, as well as several private companies, have developed proprietary protocols for plant production through in vitro tissue culture. Success stories resulting from this upsurge of interest include the massive introduction of banana, pineapple, potato and strawberry varieties. In the case of plantains, sigatoka-resistant varieties have been developed, which increased production and therefore reduced consumer prices.

IIBI has documented the molecular characteristics of fruits-of-interest for exportation, to guarantee quality and denomination of origin. These include the banilejo mango and the Creole avocado, locally sourced products with overseas market niches.

IDIAF and UASD have undertaken projects with soil micro-organisms beneficial to plants. They expect to be able to obtain inocula that will increase growth and shorten the waiting time for the first harvest of open-field legumes and species grown in a controlled environment. This line of research on soil microbiology promises to be extremely useful for improving efficiency and increasing the productivity of certain crops consumed by the Dominican population. An additional benefit is that it can be used to achieve biological control of soil pathogens, thereby reducing the use of fungicides and other agrochemicals.

Biotechnology applied to animal production has not been widely explored in the Dominican Republic. Some research has been carried out, such as the genetic characterization of dairy cattle, and at UNEV, one project with steers and another with sheep are being implemented to select outstanding animals through molecular tests that identify key genes. The use of semen selection from bulls or males of another species based on genomic test results is not yet widespread.

Efforts to develop aquaculture in the Dominican Republic have been led by IDIAF and the Dominican Aquaculture Association (ADOA). But this sector has not had enough state support, and currently has only a few members who run profitable farms, together with some recent cooperative efforts. The Strategy for the Development of Aquaculture (IDIAF, 2007) proposed the following topics-of-importance for research purposes:

- Genetic improvement of Nile tilapia for research purposes
- YY juvenile fish production
- Diversification of cultivated species (such as sea bass, snapper, crustaceans, trout, ornamental fish)
- Diversification of cultivation methods and use of water bodies (cages, corrals, raceway, intensive and polyculture).

Fresh fruits and vegetables in the market.

Table 2. Most important crops by local consumption in the Dominican Republic

Rice (*Oriza sativa*)	Cacao (*Theobroma cacao*)	Cucumber (*Cucumis sativus*)
French Bean (*Phaseolas vulgaris*)	Sweet potato (*Ipomoea batatas*)	Potato (*Solanum tuberosum*)
Banana (*Musa paradisiaca*)	Eggplant (*Solanum melogena*)	Onion (*Allium cepa*)
Plantain (*Musa paradisiaca*)	Green pepper (*Capsicum annuum*)	Garlic (*Allium sativum*)
Cassava (*Manihot esculenta*)	Tomato (*Solanum lycopersicum*)	

a. Use of genetically modified organisms

Although the use of transgenic crops has led to significant gains in countries in the region, the incorporation of living modified organisms has been extremely slow in the Dominican Republic. This is largely due to the fact that there was no law providing a legal framework or defining biosecurity measures for this purpose. At the same time, certain sectors thought they might be affected if the use of transgenics in the country were approved.

After over ten years of revision, Law No. 219-15 on Biosafety was passed in 2015. This law is concerned with the safe use of genetically modified living organisms. This legal framework may permit the start of risk-analysis processes for the introduction of transgenic seeds and crops. It is the responsibility of the Ministry of the Environment and Natural Resources (MIMARENA) to grant approval. However, by 2012, the press had begun to report the signing of agreements between Dominican and foreign companies for the introduction of transgenic seeds into the country (Listín Diario, 2012).

Since 2010, the country has had a laboratory for the identification of genetically modified crops. It is an IIBI agency created to provide certification for exporters required to prove that their products are GMO-free. This laboratory is also able to detect the undeclared importation of transgenics.

The delay in passing the Biosafety Act limited the development of genetic engineering. This law is essential to the implementation of DNA manipulation techniques such as CRISPR and the importation of transgenic seeds, which may be useful for food security in the country, especially for plants with genes for water-stress resistance and salinity tolerance. The Dominican Republic still lacks the training and infrastructure required for the development of genetically modified animals to be more productive, resistant or have greater nutritional value.

One of the ways to ensure that people ingest the nutrients required for their particular needs is through the obtainment and production of agricultural items with certain nutritional characteristics. This will be achieved through research into genetic improvement, and the obtainment and/or identification of biofortified products. These products possess higher concentrations of certain key nutrients than their unimproved counterparts. Examples include the worldwide effort to produce high-beta-carotene sweet potatoes, and the production of rice and beans with high iron and zinc content already available in the country. This will reduce problems such as anemia in children and the elderly. It should also contribute to promoting the consumption of functional foods.

Biotechnological research and other technological innovations would have a greater impact on the country's food security if they concentrated on these agricultural items.

V. Increasing the efficiency of food systems

a. Technology in agricultural production

A diagnosis of the Dominican agri-food sector showed that the main obstacles that have prevented the achievement of public-policy objectives are:

1. Low productivity, profitability and competitiveness. Although there are very dynamic groups of producers, in general, lags persist in the agricultural sector.

2. Rural financial system. This is one of the most obvious problems, since for many producers, formal credit is scarce or extremely expensive.
3. Limited economies-of-scale in production functions. This is related to the small size of the domestic market as well as to the high fragmentation of agricultural holdings.
4. Low incorporation of national added value into primary production. This is mainly due to the lack of processing and marketing structures and a dearth of information on market opportunities.
5. Incidence of natural phenomena such as hurricanes, storms, floods and tornados. These have historically affected agri-food production and resulted in a decline in production.

The following priorities have been established to reverse this situation:

A. Improve the sustainability of production systems, based on sustainable agriculture practices and the protection of fragile forest ecosystems.
B. Increase the productivity and profitability of farmers to eliminate the delays that prevent competitive insertion into markets.
C. Improve rural social equity and reduce the poverty in which a significant part of the rural population lives, for which a model has been developed, combining the achievement of economic, social and environmental results and targeting specific population groups.

b. Increasing the efficiency of food systems

In order to increase the efficiency of food systems, the following actions have been proposed for the agricultural and rural sector in the Dominican Republic: a) strengthening of nutritional food security and combat poverty; b) strengthening of the Social Protection Network for the most vulnerable sectors; c) use and management of water resources; d) protection of natural resources and the environment; e) support for human capital development and business management, and f) community rural development.

In order to achieve food and nutrition security in the country, it is essential to increase investment in farmers' assets as a successful strategy for combating poverty. The efficiency of these investments depends on a set of conditions including coordination among macroeconomic, sectoral and rural development policies; the establishment of a decentralized, participatory regional approach to rural development; and strengthening institutions to support income-generating activities in rural areas.

The basic, interrelated components, divided into short-, medium- and long-term actions, are as follows:

1. Productive reconversion and diversification. The Dominican Republic must leverage the comparative advantages it has on traditional export crops (coffee, cacao, sugar and bananas), as well as non-traditional crops such as mango, avocado, oriental vegetables, pineapple, bananas and tomatoes.
2. Support for the development of rural micro-financing services. Access to financial services in rural areas is still limited. This component seeks to increase the supply of rural financing for producers, contribute to reducing transaction costs and strengthen community and other producers' organizations to promote "financial intermediation" in rural areas.
3. Strengthening the technical capacities of small- and medium-sized producers and the development of value chains. The purpose is to contribute to the creation of technical capacities and an organizational structure, through education, access to technologies and the formation of value chains, so that producers can intensify and diversify production, meeting quality, safety and market price standards, which will ensure the population's food and nutrition security. The efficient integration of value chains is of great importance for successfully competing in both national and international markets.
4. Promotion of rural, peri-urban and agricultural markets. The aim would be to establish a market-intelligence mechanism (such as market niches, access requirements and packaging), to provide useful business

information to reorient production and marketing patterns, and to assist producers in setting up innovative direct marketing, processing and packaging systems.

5. Strengthening social organization. Activities to strengthen the capacities of communities in their organization and participation, including the undertaking of participatory diagnoses and plans. To this end, emphasis is placed on training and assistance in preparing management and investment plans on the farm and in communities.
6. Strengthening of rural municipalities through investment in productive and social infrastructure. Strengthen rural municipalities through the training and financing of community projects and municipal outreach, as a means to enhance community development. The latter will include basic infrastructure (such as neighborhood roads, irrigation canals and collection centers) and other services.
7. Community rural development. This initiative complies with the commitments undertaken by the government of the Dominican Republic to meet the Sustainable Development Goals (SDG) and is part of the National Development Strategy. Support would focus primarily on areas with the highest levels of poverty and food insecurity. This situation affects the SW region and certain border communities in the NW region.
8. Technological innovation. The aggregate technological level of Dominican agricultural production is low except for subsectors of poultry production, certain fruits and vegetables, specialty coffee, organic bananas and the measures adopted by certain individual producers.

Some markets offer meat that failes to meet safety standards.

Availability of a variety of grains contributes to good nutrition.

Two different subsectors currently coexist: one that is modern or undergoing modernization, with relatively advanced technology and a market orientation, and a small-scale one, with limited business-management capability that tends to be concentrated in fragile environments with low fertility soils. The aims is to strengthen national institutions (public and private) for the generation and transfer of agricultural technologies, in order to promote productive efficiency, competitiveness and environmental sustainability, as requirements for guaranteeing food and nutrition security in the Dominican Republic.

VI. Health Considerations

a. FoodBorne Diseases (FBD)

The World Health Organization (WHO) defines FoodBorne Diseases (FBD) as those resulting from the ingestion of food with etiological agents in sufficient amounts to affect the consumer's health. The most common symptom is diarrhea or other gastrointestinal symptoms.

According to the Ministry of Public Health and Social Welfare of the Dominican Republic (MISPAS), during the 1995-2002 period, 267 outbreaks of FBD were reported, of which only 55% were investigated. The most commonly involved food was fish, accounting for 61% of the total (MISPAS, 2003).

The 2014 General Health Report of the General Directorate of Epidemiology (MISPAS, 2014) indicates that in 2013, there were 471,383 outpatient consultations (8.03% of the total) due to diarrhea and gastroenteritis of presumably infectious origin. According to international estimates, the main cause of diarrheal or gastroenterological problems is the consumption of unsafe food or contaminated water (Peralta, 2011). In the Dominican Republic, only 84.4% of the population has access to improved sources of drinking water, according to the General Health Report 2014. The same report documents the deaths of 57 children ages 1 to 4 from acute diarrheal disease, a rate of 3.1%.

According to Peralta Girón (2011), during the 2004-2010 period in the Dominican Republic, 103,102 cases of FBD and 164 outbreaks (a proportion of 153/100,000 inhabitants) were reported. Of these outbreaks, 21% required hospitalization. A total of 3,010,915 cases of Acute Diarrheal Disease (ADD) were also reported. The WHO estimates that 100% of the Dominican population has suffered at least one case of FBD during their lifetime. The main foods involved were fish and shellfish (34%), water (18%), dairy products (15%) and meat and poultry (9%). Likewise, the infectious agents isolated were, in order of importance, *E. coli, Staphylococcus aureus, Entamoeba histolytica, Salmonella* spp. *Shigella*, hepatitis A virus and Norovirus.

Due to the island's geographic location, it is important to mention ciguatoxin, transmitted by the consumption of fish during certain months of the year, when they feed on the microalgae that produce it. Fish and shellfish were responsible for 34% of cases of FBD in the 2004-2010 period (Peralta, 2011).

In recent years, cholera has become a threat to the health of the island's population, mainly in Haiti, to which it was brought by Nepalese UN troops. From Haiti it spread to the Dominican Republic, presumably due to the constant migration of Haitian nationals to this country. In 2013, 1,954 cases of cholera occurred in the country, at a rate of 20 cases/100,000 inhabitants, with La Altagracia, one of the country's main tourist areas, being the most severely affected province, with a rate of 317 cases/100,000 inhabitants (MISPAS, 2014).

FBD not only constitute a public health problem, but also affect tourism, the main source of foreign exchange in the Dominican Republic. Domenech-Sánchez et al., (2009) report the results of a study on a Norovirus outbreak at two hotels in the Dominican Republic. Jiménez et al., (2011) report on an international outbreak of cholera contracted at a wedding in the Dominican Republic, which infected people from four different countries. Blume et al., report cases of ciguatera in German tourists in 1983 (Blume et al., 1983).

b. Overconsumption of food

Postmodern society has been characterized by an increase in overweight and obesity rates, as a result of the imbalance between caloric intake and energy expenditure, mainly due to more sedentary lifestyles and changes in dietary patterns. The Dominican Republic is no exception. Obesity is a risk factor related to chronic noncommunicable diseases, and in many cases is the trigger for many secondary comorbidities affecting all Latin-American countries. The Body Mass Index (BMI) will be used as an indicator for the excessive consumption of food in the Dominican Republic.

Data on overweight and obesity rates in the Dominican Republic vary according to the sources consulted. According to a report by Deloitte published in the national press, obesity increased from 6% in 1980 to 22% in 2014 (Diario Libre, 2016), meaning that the country ranks 11th of 21 American countries. The Second Latin-American Obesity Consensus (Gómez et al., 2014) reports that in the Dominican Republic, 27.1% of the people are obese and 37.5% are

IDIAF-3 rice variety selected by local researchers.

overweight, making a total of 64.6% of the population with high weight. The FAO National Food and Nutrition Security Profile (2015), citing WHO, places obesity in the population over 18 years of age at 23.9%, segmenting that data into 18.2% of men and 29.5% of women. According to the same source, 7.6% of children under 5 are overweight.

This situation is the result of the significant increase in caloric intake that the Dominican population has experienced from 2,118 kcal/day/person in 1900 to 2,620 kcal/day/person at present. Another possible cause of the growth of overweight and obesity rates could be the increase in the number of people who consume food outside the home, especially in large cities, for work or recreational reasons. This is exacerbated by the proliferation of high-calorie fast-food restaurants in the past 20 years and their greater affordability. Moreover, Dominican food is low in fruits and vegetables (12% of calories consumed), and extremely rich in sugars (13% of calories consumed) (FAO, 2015).

According to the Second Latin-American Obesity Consensus, the Dominican Republic is expected to be one of the countries with the highest obesity rate in the world by 2020 (Gómez et al., 2014). There is also a high prevalence of diabetes and hypertension, two diseases that have been linked to eating habits, and that constitute a risk factor for obesity. According to the 2014 Report by the General Directorate of Epidemiology (MISPAS, 2014), diabetes affects 10.4% of men and 9.9% of women in the country. Hypertension affects 34.4% of the adult population in the Dominican Republic.

High levels of inequality persist in the country. This is why, despite the problems caused by overconsumption of food, malnutrition continues. According to WHO data cited by FAO (2015), malnutrition in children under 5 years of age was 4%, subdivided into 7.1% of children under 5 with chronic malnutrition and 2.4% with acute malnutrition. However, the General Directorate of Epidemiology reported that, for the same year, 9.8% of children under 5 suffered from chronic malnutrition. Likewise, 8.1% of children are born with low body weight (MISPAS, 2014). According to FAO (2015), the incidence of micronutrient deficiencies is as follows: 34.6% display anemia; 86% iodine deficiency and 13.7% Vitamin A deficiency.

Accordingly, the Dominican Republic needs to address the issue of food security while developing nutrition-education policies to help prevent problems of obesity and other diseases such as diabetes and high blood pressure.

c. Expected changes in food consumption patterns and their implications

In traditional Dominican food, lunch is the main meal and comprises rice, beans, meat (if possible) and a salad that consists, in most cases, of lettuce or cabbage with tomato and cucumber. Breakfast and dinner were generally made up of "provisions" (bananas, cassava and other root vegetables and/or tubers) with egg, salami or cheese. In many cases, bread has replaced these provisions. Many of these foods are eaten fried.

However, in recent years, changes in eating habits have been observed in Dominicans, especially in the middle and upper socioeconomic strata. These changes in eating habits are caused by many people's interest in leading healthier lives and controlling their body weight. These changes, however, are not necessarily guided by specialized nutritional advice, but by various sources of doubtful scientific validity.

Globalization has led to the internationalization of cultural and economic patterns, which in turn influence people's eating patterns. The change in working hours mean that many people, especially in Santo Domingo, are forced to eat lunch outside the home, either in the cafeterias of the companies where they work, or at nearby restaurants.

One type of restaurant that has expanded greatly in the past 25 years are fast-food chains. The first fast-food franchise in the Dominican Republic was established in 1992. By 2015, there were already 41 hamburger restaurants in the country's largest cities and tourist resorts (Listín Diario, 2015). There has also been a noticeable expansion of pizza shops, and stalls selling hot dogs, fried empanadas and meat and fried derivatives. Fast food constitutes an important part of the eating pattern of Dominican children and young people (Listín Diario, 2015).

In 2007, the Central Bank of the Dominican Republic conducted the National Survey of Household Expenditure and Income. The absolute total and the percentage distribution of household expenditure on food and non-alcoholic beverages were obtained. Menchú et al., (2013) determined the composition of the Dominican diet by analyzing data from this survey by examining the food purchased by Dominicans during a specific week.

According to this survey, the most commonly consumed foods were: poultry, eggs, wheat bread, plantains and bananas, prepared foods and processed natural juices. In some regions, people also ate onion, condiments, dehydrated soups and sauces and dressings. These were followed by: milk, sausage, rice, sugars, vegetable oil, potatoes and root vegetables, onion, chili, savory snacks, carbonated drinks, dehydrated soups and sauces or dressings. In some regions, coffee, tea and chocolate were consumed.

As one can see, food patterns are changing, expressed in the addition or elimination of certain foods from the food basket and the availability of fast-food outlets. It is important to emphasize that purchasing power and time constraints are the main reasons why families to choose to buy ready-to-eat products.

d. Understanding and encouraging behavioral changes and the emergence of personalized nutrition

Although a Food and Nutrition Security and Sovereignty Law has existed since 2016, many tasks remain pending, one of them being to study the nutritional quality of Dominican food in depth. On the basis of this research, it will be

Support for small-scale farmers can have a favorable impact on food security.

possible to understand and encourage changes in the patterns of food consumption on the basis of scientific criteria.

The Dominican Republic must take the necessary precautions to combat the growing problem of overweight and obesity, in addition to diabetes and high blood pressure. At the other end of the scale, the persistence of high rates of child malnutrition, anemia, iodine deficiencies and Vitamin A must be addressed.

VII. Policies to contribute to food and nutrition security

The Dominican Government defined the following as the most relevant specific objectives of its Food and Nutrition Security policy: increase food availability; facilitate physical and economic access to food; achieve the recommended consumption of food, in quantity and quality, and strengthen preventive and curative actions that will contribute to the biological use of food.

Nutritional food-security policies also prioritize the development of human resources and highlight the need to strengthen education in nutrition and food security in basic education and build teachers' capacities, which will contribute to the comprehensive education of children, and adolescents. The target population of Food and Nutrition Security activities includes the following groups: children under five and of school age; women heads of household; expectant mothers; nursing mothers; youth; older adults, and other segments representing families living in extreme poverty in economically, socially and environmentally deprived areas.

Organic cacao is one of the high quality exportable products.

Local consumption and exports of mango are extremely important.

In vitro culture of fungus-free banana.

Local eating habits do not include the consumption of fish.

a. Legal framework

The country has a legal framework that addresses the issue of food and nutritional security at various levels. This includes the following:

a. The Constitution: Modified in 2010, the Constitution recognizes the right of all citizens to have access to quality goods and services (Article 53). Article 54 refers directly to food security. Likewise, Article 61 on the right to health stipulates that the State must ensure access to drinking water and improved food, among other aspects.

b. Law on Food Sovereignty and Security (No. 589-16): The purpose of this document is to establish the institutional framework for the design and development of food and nutrition sovereignty and security policies as a guarantee for preserving the right to food (Art. 1).

   Article 6 defines the right to proper food for everyone, which means that they can feed themselves, have financial capacity, protection from the risk of losing access to food, the opportunity to consume healthy, nutritious food, and access to accurate information. At present, the formulation of the Law of Sovereignty and Food Security is still pending.

c. National Development Strategy: Through Law No. 1-12, passed on January 25, 2012, the National Development Strategy (NDS) was approved, which will be in force until 2030. Providing a country vision, it is linked to the formulation of multi-annual plans for each government, institutional, sectoral and territorial plan, and national and municipal budgets.

   The NDS has four strategic axes. Among the objectives of the third axis are two that are directly related to food sovereignty and food security. These are Objective 3.4, which proposes sufficient, decent jobs, and Objective 3.5, which seeks to achieve a sectoral, territorially coordinated productive structure that is competitively integrated into the global economy and leverages local market opportunities.

d. Sectoral Strategic Plan for Agricultural Development 2010-2020 of the Ministry of Agriculture: This Strategic Plan establishes political lines, through strategic axes with its respective objectives and goals, prior to which it undertakes an analysis of the sector. In general, the plan is dominated by a neoliberal approach and the promotion of business production mainly oriented toward the export of goods. However, it contains very little about a vision on food and nutrition security.

b. Macroeconomic policies concerning food

Macroeconomic policies permit large-scale imports and maintain a steady and increasing deficit in the relationship between imports and exports. In 2015, the deficit was €6.985 million Euros, representing 11.38% of GDP. This undermines food and nutrition security.

Obtaining the currencies to support the import model has required increasing external debt. In 2015, external debt stood at €21,159 million Euros, equivalent to 34.94% of the GDP and €2,118 Euros per capita. This trend will jeopardize the stability and availability of food for the population.

c. Financing policy

Financing for the agricultural sector relies mainly on public financing through the Agricultural Bank and the Economic Fund for Agricultural Development (FEDA). The Strategic Plan is designed to strengthen these organizations and reinforce agricultural insurance, all from a state perspective. It is necessary to develop policies which, at the same time as they increase the public financing of agricultural production, oblige commercial banks to transform their loan portfolio, by facilitating loans to finance production rather than just consumption.

One element regarded as positive yet which distorts public policy are the "surprise visits," whereby the president visits communities and allocates resources directly in accordance with the demands submitted to him. This practice is detrimental to the corresponding institutions, since resources are allocated directly to groups of agricultural producers, without proper planning, analysis of the situation or technical and business monitoring, and are therefore destined not to produce any long-term productive effect.

Citrus production has been destabilized nationwide due to disease.

d. Land reform policy

The Strategic Plan drawn up by the Ministry of Agriculture in 2010 proposes an agrarian reform policy that includes strengthening the mechanisms for implementing agrarian reform, a vision of rural territorial development for the development of the reformed sector, obtaining land through the recovery of State land, the enforcement of the fair share law, land purchase and the renovation of current settlements, as well as the strengthening of associated groups and cooperativism.

According to the National Register of Agricultural Producers (updated in 2003), the country's agricultural area was 1.9 million ha. A high percentage of the land is owned, with 34.6% of owners possessing farms with more than 100 ha, approximately 49% owning units with between 5 and 100 ha and only 17.4% possessing farms with fewer than 5 ha. Part of the productive land is being given over to other non-agricultural uses such as urban growth, tourist infrastructure, mining, airports and other types of infrastructure. Unless more aggressive policies are implemented to conserve and reclaim productive land, food and nutrition sovereignty and security will be a chimera.

e. Research policy and technology transfer

The Strategic Plan for the Sector (2010-2020) proposes to promote research, technological development and innovation to improve the production, processing and marketing of agricultural products through new practices that will enable producers to increase production and productivity, and enter national and international markets. It also proposes to introduce new agricultural and animal varieties and novel techniques for the extension and dissemination of research.

f. Food and Nutrition Security Policies

The legal instruments that express Food and Nutrition Security policies have previously been mentioned in the Legal Framework section. These policies depend on political will focusing on three aspects: 1) Allocating resources through the budget and increased private financing; 2) Strengthening institutions in the sector and transforming some of them, and 3) Efforts to develop Associative Rural Firms.

References

Asociación Dominicana de la Industria Eléctrica (ADIE). Retrieved at: https://goo.gl/kgeHb4

Banco Central de la Republica Dominicana (2011). Informe de la Economía Dominicana Enero-Diciembre 2010. Retrieved at: https://goo.gl/B2U2pk

Banco Central de la Republica Dominicana (2012). Informe de la Economía Dominicana Enero-Diciembre 2011. Retrieved at: https://goo.gl/Mog2Mh

Banco Central de la Republica Dominicana (2013). Informe de la Economía Dominicana Enero-Diciembre 2012. Retrieved fat: https://goo.gl/7BRECm

Banco Central de la Republica Dominicana (2014). Informe de la Economía Dominicana Enero-

Diciembre 2013. Retrieved at: https://goo.gl/LMtqfj

Banco Central de la Republica Dominicana (2015). Informe de la Economía Dominicana Enero-Diciembre 2014. Retrieved at: http://www.bancentral.gov.do/publicaciones_economicas/infeco/infeco2014-12.pdf

Banco Central de la Republica Dominicana (2016). Informe de la Economía Dominicana Enero-Diciembre 2015. Retrieved at: http://www.bancentral.gov.do/publicaciones_economicas/infeco/infeco2015-12.pdf

Banco Central de la Republica Dominicana (2016). Informe de la Economía Dominicana Enero-Diciembre 2016. Retrieved at: http://www.bancentral.gov.do/publicaciones_economicas/infeco/infeco2011-9.pdf

Banco Interamericano de Desarrollo (BID) (2012). Programa de Investigación y Desarrollo Agropecuario (DR-L1054). Perfil de documento de préstamo. Santo Domingo, DO. 18p.

Banco Mundial, World Development Indicators (2016). Documento en línea. https://goo.gl/TxrQQo Retrieved: November 4, 2016.

Blume, C.; M. Rapp, J. Rath, H. Köller, G. Arendt, D. Bach, B. Grabensee (1999). Ciguatera poisoning. Growing differential diagnostic significance in the age of foreign tourism. In: Medizinische Klinik, Vol. 94(1), January 15, 1999, pp. 45-49.

Caribbean Community Climate Change Centre; Ministerio de Agricultura, Consejo Nacional para el Cambio Climático y Mecanismo de Desarrollo Limpio; Fundación Plenitud (2014). Estrategia Nacional de Adaptación al Cambio Climático en el Sector Agropecuario de la República Dominicana, 2014-2020. Retrieved at: https://goo.gl/Spje5L

CDEE; EGEHID; ETD (2016). Informe de Desempeño del Sector Eléctrico. Retrieved at: http://cdeee.gob.do/transparencia/?wpfb_dl=609

CEPAL, FAO, IICA (2014). Perspectivas de la agricultura y del desarrollo rural en las Américas: una mirada hacia América Latina y el Caribe. Retrieved at: http://www.fao.org/docrep/019/i3702s/i3702s.pdf

Clay, E. (2002). Food Security: Concepts and Measurement, Paper for FAO Expert Consultation on Trade and Food Security: Conceptualising the Linkages Rome, 11-12 July 2002. Published as Chapter 2 of Trade Reforms and Food Security: conceptualising the linkages. Rome, Italy: FAO; 2003.

Congreso Nacional, Ley No. 589-16 (2016). Ley que crea el Sistema Nacional para la Soberanía y Seguridad Alimentaria y Nutricional de República Dominicana. In press, Gaceta Oficial de la República Dominicana.

Consejo Nacional para el Cambio Climático y el Mecanismo de Desarrollo Limpio –CNCCMDL (2017). https://goo.gl/wN9dcW

Constitución de la República Dominicana, proclamada el 26 de enero. Publicada en la Gaceta Oficial No. 10561, del 26 de enero de 2010. Retrieved at: http://www.ifrc.org/docs/idrl/751ES.pdf

Cooperación Dominicana de Empresas Eléctricas Estatales (CDEEE) (2015). Estudio de Impacto Ambiental del Proyecto de Modernización Red de Distribución y Reducción de Pérdidas Eléctricas Banco Mundial. Retrieved at: https://goo.gl/YYcrLu

Corporación Dominicana de Empresas Eléctricas Estatales. Available at http://cdeee.gob.do/cdeeesite/

Diario Libre (23 de mayo de 2016). República Dominicana aumentó su población obesa de 6% a 22% en 34 años. Retrieved January 8 2017 from: https://goo.gl/tBD4b7

Domenech-Sánchez, J., A. Rullán, J. Pérez, C. Berrocal (2009). Gastroenteritis outbreaks in 2 tourist resorts, Dominican Republic. Emerging Infectious Diseases (www.cdc.gov/eid) Vol. 15(No. 11), November 2009.

Del Rosario, P., Morrobel J., Escarramán A. (2014). La territorialidad dominicana: de la dicotomía a la gradación rural-urbana. Instituto Dominicano de Investigaciones Agropecuarias y Forestales-IDIAF. Santo Domingo, DO. 163p.

El Caribe (12 julio 2016). Gobierno anuncia medidas sobre etiquetado: "Ante todo protegeremos la salud del pueblo". Retrieved at: https://goo.gl/5MTPXK

FAO (2015). Perfil Nacional de Seguridad Alimentaria y Nutricional República Dominicana. Retrieved January 19 2016 at: http://plataformacelac.org/storage/app/uploads/public/562/851/a60/562851a600cda470466552.pdf

FAO (2015). Panorama de la Inseguridad Alimentaria en América Latina y el Caribe: La región alcanza las metas internacionales del hambre. Retrieved at: http://www.fao.org/3/a-i4636s.pdf

FAO (2016). FAO felicita a legisladores por aprobación ley SAN. Publicación en página web de la FAO el 13 de junio de 2016. Retrieved January 17 2016 at: https://goo.gl/JpMeMM

FAO (2017). Bases de datos estadísticos en línea sobre indicadores por país (FAOSTAT; http://www.fao.org/faostat/es/#country). Online. Accessed 19 enero 2017.

FAO, AQUESTAT (2017). Available at: http://www.fao.org/nr/water/aquastat/countries_regions/DOM/indexesp.stm

FAO, Ministerio de Agricultura de la República Dominicana, ONE, Unión Europea (2011). Precenso Nacional Agropecuario 2015: Informe de resultados. Retrieved at: http://www.one.gov.do/Categoria/Publicaciones/1552

FUNGLODE (2011). Diccionario Enciclopédico Dominicano de Medio Ambiente. Retrieved at: http://www.diccionariomedioambiente.org/diccionariomedioambiente/es/

Gómez-Cuevas, R. (2014). Segundo Consenso Latinoamericano de Obesidad. Retrieved 18 enero January 2017. Retrieved at: http://www.seme.org/docs/Resumen-II-Consenso-Latinoamericano-Obesidad.pdf

Heidhues, F., Atsain A., Nyangito H., Padilla M., Ghersiay G. and Le Vallée J. (2004). Development Strategies and Food and Nutrition Security in Africa: An Assessment. 2020. Discussion Paper No. 38.

IDIAF (2007). Plan Estratégico para el Desarrollo de la Acuicultura en la República Dominicana. Available online at: http://www.idiaf.gov.do/publicaciones/Publications/estrategiaacuiculturard/HTML/index.html#/49/zoomed

Instituto Nacional de Recursos Hidráulicos, INDRHI. Datos estadísticos. Available at: http://www.indrhi.gob.do/index.php/cultura-agua

Jardín Botánico Nacional. Available at: http://www.jbn.gob.do/

Jardín Botánico Nacional; Ministerio de Educación Superior Ciencia y Tecnología; Ministerio de Medio Ambiente y Recursos Naturales (2016). Lista Roja de la Flora Vascular en República Dominicana. Santo Domingo, República Dominicana, Amigo del Hogar. 763 pp.

Jiménez, M, Apostolou A, Palmera A., Meyer L.,, Hiciano S., Newton A., Morgan O., Then C., and Pimentel R. (2011). Multinational cholera outbreak after wedding in the Dominican Republic. Emerging Infectious Diseases (www.cdc.gov/eid) Vol. 17(No. 11): November 2011.

Junta Agro empresarial Dominicana (JAD) (2009). Estrategias para el Desarrollo Agropecuario y Agroindustrial Sostenible de la República Dominicana 2010-2030, Tomo I: Fortalezas, Desafíos y Oportunidades. Retrieved at: http://jad.org.do/wp-content/uploads/2015/09/Estrategia-para-el-Desarrollo-del-Sector-Agropecuario-2010-2030.pdf

Ley 1-12. Estrategia Nacional de Desarrollo 2030. Retrieved at: https://goo.gl/QAhe43

Ley de Incentivo a Energías Renovables y Regímenes Especiales (Ley No. 57-07) (2007). Retrieved at: http://retecsa.net/ley_57-07.pdf

Listín Diario (enero 8, 2012). Transgénicos en la mira. Retrieved February 21 2017 at: http://www.listindiario.com/la-republica/2012/01/08/217339/transgenicos-en-la-mira

Listín Diario (febrero 17, 2015). Las franquicias de comida rápida. Retrieved January 17 at: www.eldinero.com.do/9310/las-franquicias-de-comida-rapida/

Menchú M, Méndez H, Dary O. (2013). La Calidad de la Dieta en República Dominicana Aproximada con los Datos de la ENIGH 2007. Publicación de la USAID del 21 de marzo de 2007. Retrieved at: https://goo.gl/4CD43C

Ministerio de Agricultura de la República Dominicana. Base Estadística. Consultado en enero de 2017. Available at: http://www.agricultura.gob.do/estadisticas/siembra-cosecha-produccion-y-rendimientos/

Ministerio de Industria y Comercio (MIC) (2016). Informe de Importaciones de Productos Alimenticios Julio 2016. Retrieved on January 17 2017 at: http://www.onec.org.do/wp-content/uploads/2016/09/Informe-importaciones-julio2016.pdf

Ministerio de Medio Ambiente y Recursos Naturales; GEF; PNUMA, Cobi. ORG. (2012).

Especies Exóticas Invasoras una Amenaza a la Biodiversidad. Retrieved at: http://ambiente.gob.do/wp-content/uploads/2016/10/Especies-Exoticas-Invasoras.pdf

Ministerio de Medio Ambiente y Recursos Naturales (2000). Ley sobre Medio Ambiente y Recursos Naturales (64-00), publicación oficial, Santo Domingo República Dominicana.

Ministerio de Medio Ambiente y Recursos Naturales (2011). Lista de Especies en Peligro de Extinción Amenazadas o Protegidas de la República Dominicana (Lista Roja).

Ministerio de Medio Ambiente y Recursos Naturales (MIMARENA, DO) (2014). Quinto Informe Nacional de Biodiversidad en la República Dominicana. MIMARENA, Santo Domingo, DO. 80pp.

Ministerio de Salud Pública y Asistencia Social MISPAS (2003). Dirección General de Epidemiología (DIGEPI). Análisis de la Situación de Salud de la República Dominicana 2003. Retrieved January 10 2017 at: http://www.arssenasa.gov.do/index/documentos/Analisis_Situacion_Salud_2003.pdf

Ministerio de Salud Pública (MISPAS) (2014). Indicadores Básicos de Salud.

Morillo Pérez A. (2014). El mapa de la pobreza en la República Dominicana 2014. Informe general. Ministerio de Economía, Planificación y Desarrollo-MEPYD. Santo Domingo, DO. 402pp.

Nin Pratt A. (2016). Comparing apples to apples. a new indicator for research and development investment intensity in agriculture. International Food Policy Research Institute (IFPRI). Environment and Technology Production Division. 44p.

Objetivos del Milenio (2016). Seguridad alimentaria y agricultura familiar en República Dominicana. Periódico Diario Libre. Consultado el 28 de diciembre de 2016. Available at: https://goo.gl/Mt464q

Observatorio Político Dominicano (2014). ¿Qué pasa con el agua? Retrieved at: https://goo.gl/PwMRmf

Oficina Nacional de Estadísticas (ONE) (2014). Boletín: La población dominicana en el Siglo XXI. Un panorama basado en los datos de las Proyecciones Nacionales de Población 2014. Oficina Nacional de Estadísticas-ONE. Santo Domingo, DO. 16pp.

Oficina Nacional de Estadística (ONE) (2017). Base Estadística de la Oficina Nacional de Estadísticas de la República Dominicana. Retrieved January 2017. Available at: http://www.one.gov.do/Estadisticas/4/agropecuarias

Oficina Nacional de Estadística (ONE) (2015). Pre-censo Nacional Agropecuario 2015. Consultado el 28 de diciembre de 2016. Available at: http://www.one.gob.do/Estadisticas/4/agropecuarias

OMS (2017). Enfermedades de Transmisión Alimentaria. Retrieved on January 10 2017 at: http://www.who.int/topics/foodborne_diseases/es/

Peralta Girón, R. (2011). Enfermedades Transmitidas por los Alimentos en República Dominicana. Tesis de Maestría presentada en la Universidad para la Cooperación Internacional (UCI), San José, Costa Rica. Retrieved on January 10 2017 at: https://goo.gl/ynYkKn

Periódico Hoy Digital. Disponibilidad de agua dulce bajará en 85% al 2,100. Available at: http://hoy.com.do/disponibilidad-de-agua-dulce-bajara-en-85-al-2100/

Pingali P, Alinovi L., and Sutton J. (2005). Food Security in complex emergencies: enhancing food system resilience. Disasters, Vol. 29, Junee 2005.

PNUD. PNUD en República Dominicana. Retrieved at: https://goo.gl/nHLNBF

Reynoso G. (2015). Contraste de la disponibilidad de agua por provincia (Situación actual y retos futuros). Santo Domingo, República Dominicana, Amigo del Hogar. 108 pp.

SODIAF (2016). Situación actual de los investigadores agropecuarios y forestales de República Dominicana. Informe técnico. Santo Domingo, Sociedad Dominicana de Investigaciones Agropecuarias y Forestales.

Stads G, Beintema N, Pérez S, Flaherty K, Falconi C. (2016). Agricultural research in Latin America and the Caribbean. a cross-country analysis of institutions, investments, and capacities. Washington, D.C.: International Development Bank and International Food Policy Research Institute. 44 pp.

World Food Summit (1996). Rome Declaration on World Food Security.

Food and Nutrition Security in Ecuador

High angle view of food street market in Azuay province, Ecuador © Shutterstock

Ecuador

[1] Nikolay Aguirre
[2] Charles W. Barnes
[3] María Eugenia Ordóñez
[4] Jenny Ruales

Summary

Ecuador has three distinct natural regions (Coastal, Andean and Amazonian), along with the Galapagos Islands, represents a wide diversity of ecosystems. Due in part to the land-use patterns of the oil sector, which accounts for more than half of Ecuador's export earnings, Ecuador is not self-sufficient in food and the population's access to food is limited. Iron deficiency is the most widespread problem and there are also moderate levels of vitamin A and zinc deficiency. Through salt fortification programs, iodine deficiency has been eradicated. At the same time, problems of obesity have been detected, even among children. Food safety has improved throughout the country over the past decade.

Ecuador is relatively vulnerable to natural disasters such as volcanic eruptions, floods, droughts, earthquakes and climate change.

Simple, effective, low cost technologies could significantly increase yield of certain agricultural products. Although water availability and quality are sufficient for agroindustrial processes, changes in management practices are required to preserve it. Ecuador has the opportunity to expand its markets to European and Asian countries, with the greatest challenge being to increase production, with competitive and differentiated product costs. The permanent provision of resources and support for both basic and applied research is necessary.

Ecuador: a megadiverse country with potential, yet with challenges for its future regarding food security. However, the use and development of biotechnological products will help Ecuador achieve food security

I. National Characteristics

Ecuadorian workforce is largely based in agricultural, but the value of those jobs is in decline. In 2014, agriculture accounted for 24.5% of the country's employment. However, the slowest growth in Gross Domestic Product (GDP) took place in agriculture and mining, while the construction and services sectors experienced the highest growth. A total of 8.9% of Ecuador's total GDP was produced by agriculture, hunting, forestry and fishing, with electricity, gas and water accounting for a smaller amount. Workers in the agricultural sector earned 44.3% less than the national average (National Institute of Statistics and Censuses [INEC], 2014a).

a. Geography of Ecuador

Ecuador is located in the NW of the South American continent. It covers an area of 283,561 km², including the Galapagos Islands. It borders Colombia to the North and Peru to the South and East. Its climate is tropical in the coastal and Amazon regions, and temperate in the highlands of the Andes mountain range.

Heterogeneity of the landscape and environment
Ecuador has three distinct natural regions: Coastal, Andean and Amazonian. Ninety-one types of ecosystems have been identified in continental Ecuador: 24 on the coast; 45 for the Andean region, and 22 for the Amazonian region (Ministry of the Environment, [MAE], 2013). Ecuador also has 21 of the 27 marine and coastal ecosystems recognized worldwide. However, the MAE notes that not much is known about the state of conservation of these ecosystems, without specifying the causes for this discrepancy (MAE, 2015: 30). The Galapagos Islands are unique and generally not included in this type of description.

b. Demographics and future trends

The majority of Ecuadorians (57%) live in urban areas, and 43% in rural areas. The largest ethnic group in Ecuador are mestizos, in other words, people with a mixed Spanish and Amerindian ancestry. Mestizos account for 65% or more of the population, which includes persons of 28 different nationalities. Average life expectancy for all nationalities is 71.89 years (http://www.ecuador.com.demographics/). As of July 2016, the estimated population of Ecuador was 16,080,778, with an annual growth rate of 1.31% (CIA, 2017). If this growth rate continues, Ecuador's population is expected to reach 30,833,000 in the next 50 years.

c. Population suffering from food insecurity and malnutrition

A significant portion of the population lacks proper nutrition. In 2015, 10.9% of the population suffered from malnutrition, although this was significantly less than the 19.4% reported in 1991. In 2012, 6.4% of children under 5 were underweight, slightly above the 6.2% reported in 2004 (United Nations Food and Agriculture Organization [FAO], 2017a). However, according to Freire et al. (2014), there has been a dramatic increase in the number of Ecuadorians with overweight and obesity, particularly among women of reproductive age, while nutritional deficiency rates have failed to decline. In over 13% of households, there is an overweight mother living with a child with stunted growth, while one-third of women of childbearing age are overweight and zinc-deficiency. The authors suggest that the "double burden" of people and households with overweight and malnutrition is due to excess consumption of carbohydrates (rice) coupled with a low intake of fruit and vegetables.

There are various forms of agriculture, depending on the crop and the region where it is grown. Fruit, for example, is produced on large industrial plantations for export in the western tropical lowlands, whereas in the highlands, there are small farms for the local market, and family farming in the Amazon region. According to the most recent agricultural census published in 2002, farms with fewer than 5 hectares (ha) account for 63% of all farms, occupying only 6.3% of agricultural land, whereas those with 200 ha accounted for 0.78% of all farms, occupying 29% of the total agricultural land. Intermediate-sized farms occupy between 14% and 19% of agricultural land (FAO, 2006).

d. Main crops by production in tons

According to the most recent information available at FAOSTAT (http://www.fao.org/fastoat/es), the top ten crops in Ecuador - by millions of tons of production in 2014 - are shown in **Figure 1**. **Table 1** lists the values in millions of tons of the main crops, and the average changes in production over the past five and twenty years. Maize, palm oil, cocoa and quinoa saw a significant increase in tons harvested in the past 20 years, whereas green coffee, barley and wheat suffered the largest decline in area and tons harvested.

[1] **Nikolay Aguirre,** National University of Loja. nikolay.aguirre@gmail.com
[2] **Charles W. Barnes,** Instituto Nacional de Investigaciones Agropecuarias (INIAP). cbarnes333b@gmail.com
[3] **María Eugenia Ordóñez,** Pontificia Universidad Católica del Ecuador (PUCE). meordonez@puce.edu.ec
[4] **Jenny Ruales,** Coordinator, Escuela Politécnica Nacional (EPN). jenny.ruales@epn.edu.ec

In the case of bananas, of the total area planted, only 14%, 33%, and 34% receive irrigation, fertilization and pest control, respectively; in other words, roughly 60% of the area lacks access to technology. Ecuador is the third largest producer of bananas by weight, but the leading producer in terms of the amount of US dollars generated by exports. The country supplies 26.5% of the world banana market on the basis of its dollar value. Latin American and Caribbean countries are responsible for 59.3% of world banana sales.

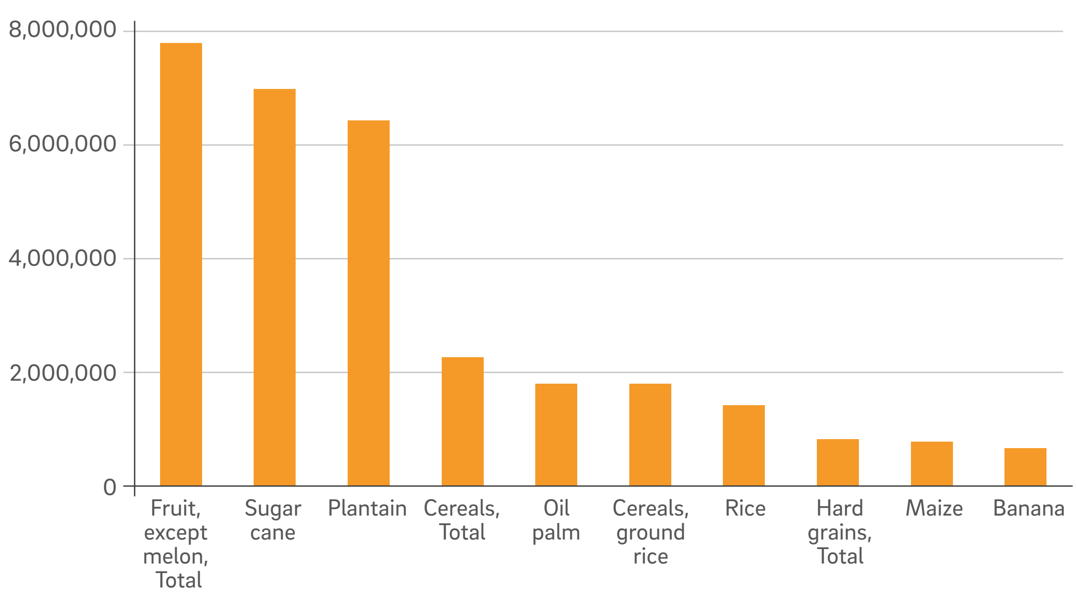
e. Animal agriculture

Like plant crops, the number of heads of many types of livestock decreased between 1995 and 2014. Sheep and goats have declined by more than 50% and only hens have significantly increased (164%) over the past 20 years (**Table 2**). Economics and disease have played an important role in animal production in Ecuador. According to the US Department of Agriculture's Foreign Agriculture Service, Ecuadorian cattle declined in number from 2010 to 2013, partly because of low beef prices (https://www.fas.usda. Gov/data/ecuador-ecuador-livestock). Economic returns can influence farmers to make changes in their production. Moreover, the presence of Foot-and-Mouth Disease (FMD) has contributed to the decrease in the number of cattle. In 2014, the number of cattle in Ecuador was estimated on the basis of the number of animals vaccinated against FMD. Based on the success of the vaccinations, the World Organization for Animal Health (OIE) has declared Ecuador free of FMD. This resulted in increased imports of live cattle, and set the goal of increasing national livestock to export beef, which is expected to begin in 2017.

f. Is the country self-sufficient in agriculture?

No. According to land use patterns, Ecuador is not self-sufficient in food (Fader, Gerten, Krause, Lucht and Cramer, 2013). Based on the model used in this study, by the year 2000, Ecuador lacked sufficient land to produce what is eaten in the country. The model predicts that by 2050, Ecuador would have to optimize crop management to achieve the highest possible yield in order to attain self-sufficiency. However, this would only apply with lower population-growth scenarios. This contrasts with the situation in other countries, which are either already self-

Figure 1. Ecuadorian products with the highest production in tons, 1995-2014



Source: FAO, 2017b (latest available data on March 6, 2017).

Table 1. Areas (in hectares) and tons produced from individual crops in Ecuador from 1995-2014, and changes in the past 20 and 5 years

Crop	1995	2010	2014	% change in 20 years	% change in 5 years
Sugar cane					
Ha harvested	106,210	106,928	96,892	-8.8%	-9.4%
Tons harvested	6,750,000	8,347,182	8,251,306	22.2%	-1.1%
Banana					
Ha harvested	227,910	215,647	182,158	-20.1%	-15.5%
Tons harvested	5,403,304	7,931,060	6,756,254	25.0%	-14.8%
Palm Oil-Fruit					
Ha harvested	91,010	193,502	272,011	198.9%	40.6%
Tons harvested	1,025,310	2,850,465	3,468,510	238.3%	21.7%
Rice					
Ha harvested	395,600	393,137	354,136	-10.5%	-9.9%
Tons harvested	1,290,518	1,706,193	1,379,954	6.9%	-19.1%
Maize					
Ha harvested	511,010	440,346	485,696	-5.0%	10,3%
Tons harvested	556,558	984,096	1,667,704	199.6%	69.5%
Potato					
Ha harvested	65,980	44,245	33,208	-49.7%	-24.9%
Tons harvested	473,204	386,798	421,061	-11.0%	8.9%
Green coffee					
Ha harvested	384,010	144,931	35,483	-90.8%	-75.5%
Tons harvested	148,205	31,347	4,225	-97.1%	-86.5%
Cacao					
Ha harvested	349,370	360,025	372,637	6.7%	3.5%
Tons harvested	85,505	132,100	156,216	82.7%	18.3%
Citrus fruits					
Ha harvested	4,500	6,463	7,327	62.8%	13.4%
Tons harvested	24,212	20,776	19,516	19.4%	-6.1%
Wheat*					
Ha harvested	28,430	8,533	6,082	-78.6%	-28.7%
Tons harvested	19,763	7,605	6,814	-65.5%	-10.4%
Barley					
Ha harvested	48,680	26,374	15,688	-67.8%	-40.5%
Tons harvested	31,683	18,733	14,490	-54.3%	-22.6%
Quinoa					
Ha harvested	800	2,034	4,122	415.3%	102.7%
Tons harvested	408	1,644	3,711	809.6%	125.7%

Source: FAO, 2017b.
* In 1969, there were 100,231 ha of wheat, whereas by 2014, only 6% of the area remained under wheat cultivation.

sufficient or may become self-sufficient, either by increasing productivity or by expanding land and water use, or may need to expand land and water use, or are unable to become self-sufficient (Fader et al., 2013).

g. Main export/import markets and products

Total export and import values for Ecuador were $27.4 billion USD each, with a slight positive trade balance of $23.8 million USD. Crude oil represents almost 50% of the country's total exports, while banana is the main export crop, accounting for 12% of Ecuador's total exports. Ecuador is the leading banana exporter, accounting for 26% of the world total, as mentioned previously, followed by the Philippines with 15% and Colombia with 7.8%. Based on the RCA (Revealed Comparative Advantage) value, Ecuador exports 167 times its equitable share in bananas (The Observatory of Economic Complexity [OEC], 2014). In terms of monetary value, Ecuador's banana exports stood at $ 2.8 billion USD in 2015, ranking first in the world, with Belgium occupying second place with $958.1 million USD (OEC, 2014). The largest importers of Ecuadorian products in 2014 were the US ($11.1 billion USD), Chile ($2.25 billion USD) and Peru ($1.68 billion USD) (OEC, revised March 2017).

Based on monetary value of 2014, after bananas, Ecuador's largest exports were crustaceans (9.3%), processed fish (4.7%), cut flowers (2.8%) and cacao (2.2%). In addition to bananas and cacao, Ecuador exports coffee/tea extracts, processed fruits and nuts, animal meal and pellets, and fruit juice. Sixty three percent of its banana exports are sent to Europe (19% to Russia), 15% to North America (13% to the US) and 12% to Asia (4.2% to China). Half the cacao exported goes to North America (39% to the US) and 33% to Europe (9.4% to the Netherlands) (OEC, 2014).

As mentioned earlier, the value of the country's imports equals that of its exports, resulting in an equitable trade balance. Based on their monetary value in 2014, Ecuador's main imports were refined petroleum and tar oil, accounting for 13% and 8.3% of the total value of imported goods, equivalent to $3.44 billion USD and $2.27 billion USD, respectively (OEC, Consulted March 2017). Regarding agricultural goods, highest expenses for imported animal products were unfilleted frozen fish (US $51 million), eggs ($23.5 million USD) and poultry ($16.6 million USD). Of the imported plant products, soybean meal has the highest costs per year at $368 million USD, but is used for animal feed, human consumption and oil-based products. After soybean meal, the next largest expense is wheat imports ($240 million USD), animal feed ($182 million USD), coffee ($92.6 million USD) and maize ($71.1 million USD). The main countries from which Ecuador imports are the US, from which it imports $7.56 billion USD, equivalent to 28% of all its imports, followed by China with $4.59 billion USD, Colombia with $1.8 billion USD and Peru with $901 million USD.

Import and export trends should be considered over relatively long periods. Economic factors such as taxes, tariffs, trade agreements, and natural factors such as pests, diseases, droughts or floods, can have significant effects on agricultural production in relatively short periods of time. Moreover, natural factors can influence regulations for the import/export of agricultural products and foodstuffs.

Table 2. Changes in livestock production (number of heads) from 1995-2014

Livestock	1995	2010	2014	% change in 20 years	% change in 5 years
Cattle	4,995,000	5,253,536	4,579,374	-8.3%	-12.8%
Pork	2,618,000	1,4897,961	1,910,319	-27.0%	-87.2%
Sheep	1,692,000	792,499	619,366	-63.4%	-21.8%
Goats	295,000	134,825	20,793	-93.0%	-84.6%
Hens	61,512	152,926	162,300	163.9%	6.1%

h. Potential sources of instability of food security

FAO reports a 10-year decline from 1998 onward in stunted growth and low weight in children under the age of five in Ecuador. Iron deficiency is the most prevalent problem of micronutrients in Ecuador, affecting more than 50% of the population in most age groups, together with moderate levels of vitamin A and zinc deficiencies (FAO, 2010). However, the indigenous population is disproportionately affected. For example, 42% of indigenous children under the age of five suffer from stunted growth.

Ecuador is relatively vulnerable to natural disasters such as volcanic eruptions, floods, droughts, earthquakes and climate change. The earthquake of April 16, 2016, with a magnitude of 7.8, claimed over 670 lives, leaving nearly 28,000 injured. The UN World Food Program distributed food to more than 105,000 people after the earthquake. Among the many active volcanoes in Ecuador, the Cotopaxi volcano – the world's second largest active volcano - erupted from August 2015 to January 2016. It is located only 50 km from Quito, the capital city with approximately 2 million habitants. Moreover, Ecuador receives the largest influx of refugees in Latin America (World Food Program [WFP], 2017). Climate change will affect water availability and temperature fluctuations/extremes, among other factors, and encourage the presence of invasive alien species that will influence the ability to grow and maintain certain crops rather than others (Early et al., 2016).

i. Major challenges in agriculture

As indicated earlier, the main challenges of agriculture are the management of water and land resources to increase productivity (Fader et al., 2013).

II. Institutional framework

a. National Agricultural Research System

The National Institute of Agricultural Research (INIAP) is Ecuador's government agricultural research institution. There are eight experimental stations distributed throughout the country with programs for rice, bananas and other Musaceae, cocoa, coffee, rubber, cereals, forestry, fruit farming, livestock and pasture, legumes and Andean grains, maize, oilseeds, potato, pineapple, yucca and sweet potato. Most warm-climate crops are grown on either side of the Andes mountain range, while cooler-climate and dry-land crops occur in the highlands. INIAP offers a wide range of services associated with the crops in the various programs. These range from extensive soil and water analysis, through the chemical analysis of the crops themselves, quantification and identification of microbes in soils, plants and seeds, to DNA analysis, including the sequencing and generation of microsatellite markers. The prices and location of the laboratories providing these services are available online. It is clear from the information on the website that INIAP focuses on services and research to improve the country's agricultural productivity. However, the INIAP website does not provide data on specific research activities or on the activities of its researchers. Although information on research publications, collaborations and interests can be found in public databases such as ResearchGate, details must be sought individually.

b. Is there a need to increase research skills?

Yes. In Ecuador there are two fundamental aspects affecting research development: the lack of financing and the difficulty of accessibility. Research is relatively expensive and new technologies even more so. Moreover, the lack of access to new technologies, and often even to common technology, reduces the opportunities to produce publishable research. The personnel's interest in research is gradually declining, as are infrastructure and research capacities. Ecuador invests barely 0.18% of its agricultural production (GDP-Ag) in research, the lowest percentage of GDP-Ag expenditure in Research and Development in South America. In 2013, the last year of available data, Ecuador had just 11.8 researchers per 100,000 farmers; only Peru had a smaller number (Agricultural Science and Technology Indicators [ASTI], 2013). The data used by the ASTI website are drawn from the World Bank, World Development Indicators. Lack of access to online literature also hinders the development of research, which in turn is due to lack of investment. In January 2017, the Ecuadorian government began to search for and evaluate options for accessing online literature services for its employees, such as SpringerLink. However, even with access to up-to-date literature, researchers still experience difficulty reading and understanding articles written in English, and/or a general lack of material translated into Spanish. Access alone will not significantly improve productivity and research activities.

c. Scientific collaboration networks inside and outside the country

Ecuador has a system for promoting collaborative research agreements among governmental, non-governmental and international institutions. The National Secretariat of Science and Technology has financed postgraduate studies for Ecuadorians abroad. Sometimes, the research for Ecuadorian students' theses is undertaken in Ecuador. As a result, these student theses establish international collaboration projects which, in turn, encourage other postgraduate studies and new collaborative projects.

d. Access to and maintenance of databases for monitoring farming systems

Although the INIAP provides databases on its website, they are not periodically updated and there are categories with no information, such as the list of publications. However, other government websites offer various forms of data. The Ministry of Agriculture, Livestock, Aquaculture and Fisheries (MAGAP) (2017a) offers comprehensive, up-to-date databases and training videos on product prices, censuses and surveys, production and various production costs such as agrochemicals, although only for Ecuador's main crops. The Ecuadorean Agency for Agricultural Quality Assurance (AGROCALIDAD, 2013) also provides search databases for information on health guidelines for the import, export and transit of agricultural products within the country. These databases also appear to be limited to the main crops and livestock. However, they are user-friendly and provide relevant information for farmers, companies or researchers needing to transport agricultural products.

e. Universities and Research Institutes

The Ecuadorian government recently launched a program to rate and certify the country's universities and colleges. The Council for the Evaluation, Accreditation and Quality Assurance of Higher Education (CEAACES, 2016) lists a total of 52 certified universities and polytechnic schools throughout the country. To ensure and improve the quality of education, CEAACES assessed all of the higher education institutions based on the standards established by the government and evaluated by external assessors. Subsequently, all universities and polytechnic schools were placed in four categories: A-D, with A the highest. There are six undergraduate universities with a categorization of A, 26 in category B, 16 in category C and four in category D. An independent website (altillo.com copyright 2016) listed 72 universities and colleges in Ecuador, organized by province and as private or public universities. The website mentions a total of 30 public universities and 42 private universities and colleges, with five public and 14 private institutions offering online or distance education. Most of the less populated provinces have only one public university. Seventy-five percent or more of the universities in the provinces of the large cities of Cuenca, Guayaquil and Quito are usually private institutions. However, the same government categorization system is maintained. QS Top Universities (topuniveristies.com 2017) also report more than 70 universities in Ecuador with an enrolment of over 61,000 students. These data refer to Ecuador's higher education centers in general.

Evaluations by CEAACES have pressured universities to increase their scientific output. If one regards the number of publications as a measure of the progress of Ecuador's research, there has been a steady increase in recent years. For example, the number of scientific publications registered in Scopus® for 2012 was 642, while 2,146 publications were registered in 2016. The largest number of publications, representing 25.5%, was in the area of agriculture and biological sciences, followed by medicine with 24.1%. If we compare these data with publications registered in 2016 by other countries in South America, Ecuador ranks fifth regarding the number of publications per capita, after Chile, Brazil, Argentina and Colombia. However, these figures are much lower than those recorded for Canada and the US. Although low investment in research, the high cost of inputs and equipment and the limited number of researchers with PhDs have limited Ecuador's scientific production, recent years have seen a steady rise in the latter.

III. Resource and ecosystem characteristics

a. Water resources and challenges for the next 50 years

Water is a globally threatened resource. It has been estimated that there are approximately 1.4 billion cubic kilometers of water on the planet, of which approximately 3% are freshwater. In Ecuador, average annual rainfall is 2,274 mm, corresponding to 583 km³/year throughout the mainland (FAO, 2016). The total amount of water available in all of its hydrographic systems is 432 km³/year. Ecuador has 31 hydrographic systems consisting of 24 in the Pacific slope, with a total area of 124,644 km² and seven on the Amazon slope, with an area of 131,726 km², corresponding to 49% and 51%, respectively. The hydrographic systems are divided into 79 watersheds, of which 72 belong to the Pacific Ocean slope - one part belongs to coastal areas with 123,216 km² (48%), and the other to the neighboring island territories, covering 1,428 km² (1%). These basins are home to 88% of the population. The other seven basins form part of the Amazon slope with 131,726 km² (51%) and 12% of the population. The country's overall water balance is positive, although there are basins with a water-supply shortfall in various parts of the country concentrated in the province of Manabí (hydrographic systems of Jama, Portoviejo and Jipijapa), and to the East and South of the Gulf of Guayaquil (Taura systems, Balao and Arenillas-Zarumilla).

One of the main problems in Ecuador is that agricultural drainage has been neglected, in both irrigated areas and wetlands, which has caused degradation and salinization effects on soils, severely limiting the use of potentially productive areas. The latter have produced a decline in crop yields and many farmers have had to expand the agricultural frontier to increase production. The greatest challenge for Ecuador is to create a combination of financial resources, capacity building and political will. Infrastructure for water supply, sanitation and wastewater treatment is expensive, for which public and private funding sources are insufficient. There is also an enormous lack of technical capacity in the operation and maintenance of water and sanitation systems, resulting in total or partial destruction in the short term. Moreover, the lack of proper management models focusing on small municipalities and rural areas leads to unsustainable systems requiring permanent subsidies.

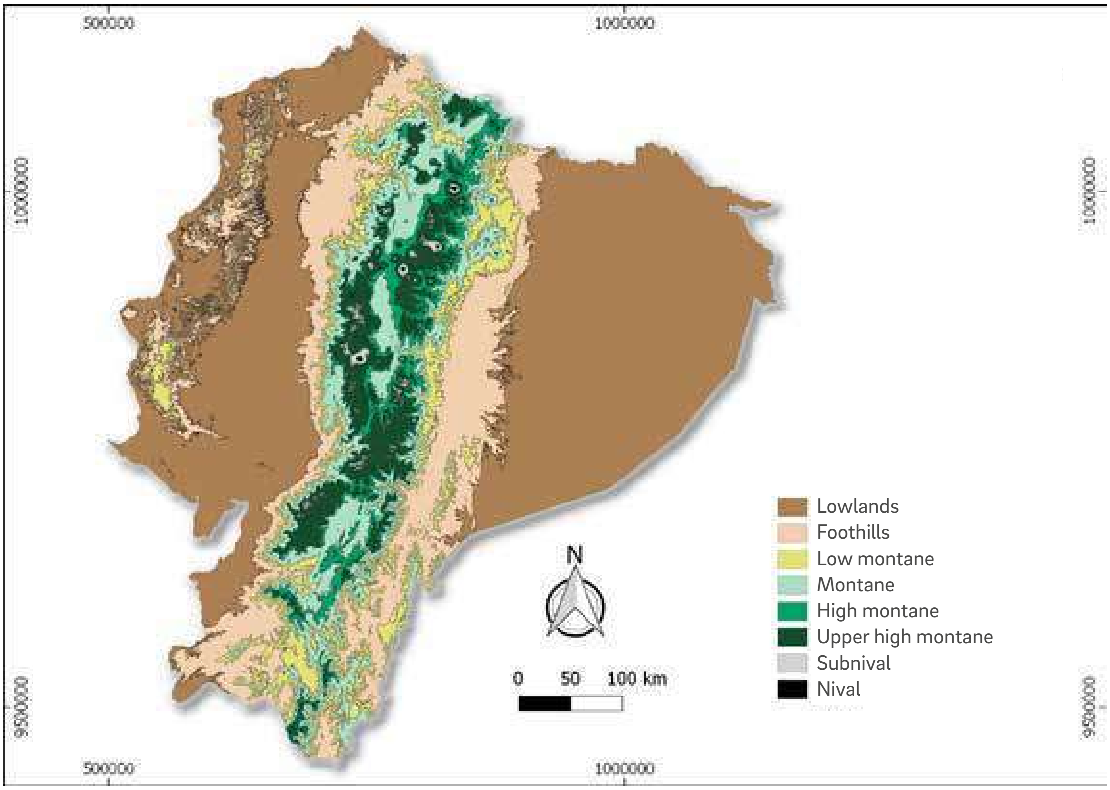
Agriculture will face complex challenges between now and 2050 to satisfy an estimated world population of 9 billion. One thing that is certain, however, is that more water will be needed to produce an estimated 60% of the additional food needed. Water issues to be addressed include: producing more food while using less water, creating resilience in farming communities to cope with floods and droughts, and using safe water technologies to protect the environment.

b. Land resources and challenges for the next 50 years

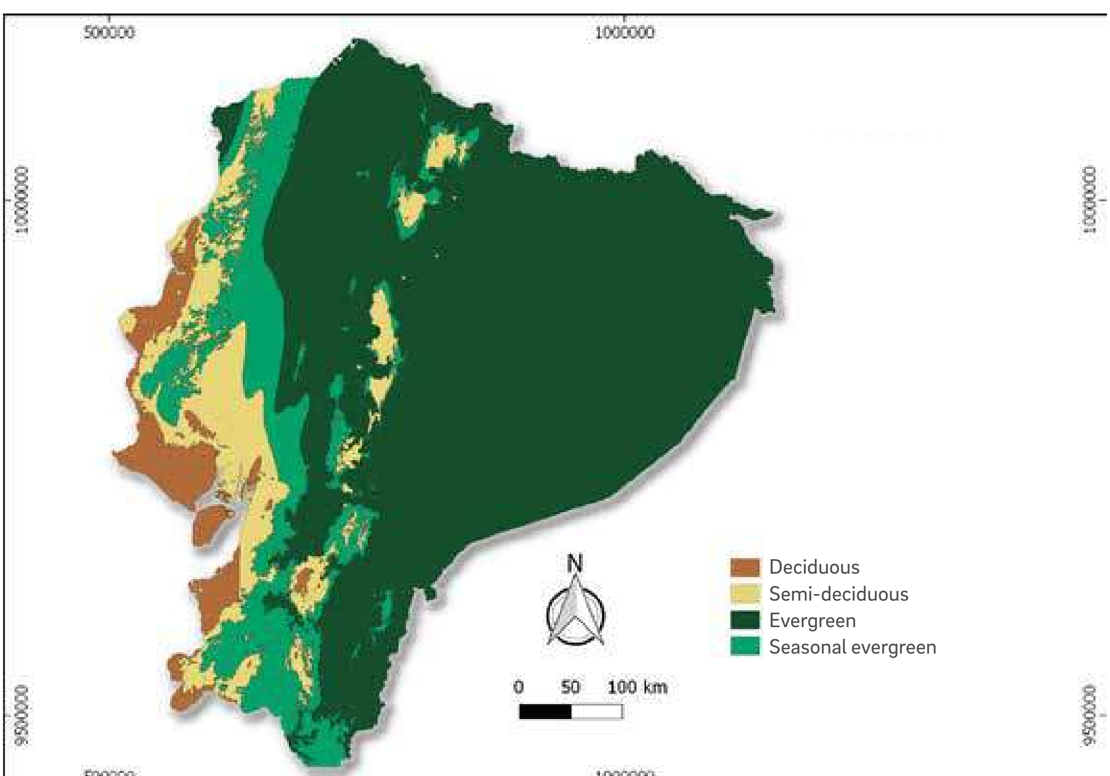
Ecuador is divided into three continental regions: Coastal, Andean and Amazonian, in addition to an island region: the Galapagos Islands. The coastal region, lying between the Pacific Ocean and the Andes Mountains, consists of lowlands and mountains. The greatest difficulties are undoubtedly faced by pastures in the high Andes, particularly in the drier parts of the mountain chain (FAO, 2016). In Ecuador, there is a significant degree of indigenous communal coordination. Rural development initiatives can therefore be effectively supported by these organizations, although one of the main challenges they face is the scarcity of economic options available at these altitudes.

The main limitation of animal pastures is availability, followed by the quality of fodder, in an environment where growth is severely limited by low temperatures and rain, hampering the process of restoring grassland. Whenever strategic

Map 1. Bioclimatic zonation of Ecuador



Map 2. Phenological patterns of Ecuador



irrigation is available, these limitations can be overcome through strategic supplementation of animal feed with planted pastures. The yield of *Lolium* and alfalfa species, as well as grasses with white clover, can achieve reasonably high levels through fertilization with nitrogen and potassium. However, a higher level constraint on the application of these solutions is the lack of policies and credit, coupled with limited consultancy services, as well as the inaccessibility to many of these services in many parts of the upper Andes.

It should be noted that native Andean grasslands, particularly in the moors, have been overexploited for decades. Given the severe climatic conditions, reversal of this situation is only possible in the long term and if suitable policies are available that take into account the assessment of their biodiversity and the ecosystem services they offer. These are challenges that have yet to be addressed by government agencies. This is unlikely due to more immediate concern with the promotion of high value export crops and other products mainly produced in the lowlands.

c. Energy Challenges

In Ecuador, the oil sector accounts for over half the country's export earnings and about two-fifths of public-sector revenues (CIA, 2017). A nationalistic approach to resources and debates over the economic, strategic and environmental implications of oil-sector development are prominent issues in Ecuador's policy and those of its government. Ecuador is the smallest producer in the Organization of Petroleum Exporting Countries (OPEC), yielding 556,000 barrels per day (bbl/d) of oil and other liquids in 2014, of which crude oil production accounted for 555,000 barrels a day (bbl/d). The lack of sufficient national refining capacity to meet local demand has forced Ecuador to import refined products, limiting net oil revenues (U.S. Energy Information Administration, 2011: 1-2).

The Ishpingo-Tambococha-Tiputini (ITT) fields in Yasuní National Park have an estimated 846 million barrels of reserves. The development of the ITT region could be challenging and costly. To minimize costs and environmental damage, ITT projects require foreign investment and experience in horizontal drilling. It is unlikely that the necessary investment and experience will be achieved, given the pro-nationalist position of the current Ecuadorian Government. The resistance to the development of indigenous groups also poses operational challenges.

Ecuador has relatively small natural gas reserves and a limited natural gas market (US Energy Information Administration, 2011: 6). In January 2015, Ecuador had an estimated 212 Billion cubic feet (Bcf) of natural gas reserves. The country's gross natural gas production was 54 Bcf in 2013, of which 37 Bcf were sold and the remainder flared and vented. Low natural gas-use rates in Ecuador are mainly due to the lack of infrastructure needed to collect and market natural gas (US Energy Information Administration, 2011: 6).

In 2014, hydroelectricity accounted for over 45% of the country's electricity. The other major source of electricity is a group of conventional, oil-fired power stations. Ecuador has over 200 power plants, 89 of which supply power to the national grid (US Energy Information Administration, 2011: 5). The other major source of electricity supply is the series of conventional thermal power plants in Ecuador, mainly designed to burn oil.

Of the renewable non-hydrogen fuels, bagasse - a fibrous residue from processed sugar cane - is used in industry, while traditional biomass is employed in rural households. However, traditional biomass consumption estimates are inaccurate because biomass sources (firewood, charcoal, manure and crop residues) are not normally marketed in markets. Ecuador also has limited wind and solar capacity, supported by feed-in tariffs (U.S. Energy Information Administration, 2011: 3).

d. Conflicts and challenges for biodiversity

Ecuador is one of the world's most biodiverse countries and has nearly 25,000 species of vascular plants, with high endemism distributed throughout its geographic regions (Tapia et al., 2008: 19), and the forests in the Western Amazon are characterized by high plant diversity. Over the past few years, a large part of these forests have undergone intense exploitation, experiencing large-scale genetic erosion in certain plant species such as Ecuadorian ivory palm (*Phytelephas aequatorialis*), Laurier (Ocotea spp.) and Royal palm (*Ynesa colenda*). Cloud forests (between 900 and 3,000 meters above sea level [masl]) are home to about half of Ecuador's plant species, although they occupy only 10% of the country's area. They are particularly rich in plants from the *Bromeliaceae* and *Orchidaceae* families. The various geographic regions are extremely rich in wild relatives related to cultivated species such as potato, bean, tomato and tropical and subtropical fruit trees. The country's natural forests are also home to the wild relatives of species such as avocado (Persea spp.) and papaya (Carica spp.). The high diversity of medicinal species is used on an everyday basis for the treatment of innumerable diseases, thanks to the traditional knowledge developed over thousands of years and advances in ethnobotany.

i. Problems associated with overexploitation

Overexploitation refers to the collection of a renewable resource to the point of diminishing yields. Sustained overexploitation can lead to the destruction of the resource. The term applies to natural resources such as wild medicinal plants, grasslands, game animals, fish stocks, forests and aquifers.

Ecuador has limited information on the distribution and current status of wild species and local cultivars, although habitat destruction, changes in dietary habits, logging, oil exploitation, shrimp farming, Industrial monocultures and highway construction are obviously among the factors that contribute to genetic erosion. Deforestation in Ecuador is considered to be most serious in the Amazon basin, affecting more than 137,000 ha a year. The Amazon region and the Galapagos Islands have been identified as the most important areas for conducting studies for drawing up inventories and ensuring the conservation of genetic resources, due to their high susceptibility to the dangers of genetic erosion caused by the expansion of agricultural areas and road infrastructure, urban settlements, the introduction of invasive plants and animals and oil drilling (Tapia et al., 2008: 20).

The second place is the Sierra region, which faces threats of deforestation and soil erosion causing a great loss of Andean biodiversity. Although the natural vegetation has been almost entirely replaced by crops and urban settlements, indigenous communities still continue to plant and conserve multiple traditional varieties of various crops. The most important ones are maize (*Zea mays*), potato (*Solanum tuberosum*), sweet potato (*Ipomoea batata*), melloco (*Ullucus tuberosus*), oca (*Oxalis tuberosa*), white carrot (*Arracacia xanthorrhiza*), quinoa (*Chenopodium quinoa*), Andean lupin (*Lupinus mutabilis*), beans (*Phaseolus vulgaris*) and other Andean grains, tubers and roots. The coastal region is the country's most exploited area, where the damage caused by timber and shrimp companies and extensive farming systems has destroyed nearly all dry forests and coastal mangroves.

ii. Exhaustion of genetic diversity

The diversity of genetic resources for food and agriculture (in other words, plants/crops, animals, aquatic resources, forests, micro-organisms and invertebrates) plays a crucial role in meeting basic food and human nutrition needs (FAO, 2017). It is essential to maintain and improve the efficiency and resilience of production systems, as well as to contribute to sustainable food supply and the provision of ecosystem services, such as pests and disease control.

Genetic resources are the raw materials that local communities and researchers rely on to improve the quality and yield of food production (FAO, 2017). When these resources are eroded, humanity loses the potential means of adapting agriculture to new socioeconomic and environmental conditions. Because of their genetic variability, plants, animals, microorganisms and invertebrates are able to adapt and survive when their environments change. Maintaining and using a broad range of diversity - both interspecific diversity and intraspecific genetic diversity - involves maintaining the capacity to meet future challenges. For example, plants and animals that are genetically tolerant to high temperatures or droughts, or resistant to pests and diseases, are of great importance in adapting to climate change.

The diagnosis of genetic erosion in Ecuador is limited and the government has experienced enormous difficulty in combating the gradual loss of genetic diversity. Although Ecuador recognizes the importance of assessing genetic erosion and vulnerability, the methodologies for conducting these types of studies have only just been established. The FAO Early Warning System (WIEWS) is an important tool for assessing genetic erosion in Ecuador. External support is therefore crucial to having the equipment and personnel needed to meet the WIEWS goal. The creation of a National Commission on Genetic Resources and the reactivation of the National Working Group on Biodiversity (GNTB) are the appropriate spaces for developing and using appropriate monitoring and alert systems (Tapia et al., 2008). It is also necessary to provide external support to develop efficient systems with administrative, technical and financial structures that will allow immediate decisions to be made when the system warns of a situation of genetic erosion (Tapia et al., 2008: 32).

e. Implications of forest trends

In early 2013, Ecuador was one of the 12 countries involved in an Interpol operation to combat the illegal timber trade in Central and South America (Forest Legality Initiative, 2014). Ecuador has also prioritized the reduction of its deforestation rate through a number of national policies and is the first country to grant inalienable rights to nature in its Constitution. It also launched the Forest Partner Program in 2008 to encourage the protection of forests. Finally, the government developed the Good Living Plan in 2009, and established a national target to reduce deforestation by 30% by 2013.

In 2008, the Ecuadorian people approved a Constitution that was the first in the world to recognize the rights of nature (Forest Legality Initiative, 2014). Forests were declared fragile ecosystems, therefore, special protection was given to moors, wetlands and mangroves. The Ecuadorian Constitution recognizes the inalienable right of ecosystems to exist and thrive.

The Forest Partner Program is an incentive based policy for forest conservation, developed by the Ecuadorian Ministry of the Environment. Plans have been developed for a two-pronged forest conservation and poverty-alleviation strategy. The program seeks to achieve its two-fold objectives by offering direct monetary incentives per hectare to local landowners and indigenous communities that preserve native forests. Since its inception, the program has been expanded to include areas with higher altitude prairies (moors) and forest restoration. Since October 2012, the Socio Bosque program has protected more than 1.1 million ha of native ecosystems and has over 123,000 beneficiaries.

f. Potential impacts of climate change

Global Climate Change is regarded as the most serious, critical environmental problem facing mankind this century. The term refers to the increase in the Earth's surface temperature due to the rapid increase in the concentration of greenhouse gases in the atmosphere. These variations will have a direct impact on certain climate parameters (National Aeronautics and Space Administration [NASA], 2017).

Climate change is expected to increase pressure on water resources, with a wide range of impacts on humans and the environment. By modifying the water cycle, including rainfall, soil moisture, runoff, evaporation, atmospheric vapor and water temperature, climate change will result in more extreme conditions. The increasing variability of traditional climate patterns, in both time and space, compounded by other global changes such as urbanization, change in food consumption and migration, has exacerbated existing pressures on water resources in the Americas, including Ecuador.

Ecuador is a relatively small developing country, thus making only a marginal contribution to greenhouse gases (Tapia et al., 2008: 15). However, climate change is a global problem that affects all countries, particularly developing ones, such as Ecuador. Accordingly, it signed the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, which establishes the need to address the mitigation of these gases. Given that the vulnerability to climate change of developing countries is higher than that of developed countries, climate change adaptation strategies and actions identified in Ecuador will have high priority, although national sustainable development policies must also be prioritized.

g. Resilience to extreme events

Ecuador's geographical location and its rugged topography make it particularly vulnerable to the impacts of climate change. Wet and dry seasons have shifted or become longer and more intense, moors have been degraded, glaciers have receded (losing 30% of their mass in the past 30 years) and the ability of ecosystems to regulate the water supply has declined (Hines, Alvarado and Chiriboga, 2013: 1). Variability and climate change threaten livelihoods, food and nutritional security and communities' food sovereignty. The challenges of extreme weather events are expected to become more frequent. In the past decade, Ecuador has lost more than $4 billion USD as a result of droughts, together with $70 million USD due to floods in 2012.

Climate-related disasters affect key sectors such as agriculture, water resources, fisheries, infrastructure and tourism, and are particularly damaging to rural areas with large indigenous and Afro-Ecuadorian populations. Climate variability, including the increasingly frequent and intense El Niño and La Niña phenomena, together with pockets of food insecurity and poverty, have led Ecuador to prioritize sound planning and replicable implementation models to address these threats.

Ecuador has launched a project to build resistance to climate change and improve food security in four provinces (Pichincha, Azuay, Loja and El Oro) (Hines et al., 2013). The government launched the project in cooperation with the United Nations World Food Program (WFA), supported by the Adaptation Fund (UNFCCC), to restore community and ecosystems and reduce climate vulnerability. The project brings together communities and local authorities, several branches of national government and the United Nations World Food Program. Its two pronged approach involves developing community awareness and concrete plans for adaptation actions, within an ecosystem-based approach.

h. Future prospects

With its diverse range of natural environments - from the coastal plain, high mountains to the Amazon jungle - Ecuador is expected to experience a number of impacts due to climate change (Nachmany et al., 2015: 3). As a relatively small, middle-income country, Ecuador does not support emission targets for developing countries that do not cause large anthropogenic emissions. However, the government has now made climate change adaptation and mitigation one of its objectives. The Constitution establishes that Ecuador will "adopt policies to mitigate climate change" and promote the development and adoption of clean technology (Nachmany et al., 2015: 4).

The ambitious, wide-ranging national climate-change strategy fits into a broader development strategy. Its aim is to protect the country's biodiversity, a fundamental resource for health and well-being. The strategy is closely linked to other policy areas: the sectors prioritized in the National Plan for Good Living also receive priority in the national strategy for climate change in order to provide policy coherence. These priority areas are: agriculture and livestock security, development of fisheries and aquaculture, maintenance of water supply and natural ecosystems, tourism development, infrastructure improvement and strengthening human settlements. The strategy is part of a broader set of measures under the new constitution being put in place to promote more sustainable development in Ecuador.

IV. Technology and Innovation

a. Role of biotechnology in agriculture and livestock

According to the Convention on Biological Diversity (UN, 1992), 'biotechnology' is defined as "any technological application that uses biological systems and living organisms or their derivatives for the creation or modification of products or processes for specific uses". According to this definition, agriculture and traditional breeding techniques for plants and animals could be regarded as biotechnology. A broader, more modern approach to biotechnology includes the use of genetic manipulation techniques, tissue culture, molecular markers, among others, to obtain organisms or products with desirable qualities. The use of certain biotechnologies, such as Genetically Modified Organisms (GMO), has been controversial and in Ecuador their adoption has been limited for reasons that will be discussed later. However, there is evidence that the adoption of GMO has resulted in increased crop productivity, lower use of agrochemicals, increased nutritional quality of food and greater tolerance to biotic and abiotic stress (Adenle, 2011; Hellmich and Hellmich, 2012; Klümper and Qaim, 2015; Pérez-Massot et al., 2013; Zhang, Wohlhueter and Zhang, 2016). They are unquestionably a useful tool in the search for food and nutritional security in Ecuador.

The use of GMO is not a panacea, however, and other technologies must be adopted to meet the demand for food in future decades. Table 3 shows the yield changes for maize, wheat and rice, according to the technology adopted, considering scenarios of both higher and lower temperature and rainfall, modeled by Rosegrant et al. (2014). These environmental conditions would be possible scenarios in a changing climate, as expected in the future. According to this model, wheat in Ecuador would benefit most from the use of technology to raise yield, while maize and rice would also experience significant increases. Ecuador imports almost all of the country's wheat demand, estimated at 800,000 metric tons in 2016 (US Department of Agriculture [USDA], 2016a). Achieving an increase in the yield and production of wheat and other cereals would contribute significantly to the country's food security through the adoption of simple technologies such as non-tillage. Wheat cultivation in Ecuador and its production have declined enormously since the 1970s. Several factors have contributed to this reduction, including low yield and the susceptibility of varieties to diseases such as rust, low wheat prices, the higher quality of imported wheat and marketing systems that mainly benefit intermediaries. Wheat now has a substantial government subsidy for its importation, which places the few domestic producers at a disadvantage.

The use of other more advanced technologies, such as precision agriculture, could also significantly increase the yields of several products, according to the Rosegrant et al. Model (2014). However, their adoption would be limited by costs and the use of complex technology. Methods such as precision farming are not practical for small landholders in Ecuador, at least in the near future. Small farmers, those most in need of solutions to ensure their food and escape from poverty and malnutrition, need simple, effective, low-cost technologies.

As for the use of modern biotechnology for cattle breeding, although Ecuador does not develop or commercialize genetically modified

Table 3. Increase (%) in yield of maize, wheat and rice in Ecuador by 2050, by use of technology, under higher and lower temperature and rainfall climate conditions and without irrigation

Technology	Higher temperature and rainfall			Lower temperature and rainfall		
	Maize	Wheat	Rice	Maize	Wheat	Rice
Without tillage	43.3	124.2	NA	37.7	123.4	NA
Drought tolerance	7.0	17.1	1.8	11.8	15.1	3.4
Heat tolerance	7.2	42.8	1.2	12.4	29.2	4.6
Integrated soil fertility management	14.6	55.4	22.2	16.7	34.5	17.8
More efficient nitrogen use	27.5	9.2	26.3	24.1	9.5	32.5
Precision farming	1.1	78.4	16.6	0.7	42.9	10.9
Rainwater collection system	0.2	35.3	NA	0.5	24.2	NA
Crop protection from disease	12.1	12	17	12.7	14.4	17.2
Crop protection from insects	9.1	4.4	13.1	8.8	4.3	14.0
Crop protection from weeds	11.8	8.2	10.6	12.2	8.2	10.5

Sources: Agritech Toolbox, 2017; Rosegrant et al., 2014. *NA = Data Not Available.

animals, there are no laws or regulations prohibiting or limiting their use (USDA, 2015). The use of technologies in animal husbandry, particularly in the area of disease diagnosis and vaccine production, is an incipient area in Ecuador, which, if implemented, could result in a more productive activity and economic benefits for farmers and the population in general (Madan, 2005). Biotechnologies aimed at improving reproductive physiology, animal health and nutrition should be adopted and developed.

b. Prospects for novel agricultural products

Like the rest of the world, Ecuador will be affected by climate change, and technology must provide novel solutions to produce more food under conditions of drought and high salinity, in addition to ensuring high yield and pest and disease resistance. Innovation must be able to offer agricultural products that are also environmentally friendly, in other words, that will help reduce greenhouse gas emission and guarantee more efficient use of soil nutrients to reduce the use of nitrogen fertilizers (Global Food Security Index, 2015).

Ecuador is one of the few countries regarded as mega-diverse (Myers, Mittermeier, Mittermeier, da Fonseca and Kent, 2000). It has a rich genetic stock from which genes could be obtained through the use of biotechnologies and used to improve crops with greater resistance to the changing populations of pests and diseases, or adverse environmental conditions that reduce food productivity. Likewise, genetic diversity can be used to develop products with better nutritional value. It is the responsibility of the government and Ecuadorians to ensure the conservation and proper use of these resources.

c. Opportunities and obstacles for the management of new technologies

In order for a technology to be successful, it must first be accepted and adopted. In Article 401, the Ecuadorian Constitution of 2008 declared the country free of GMO. There is therefore a legal impediment to the use of technologies that could help make Ecuador self-sufficient in food and with a well-nourished population. However, Article 281 of the same Constitution also stipulates that it is the state's responsibility to ensure adequate scientific and technological development to achieve food sovereignty and regulate biotechnology use and development. In fact, Ecuador has already developed methodologies to modify bananas, for example, to deal with black sigatoka disease (Santos et al., 2016). INIAP has begun trials with genetically modified maize to evaluate its usefulness in Ecuador, which would be permitted under Ecuadorian laws (USDA, 2016b). Ecuador therefore has the capacity to develop research on new biotechnological products. With clearer legislation and uncomplicated procedures for the use and development of biotechnological products, with investment capital, infrastructure and training, Ecuador could achieve food security through biotechnology.

The use and development of new technologies must go hand in hand with public education campaigns to prevent a negative perception of the use of biotechnologies in human and animal feeding, which could affect the extent of their use. There are examples in the Americas, such as the US, Canada, Brazil or Argentina, where new biotechnologies have been adopted that increased yields of agricultural products to the point that they produce more than these countries consume (Clapp, 2017). With the appropriate use of new biotechnologies, Ecuador could also achieve that level of productivity.

d. Development of marine/aquatic resources

Fishing and aquaculture are an important economic activity in Ecuador. Fish and seafood exports account for 12% of the country's total exports, second only to oil and equal to banana. The main fishing product is tuna, Ecuador's tuna industry being the largest in the South Pacific (FAO, 2011). There is an important artisanal fishing activity which, according to the latest available data from 2013, created a local market of approximately $200 million USD per year (Martinez-Ortiz et al., 2015).

Ecuador has enormous potential for aquaculture development, a sector that has experienced significant growth in the past 30 years in developing countries (FAO, 2011b). The Ecuadorian government is seeking to diversify aquaculture for marine and freshwater products, which have mostly been based on shrimp and tilapia cultivation, to contribute to achieving food sovereignty (MAGAP, 2017b). Moreover, the government, through public entities related to aquaculture, is attempting to make this sector sustainable. This not only requires the adoption of relevant technologies, but also appropriate dissemination and training in the use of technology for the population engaged in this activity (MAGAP, 2017b).

Among the technologies applied to the development of aquaculture, the most important ones are related to the reproduction and genetic improvement of livestock, an activity that has yet to be fully exploited in agriculture. Other techologies include disease diagnosis techniques, vaccine development, the use of bioremediation techniques to reduce the environmental impact of commercial activity and methods based on molecular techniques for the early detection of toxic algae (FAO, 2011b).

With regard to the challenges for industrial and artisanal fisheries, adequate management plans should be developed to avoid overexploitation of resources. However, further studies are needed on the composition of the species being exploited and their population dynamics are needed in order to make better recommendations. There is a need for educating large and small fishing communities about the importance of the integrated and sustainable management of fishery resources, and for support to boost fishing activity so that it is competitive and productive as well as a contributor to the social and economic development of the population engaged in this activity.

V. Increased efficiency of food systems

a. Outlook for increased technology-based agricultural production

Modern technologies, including biotechnology, such as propagation and artificial insemination, could be used to boost agricultural and livestock production. In order to develop suitable varieties for the market or a food product, proteomics and meta-genomics would be useful for increasing production. The use of meteorological information and Geographic Information Systems (GIS) for the production and monitoring of production would help expand production.

b. Infrastructure needs

Although Ecuador has research laboratories at its universities and research centers, they are insufficient and lack the resources to be able to undertake studies, particularly consumables that are required even when the necessary equipment is available. Basic scientific studies require internal funding. However, external funds are required for nearly all research projects, and tend to be limited extent to large research teams.

There is a need for an ongoing upgrade of equipment and technologies at research centers and universities, but this implies resources that must be provided through research projects.

c. Aspects related to food use and waste minimization

The country's poor performance in food production and manufacturing means that joint cooperation between industry and research centers must be encouraged and financed.

Post-harvest losses can be reduced through the application of cooling treatments and the use of coatings and storage in modified or controlled atmospheres or containers, as required.

Manufacturing processes, unit operations and the application of technological alternatives must be optimized to reduce waste and increase their value. Joint work between industry, academia and research centers in general is therefore important.

d. Conflicts, if any, between food production and energy and fiber production

Many industries have failed to optimize energy use and, in order to reduce consumption, most require the implementation of new facilities or the modification of existing ones, which requires investment. The relatively low cost of energy in Ecuador obviates the need to optimize its use, which is compounded by the lack of ecological awareness. Production units are relatively small and require technical-economic analysis prior to the implementation of energy generation systems from the by-products of agroindustrial industries.

At the same time, biofuel has begun to be produced from non-traditional plant species, but requires the use of land intended for food production. There are currently initiatives with mediocre results, although in the future, conflicts may arise as a result of this activity.

The cultivation of plants for fiber production is relatively low, with abaca and cabuya being the species cultivated specifically for this purpose.

VI. Health Considerations

a. Foodborne diseases

Through the National Directorate of Food Safety, Ecuador carries out actions to prevent foodborne diseases, its mission being: "To guarantee the quality of food in its primary phase of production, through the implementation of good production practices and the control of contaminants in agricultural products to ensure the country's food sovereignty" (AGROCALIDAD, 2017).

The Management Program for the Certification of Primary Production and Good Practices has published Good Agricultural Practices (BPA) Guides and Manuals, as well as Manuals for Good Livestock Practices (BPP). There is also a national program for the Monitoring and Control of Pollutants in Primary Production (ResolutionDAJ-20133EC-0201-0096), which defines the control and monitoring of pollutants, maximum permitted levels and areas of use for products consumed at the national level, produced in the country, imported or for export.

The Ministry of Health, through the Under Secretary of Public Health Surveillance and National Epidemiological Surveillance Directorate, has reported salmonella infections among waterborne and foodborne diseases. A decline in cases was observed in 2014 and 2015, although unfortunately, at the end of 2016, an upsurge was reported in the last four months, registering 120 new cases (Ministry of Public Health [MSP], 2016: 12). It is important to note that the Ministry of Health monitors cases at the national and province level. In the case of food poisoning, monitoring is conducted at the national level by age, gender and zone. At the national level, the most vulnerable group reported in 2016 is the male and female population aged 20-40 years (MSP, 2016: 13).

The number of cases of Shigellosis did not vary significantly from 2014 to 2016, with 25 cases being reported in 2015 (MSP, 2016: 14).

b. Overconsumption

Article 1 of the Ecuadorian Constitution stipulates that, "Persons and communities have the right to safe, permanent access to healthy, sufficient and nutritious food; permanently produced locally and in accordance with their cultural identities and traditions. The Ecuadorian state will promote food sovereignty". Regulations for processed food labeling have increased in recent years, for both imported and domestically produced food.

Ecuador is largely an agricultural country and food is available year-round due to its microclimates in the three natural regions. Nevertheless, prices may vary depending on the production of a particular item.

In the past two years, imports of fruits from both Colombia and Peru has been observed in months where national production has been low or non-existent. The price of these goods is obviously much higher than that of domestically produced fruit.

The National Health and Nutrition Survey (ENSANUT, 2012), undertaken by the Ministry of Public Health, conducts a study of maternal and child health, sexual and reproductive health, nutritional status, risk factors for the most prevalent chronic diseases and physical activity and sedentary lifestyles.

The prevalence of inadequate protein intake at the national level for 2016 is 6.4%. However, among individual groups the indigenous population had the highest rate at 10.4%, and the Rural Andean Region categoryhad a rate of 10.9%.

Rice is an important feature of the diet and the main source of energy (33%), carbohydrates (48%), and even protein (19%). There is excess consumption of carbohydrates and fat nationwide, particularly among the indigenous population and on the rural coast. Consumption of fruits and vegetables at the national level is 183 g/day, which is a very low value, and consequently there are programs to increase fruit and vegetable consumption. The most widely consumed processed food is sodas, whose national prevalence value for 2016 was 81.5% (INEC, 2014b: 299 and 312).

c. Expected changes in consumption patterns (and implications for food imports)

The prevalence of consumption of processed foods (soft drinks and other beverages, fast food and snacks) in the population ages 10-19 years reaches 81% for soft drinks, while the consumption of snacks stands is 64% (INEC, 2013: 31). Obesity and overweight levels have increased among the population. As a result, the prevalence of diabetes in the population aged 10-59 years at the national level (blood glucose >126 mg/dL) is the same for the population aged 50-59 years at 10.3%.

In relation to the prevalence of hypercholesterolemia (>200 mg/dL), hypertriglyceridemia (>150 mg/dL), and LDL (5) 59, according to the 2013 survey, this increases with the respondents' age, reaching values of 51.1, 43.1, 40.5, and 39.4, respectively. In order to improve this nutritional situation, the sale of junk-food products in the vicinity of schools and schools has been regulated to reduce the consumption of these products.

Ecuador is the first Latin-American country to adopt the traffic light system in its food products to alert consumers to the amount of fats, sugars and salts they contain. The guide for food labeling is available in the Food Labeling Regulations for Human Consumption, prepared by the National Agency for Health Regulation and Control (ARCSA). The traffic light system is based on the use of colors to indicate the level of products: Red is the maximal alert for excess of salt, sugar or fats in a food, yellow is a warning, and green has zero risk. Thus, the entire Ecuadorian population receives clear, simple information about what it eats.

This new system is an innovative method that will help prevent cases of obesity and diabetes from continuing to increase. It is also a way to inform the population of the products they are consuming and ingesting, so that they can make a conscious decision about their health (MSP, 2013: 2).

d. Understand and encourage behavior change, emergency personalized nutrition

According to the 1986 Ottawa Declaration (WHO, 1986), health promotion is the process that enables people to increase control over their health in order to improve it. It not only covers actions aimed directly at increasing people's skills and abilities, but also those designed to change the social, environmental and economic conditions that impact health determinants. The process of training (empowerment) people and communities can be used to determine whether or not an intervention promotes health (World Health Organization [WHO], 1986; Davies and MacDonald, 1989).

Nutritional education at the national level is limited. There is information from commercial firms about recommendations for changes in eating habits to improve health or prevent disease. Functional foods are marketed in Ecuador and regulations are issued by the INEN so that producers can declare that their products are functional foods (Instituto Ecuatoriano de Normalización [INEN], 2011: 1). Compliance with the labeling of functional foods is limited due, among other factors, to lack of information on the target population, dose, active ingredient and the particular disease it may prevent.

However, there has been a gradual increase in the culture of health and keeping fit through exercise and encouragement to eat healthy foods, depending on consumer conditions, such as age, physical activity, physiological condition, and so on.

e. Malnutrition, vitamin A and iron deficiency

According to the nutritional surveys conducted in Ecuador in DANS 1986 (MSP, 1986) and the 2012 ENSANUT-EC (INEC, 2014b) in relation to values of Hb <11 g/dL, there were no significant changes in the population under 5, despite having programs to fortify wheat flour with iron. In Ecuador, the great problem of iodine deficiency has been overcome by fortifying table salt with iodine. The prevalence of anemia due to iron, zinc and vitamin A deficiency of 25.7, 28.8 and 17.1, respectively, is higher among children ages 6-11. The Ministry of Public Health, through the Integrated Program of Micronutrients (IMP), has presented the following strategy to combat micronutrient deficiencies: supplements (iron and folic acid tablets for pregnant women; iron syrups for children under one and vitamin A capsules for children aged 6-36 months) and fortification and diversification of the diet, all supported by the Ministry's Information Education and Communication programs (IEC). The main weakness of the IMP has been the lack of resources for the continuous implementation of the program (INEC, 2014b).

VII. Political considerations

Ecuador has several public policy strategies to guarantee food security and nutrition. These regulations are structured at different levels (from the Constitution to guidelines and regulations) to cover multiple sectors linked to the country's food production, marketing and consumption. These political considerations have permitted the proposal of various processes and projects for the promotion of food security and nutrition activities. According to the FAO, 10.9% of the population in Ecuador is undernourished. Accordingly, the country has made a major effort to meet the hunger goal of the Millennium Development Objectives (CELAC), 2017.

a. Distortions created by subsidies and other agricultural-policy models

In Ecuador the agricultural production is a purely private activity, which is why public policy guidelines require the participation of producers. Accordingly, developing the mechanisms and incentives for producers to see their interests reflected and to be encouraged to assume production guidelines is a priority (MAGAP, 2016: 364).

The state has failed to provide the incentives to meet the needs of small producers. Public efforts in this field have been partial and concentrated solely in union organizations (Chiriboga, North, Flores and Vaca, 1999: 19).

Some of the challenges that have not been achieved through the use of subsidy or incentive policies include the following: the creation of conditions for farmers and their offspring to remain in the countryside, for those who left to return and for those living in cities to be encouraged to move to the countryside; the adequate inclusion of women farmers in the various agricultural programs that exclude them today (agricultural incentives, employment, etc.) (MAGAP, 2016: 112, 191 and 365), and for subsidies to provide advantages not only for large agricultural producers, but also for medium and small farmers.

b. Promotion of nutrition-sensitive agriculture to provide healthy, sustainable diets through issues associated with resource use and food prices

Ecuador's Political Constitution establishes food as an independent right for all members of society. Article 13 stipulates that persons and communities have the right to safe, permanent access to healthy, sufficient and nutritious food; permanently produced locally and in accordance with their cultural identities and traditions. This has allowed various strategies to be promoted in order to obtain better productive results, in a more environmentally friendly way, but also to encourage the consumption of healthier foods and to combat malnutrition throughout the country (Ayaviri, Quispe, Romero and Fierro, 2016: 217 and 219).

The main strategies include: (A) promotion of more profitable, responsible production; (B) promotion of healthier, more nutritious diets - the latter with the Ecuadorian Food Program created and implemented to improve food practices and access to food in the Ecuadorian population through specific projects, and (C) the Nutrition Action Program, led by the Coordinating Ministry of Social Development, which seeks to enhance the health and nutrition of children under five through the design and implementation of public policy mechanisms and inter-institutional coordination at the national and local level.

c. Policies that encourage technological innovation

As part of the national strategy for the change of the productive matrix, the Ecuadorian State is based on a set of public policies and strategies that promote technological innovation in food production. These include:

- 2008 Ecuadorian Constitution,
- Organic Law of Rural Lands and Ancestral Territories,
- Organic Law of the Regime of Food Sovereignty,
- Organic Law of Higher Education,
- Organic Code of Production, Trade and Investment,
- Ecuadorian Agricultural Policy: Toward sustainable rural territorial development 2015-2025.

d. Policies that create human resources (education, gender, equity)

Over the past decade Ecuador has seen the improvement of human capacities, especially related to the training of human talent to strengthen the education system through third- and fourth-level education. One of the fields that have received the greatest emphasis is the renewable natural resources sector, which is covered by related national policies where people's rights and priority groups are promoted in keeping with the regime of good living.

e. Policies that seek to redesign agricultural ecology (land use, bioeconomics, etc.)

Since traditional agricultural production is directly related to environmental deterioration and alterations in these activities that have been observed in the last decades, it is essential to propose alternative policy mechanisms to solve these problems. In Ecuador, some of the proposed strategies only address the need to increase productivity, and appear to contradict some of the principles put forward as rights of nature (recognized in the Constitution). However, there are other strategies that promote the redesign of agricultural ecology in the country. These alternative policies, which seek cleaner, more sustainable production, are based on the legal bases mentioned in section C, designed to improve the contribution of agriculture to guaranteeing the Ecuadorian population's food security and sovereignty.

f. Policies to promote the consumption of healthy foods

Although the benefits of healthy food consumption have been known for several decades, one of the challenges faced by producers of this type of food is scarcity of demand. Therefore, an essential feature in achieving a healthier food culture is the promotion of the consumption of healthy products. The starting point for the implementation of strategies to encourage a healthier diet is the creation and implementation of public policies in this area.

g. The country's comparative advantages in agriculture

Ecuador is a country that relies heavily on agricultural production. In recent decades, the country's income from these activities has been its second source of income, surpassed only by oil exports.

The data presented below are a summary of the results of the analyses conducted by MAGAP in its book *The Ecuadorian agricultural policy: Towards sustainable rural development* (*La política agropecuaria ecuatoriana: Hacia el desarrollo rural sostenible 2015–2025)* (MAGAP, 2016: 71-72 and 78).

During the 1960s and 1970s, sectoral government policies, applied within a global development policy to modify the current productive model, failed to achieve their objectives. Instead, they became agrarian reforms that affected the structure of land ownership, efforts to achieve technological innovation and agricultural health and subsidized direct financing.

Between 1980 and 1992, implicit agricultural policies dominated, within the framework of macroeconomic stabilization schemes, with a direct impact on the agricultural sector. In 1992, the agricultural sector modernization strategy was implemented, introducing significant reforms that reduced state intervention in the agricultural sector. In the wake of the passage of the Agricultural Development Law in 1994, emphasis was placed on the self-regulation of markets, land and productive factor markets, and producer and consumer prices were liberalized. In addition, the subdivision of communal lands was authorized, among other key changes. All this led to a systematic increase in the contribution of the agricultural sector to GDP, yet reduced farmers' income.

The outstanding features of this policy that failed to benefit the most vulnerable producers (medium and small) were maintained until 2006. Since then, MAGAP has strived to draw up medium- and long-term agricultural policies. From 2007 onward, attempts were made to restore the state's stewardship, and its role as market regulator and a key player in politics. The last decade has seen significant progress in these policies, whose efforts have been accompanied by successes and failures. Although some progress has been made, much remains to be done to achieve more profitable, inclusive and environmentally responsible production.

h. International trade matters

The Ecuadorian agricultural sector is characterized by its marked dualism. On the one hand, there is a very dynamic export sector, which produces traditional export crops and new agroindustrial crops. On the other, there are the majority of agricultural producers, basically small and medium peasant farmers, whose production focuses mainly on the domestic market (and partly the external market). These two sectors are linked to the foreign market in very different ways.

Exports

The agricultural sector has made an enormous contribution to the country's economy, responsible for 41% of the foreign currency entering the country annually from exports surpassed only by oil exports.

Between 2000 and 2013, agriculture accounted for an average of 79% of total exports. The relative importance of agricultural exports in relation to total exports (excluding oil) was 81% between 2000 and 2013, with some positive and negative changes during this period.

Of the $11.4 billion USD in agricultural exports, primary products account for 54% and agroindustrial exports for 27%. This performance has remained constant throughout this century with some variations in 2002 and 2008. In 2013, agricultural trade with a positive balance accounted for 8% of total GDP ($7.326 billion USD), 64% of expanded agricultural GDP and 30% of the total exported that year (MAGAP, 2016: 124-127).

Imports

The high demand for imports of raw materials and capital goods that characterizes most sectors in Ecuador is not reflected in the agricultural sector. The imported component of national agricultural production accounts for 8% of agricultural GDP, reflecting this sector's self-sufficiency. Agricultural activity saves foreign exchange and pressure on the country's economy and generates foreign exchange with a favorable balance in trade with the rest of the world.

An analysis of the structure and evolution of agricultural imports by use and economic destination since 2000 shows that only 7.2% of total imports have corresponded to the agricultural sector. Major imports of raw materials and intermediate products for agriculture include cereals, soybean paste, fertilizers, fungicides, herbicides and insecticides (MAGAP, 2016: 127-130).

In conclusion, Ecuador's agricultural trade balance, despite the crisis at the beginning of the century and that of 2009, has maintained positive, increasing balances since the beginning of the 21st century.

i. Market challenges

Ecuador is a small country with an economy open to the world, whose evolution has been linked to the external sector. Its economic integration into the hegemonic centers in the contemporary era began in the 19th century as the result of a primary export model. These economic links with the rest of the world have constituted a source of wealth and growth for the country, although they have also been a source of vulnerability and instability, since they are subject to variations in the prices of export products on the international market (MAGAP, 2016: 35).

Leveraging this agricultural potential, combined with the generation of added value and its competitive advantages vis-à-vis markets (national and international), would constitute a solid basis for reducing poverty and promoting sustainable rural development. Although the effective volume of production has increased in the country, and international demand for agricultural goods has risen and will continue to grow (ECLAC, FAO, Inter-American Institute for Cooperation on Agriculture [IICA] 2012: 3), but there are market challenges the country will have to address given the external economic dynamics of the current hegemonic centers.

VIII. Abstract

a. Some potential national agricultural scenarios for agricultural production in the next fifty years

- Optimize food access for the entire population with respect to quantity and quality.
- Through the opening of international markets - especially with the signing of agreements with the European Union and China – Ecuador has the opportunity to expand its markets. At the same time, its biggest challenge will be to increase production with competitive product costs.
- The use of rapid, modern processes for genetic propagation will help lower costs and develop varieties that are resistant or tolerant to fungi, diseases, etc.
- Implement post-harvest treatments to increase the shelf life of fresh produce.
- Preservation techniques for food of plant, fish, and animal origin must be improved and added value must be given to materials.
- Use of food-safe containers.
- The use of co-products of the agricultural industry for their use in the extraction of active ingredients for human, animal and industrial consumption.
- Maintain water quality and manage the optimization of its use.
- Optimize the use of alternative or traditional energy sources.

b. High-priority actions to achieve agricultural sustainability

- Create a germplasm bank of Ecuadorian materials.
- Incorporate biotechnology as a transversal science and expand its applications.
- Study biodiversity to characterize it and guide its application in food, pharmaceuticals and industrial products.
- Transform raw materials into innovative products.
- Develop systems to generate relatively low cost energy.
- Conduct water management, availability and quality studies.
- Make high-technology equipment available to study product characterization and safety.
- Train technical specialists.

References

Adenle, A. (2011). Global capture of crop biotechnology in developing world over a decade. Journal of Genetic Engineering and Biotechnology, 9, 83-95. http://dx.doi.org/10.1016/j.jgeb.2011.08.003

Administración Nacional de la Aeronáutica y del Espacio (2017). Climate change: How do we know? Retrieved January 25, 2017, from http://climate.nasa.gov/evidence/

Agencia Central de Inteligencia (2017). The World Factbook: Ecuador. Retrieved January 21, 2017, from https://www.cia.gov/library/publications/the-world-factbook/geos/ec.html

Agencia Ecuatoriana de Aseguramiento de Calidad del Agro (2013). Retrieved February 10, 2017, from https://goo.gl/xqz9Qf

Agencia Ecuatoriana de Aseguramiento de Calidad del Agro (2017). Inocuidad-Dirección de inocuidad de alimentos. Retrieved February 8, 2017, from https://goo.gl/AkTsSi

Agritech Toolbox (2017). The world is facing a huge food security challenge. Retrieved February 10, 2017, from http://agritech.harvestchoice.org/

Ayaviri, V., Quispe, G., Romero, M. and Fierro, P. (2016). Avances y progresos de las políticas y estrategias de seguridad alimentaria en Ecuador. Revista de Investigaciones Altoandinas, 18(2), 213-222. Retrieved from https://goo.gl/jKgffq

Bebbington, A. (1996). Organizations and Intensifications: Campesino Federations, Rural Livelihoods and Agricultural Technology in the Andes and Amazonia. Journal of World Development, 24, 1161-1177. http://dx.doi.org/10.1016/0305-750X(96)00028-9 · Source: RePEc

Chiriboga, M., North, L., Flores, R., and Vaca, J. (1999). Cambiar se puede: experiencias del FEPP en el desarrollo rural del Ecuador. Retrieved from https://goo.gl/gD1ayT

Clapp, J. (2017). Food self-sufficiency: making sense of it, and when it makes sense. Journal of Food Policy, 66, 88-96. http://dx.oi.org/10.1016/j.foodpol.2016.12.001

Comisión Económica para América Latina y el Caribe, Organización de las Naciones Unidas para la Alimentación y la Agricultura, Instituto Interamericano de Cooperación para la Agricultura. (2012). Respuestas de los países de América Latina y el Caribe al alza y volatilidad de precios de los alimentos y opciones de colaboración. Retrieved from http://www.cepal.org/publicaciones/xml/6/46236/boletin_2012.pdf

Comunidad de Estados Latinoamericanos y Caribeños (2017). Plataforma de Seguridad Alimentaria y Nutrición. Ecuador. Retrieved February 2, 2017, from https://goo.gl/ewSHKF

Constitución de la República del Ecuador, Registro oficial No. 449 de 2008.

Código Orgánico de la Producción, Comercio e Inversiones. Registro oficial No. 351 de 2010.

Consejo de Evaluación, Acreditación y Aseguramiento de la calidad de la Educación Superior. (2016). Proceso de evaluación institucional. Retrieved February 10, 2017, from https://goo.gl/oynocH

Convención sobre la Diversidad Biológica. (2013). The Yasuní-ITT Initiative in Ecuador. Retrieved from https://www.cbd.int/financial/doc/id177-Ecuador-Yasuni-ITT-Initiative-en.pdf

Davies, J. K., and MacDonald, G. (1998). Quality, evidence, and effectiveness in health promotion: striving for certainties. London, Ed. Routledge.

Departamento de Agricultura de los Estados Unidos (2015). Biotechnology Annual 2015: Genetically Engineered Crops and Transgenic Labeling. Retrieved from https://goo.gl/791QxT

Departamento de Agricultura de los Estados Unidos. (2016a). Ecuador Wheat Imports, Corn and Rice Production Expected to Decrease in 2016. Retrieved from https://goo.gl/3A9sL7

Departamento de Agricultura de los Estados Unidos. (2016b). Ecuador's INIAP Set to Start Field Trials of Genetically Engineered Corn. Retrieved from https://goo.gl/CeV4c6

Early, R., Bradley, B. A., Dukes, J. S., Lawler, J. J., Olden, J. D., Blumenthal, D. M., Tatem, A. J. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. Nature Communications, 7, 1-9. https://doi.org/10.1038/ncomms12485

Ecuador.com (1995-2017). Gain Insight into Ecuador's Demographics. Retrieved February 10, 2017, from https://goo.gl/4LpFm6

Fader, M., Gerten, D., Krause, M., Lucht, W., and Cramer, W. (2013). Spatial decoupling of agricultural production and consumption: quantifying dependences of countries on food imports due to domestic land and water constraints. Environmental Research Letters, 8, 1-15. https://goo.gl/YKw6Zk

FAO (2016). AQUASTAT website. Food and Agriculture Organization of the United Nations. (FAO). Website accessed on [2016/03/09].

Forest Legality Initiative (2014). Ecuador. Retrieved January 27, 2017, from https://goo.gl/o36T3i

Freire, W. B., Silva-Jaramillo, K. M., Ramírez-Luzuriaga, M. J., Belmont, P., and Waters, W. F. (2014). The double burden of undernutrition and excess body weight in Ecuador. American Journal of Clinical Nutrition, 100, 163S-164S.

Global Food Security Index (2015). The role of innovation in meeting food security challenges. Retrieved February 10, 2017, from http://foodsecurityindex.eiu.com/Resources

Hellmich, R. and Hellmich, K. (2012). Use and impact of Bt maize. Journal of Nature

Education Knowledge, 3(10). Retrieved from https://goo.gl/Enus4L

Hines, D., Alvarado, V., and Chiriboga, M. (April 2013). Enhancing climate resilience in Ecuador's Pichincha Province and the Jubones River Basin. Hunger, Nutrition, Climate Justice. Symposium given at: A New Dialogue: Putting People at the Heart of Global Development, Dublin, Ireland.

Index mundi. (2016). Ecuador population. Retrieved February 10, 2017, from https://goo.gl/P5ekBa

Indicadores de Ciencia y Tecnología Agropecuaria. (2013). Ecuador. Retrieved February 10, 2017, from http://www.asti.cgiar.org/

Instituto Ecuatoriano de Normalización. NTE INEN 2587. (2011). Alimentos funcionales. Requisitos. Retrieved from http://normaspdf.inen.gob.ec/pdf/nte/2587.pdf

Instituto Nacional de Estadística y Censos. (2013). Encuesta Nacional de Salud y Nutrición (ENSANUT-ECUADOR 2011-2013). Retrieved from https://goo.gl/pt1d85

Instituto Nacional de Estadística y Censos. (2014a). Panorama Laboral y Empresarial del Ecuador. Retrieved from https://goo.gl/vcU52U

Instituto Nacional de Estadística y Censos. (2014b). Encuesta Nacional de Salud y Nutrición (ENSANUT-ECU 2012). Retrieved from https://goo.gl/vDzwKe

Klümper, W., and Qaim, M. (2014). A Meta-analysis of the impacts of genetically modified crops. PLOS ONE, 9. https://goo.gl/vXQJdk

Ley Orgánica de Educación Superior. Registro oficial No. 298 de 2010.

Ley Orgánica de Incentivos a la Producción y Prevención Fraude Fiscal. Registro oficial No. 405 de 2014.

Ley Orgánica del Régimen de la Soberanía Alimentaria. Registro oficial suplemento No. 583 de 2009.

Ley Orgánica de Tierras Rurales y Territorios Ancestrales. Registro oficial No. 711 de 2016.

Madan, M. (2005). Animal biotechnology: applications and economic implications in developing countries. Journal de Revue Scientifique et Technique (International Office of Epizootics), 24(1), 127-139. Retrieved from http://www.oie.int/doc/ged/D1819.PDF

Martínez-Ortiz, J., Aires-da-Silva, A. M., Lennert-Cody, C. E., and Maunder, M. N. (2015). The Ecuadorian atisanal fishery for large pelagics: species composition and spatio-temporal dynamics. PLOS ONE 10(8): e0135136. Doi: 10.1371/journal.pone.0135136

Ministerio de Agricultura, Ganadería, Acuacultura y Pesca (2016). La política agropecuaria ecuatoriana: hacia el desarrollo territorial rural sostenible 2015-2025. I Parte. Retrieved from https://goo.gl/cEWXBj

Ministerio de Agricultura, Ganadería, Acuacultura y Pesca. (2017a). Ministerio de Agricultura, Ganadería, Acuacultura y Pesca. Retrieved January 27, 2017, from https://goo.gl/izJpkn

Ministerio de Agricultura, Ganadería, Acuacultura y Pesca. (2017b). Acuicultura. Retrieved January 11, 2017, from https://goo.gl/bqct3k

Ministerio de Salud Pública. (1986). Diagnóstico de la situación Alimentaria Nutricional y de Salud de la población ecuatoriana (DANS). Manual de la encuestadora. Retrieved from https://goo.gl/vqD2Qs

Ministerio de Salud Pública (2013). Reglamento sanitario de etiquetado de alimentos procesados para el consumo humano (Acuerdo no. 00004522). Retrieved from https://goo.gl/8apX2p

Ministerio de Salud Pública (2016). Gaceta Epidemiológica Semanal No. 52. Retrieved from https://goo.gl/j6bm5t

Ministerio del Ambiente del Ecuador. (2013). Sistema de Clasificación de los Ecosistemas del Ecuador Continental. Subsecretaría de Patrimonio Natural. Quito. Retrieved from https://goo.gl/xSjezL

Ministerio del Ambiente del Ecuador. (2015). Quinto informe nacional para el convenio sobre la diversidad biológica. Retrieved from https://goo.gl/AoQuRs

Myers, N., Mittermeier, R., Mittermeier, C., da Fonseca, G., and Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature, 403, 853-858. http://dx.doi.org/10.1038/35002501

Nachmany, M., Fankhauser, S., Dadidová, J., Kingsmill, N., Landesman, T., Roppongi, H., Townshend, T. (2015). The 2015 Global Climate Legislation Study. A Review of

Climate Change Legislation in 99 Countries. Retrieved from https://goo.gl/iiuuiw

Organización Mundial de la Salud (1986). The Ottawa Charter for Health Promotion. Retrieved February 3, 2017, from https://goo.gl/2b8VL5

Organización de las Naciones Unidas para la Alimentación y la Agricultura. (2011b). Biotechnologies for Agricultural Development. Retrieved from http://www.fao.org/docrep/014/i2300e/i2300e.pdf

Organización de las Naciones Unidas para la Alimentación y la Agricultura. (2017a). Ecuador. Retrieved February 10, 2017, from http://www.fao.org/faostat/es/#country/58

Organización de las Naciones Unidas para la Alimentación y la Agricultura. (2017b). Productos ecuatorianos de mayor producción (1994-2014). Retrieved January 27, 2017. Retrieved from http://www.fao.org/faostat/en/#data/QC/visualize

Organización de las Naciones Unidas para la Alimentación y la Agricultura. (2017c). Live Animals. Retrieved February 10, 2017, from http://www.fao.org/faostat/en/#data/QA

Organización de las Naciones Unidas para la Alimentación y la Agricultura. (2017d). Biodiversity for food security and nutrition. Retrieved January 27, 2017, from http://www.fao.org/nr/cgrfa/en/

Pérez-Massot, E., R., Gómez-Galera, S., Zorrilla-López, U., Sanahuja, G., Arjó, G., Zhu, C. (2013). The contribution of transgenic plants to better health through improved nutrition: opportunities and constraints. Genes & Nutrition, 8, 29-41. http://dx.doi.org/10.1007/s12263-012-0315-5

Rosegrant, M., Koo, J., Cenacchi, N., Ringler, C., Robertson, R., Fisher, M., Sabbagh, P. (2014). Food Security in a World of Natural Resource Scarcity: The role of agricultural technologies. http://dx.doi.org/10.2499/9780896298477

Santos, E., Sánchez, E., Hidalgo, L., Chávez, T., Villao, L., Pacheco, R., Navarrete, K. (2016). Advances in banana transformation through Agrobacterium tumefaciens in Ecuador: progress, challenges and perspectives. Acta Horticulturae, 1114, 197-202. http://dx.doi.org/10.17660/ActaHortic.2016.1114.27

Scopus (2017). Retrieved February 9, 2017, from www.scopus.com

Tapia, C., Zambrano, E., & Monteros, A. (2008). Estado de los Recursos Fitogenéticos para la Agricultura y la Alimentación en Ecuador. Quito, Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP).

The Observatory of Economic Complexity (2014). Ecuador. Retrieved February 10, 2017, from https://goo.gl/RT1B46

Topuniversities.com (2017). Top Universities Country Guides Study in Ecuador. Retrieved February 10, 2017, from https://goo.gl/FW9M1E

U.S. Energy Information Administration (2011). Country Analysis Briefs Ecuador. Retrieved from https://goo.gl/UEa1Q1

World Food Programme (2017). Ecuador: current issues and what the World Food Programme is doing. Retrieved February 10, 2017, from https://www.wfp.org/countries/ecuador

Zhang, C., Wohlhueter, R., and Zhang, H. (2016). Transgenic Food, Benefits, Safety, and More. Food Science and Human Wellness. http://dx.doi.org/10.1016/j.fshw.2016.04.002

Acknowledgments

The authors would like to thank the following for their support: **Israel Vaca Jiménez**, Director of Food Safety, General Coordination of Food Safety, AGROCALIDAD. **Víctor Anguieta**, Director of Agricultural Policies and Strategies, Undersecretariat of Agriculture, Vice-Ministry of Agriculture and Livestock, MAGAP. M.Sc. **Beatriz Brito**, Department of Nutrition and Quality of INIAP, MAGAP. **Hugo Huaca**, INIAP Technician. **Daniel Guzmán**, Technical Analyst, Sub-Secretariat of Agriculture, MAGAP.

Food and Nutrition Security in Guatemala

Food security for a nation of major natural-disaster vulnerability and fragile Mega-diversity © istockphoto

Guatemala

[1] Noel W. Solomons
[2] Edwin Josué Castellanos
[3] Florencio Rolando Cifuentes Velásquez
[4] Silvana Maselli Conde
[5] Mónica Ninnette Orozco Figueroa
[6] Pamela Marie Pennington
[7] Jack Clayton Schuster
[8] Gamaliel Giovanni Zambrano Ruano

Future food and nutrition security for **Guatemala hangs in a balance between modernization of agricultural practices,** adequate management of rich water and land resources and policy strengthening, **and demographic expansion, poverty, defiling the environment and natural disaster vulnerability.**

Summary

The Republic of Guatemala is the northernmost country of the Central American Isthmus. It is topographically and geographically diverse, with both an Atlantic and Pacific coastline, coastal plains and central mountainous highlands, with lakes, rivers and forests. Features of its geography and geology make the country inordinately disaster-prone, including major earthquakes, disruptive volcanic eruptions, periodic droughts alternating with hyper-precipitation with flooding and landslides. Guatemala is one of 17 nations declared to be "mega-diverse", by virtue of its rich genetic diversity in native flora and fauna species.

Since the middle of the last century, Guatemala has experienced a quintupling of its population, now estimated at 16 million. It is a blend of European (Iberian) culture, introduced by the Spanish colonizers and Maya culture from its indigenous inhabitants. The partition of non-indigenous and indigenous residents is roughly equal, with the latter predominating in the rural areas and the former in its urban settings.

Some 34% of the 108,900 km² surface-area is covered by forest, including the second largest rainforest in the Americas, but this has almost been halved over the last four decades. Thirty-eight percent of the land is devoted to agricultural pursuits (livestock, export cropping, staple crops and horticulture). Guatemala's economy is exportation-dependent, with the main commodities being traditional crops such as coffee, sugar, banana, cocoa and cardamom.

The popular Guatemalan diet is still based around the traditional elements of maize, legumes, vegetables and coffee, with minimal animal-food sources. The North American Free Trade Agreement (NAFTA) has, however, increased the availability of inexpensive, imported processed foods. More than half the Guatemalan population suffers from food and nutrition insecurity as measured by the 8-point Latin American and Caribbean Household Food Security Scale (ELCSA). These are in the context of the highest prevalence of stunted growth (short stature) in the Western Hemisphere.

Guatemala is renowned for its productivity in research and universities and specialized research units, but the training of professionals, investment in resources and mutual coordination are all in need of strengthening to modernize and meet the problems of climate change, rampant deforestation and food insecurity.

I. National Characteristics

a. Country physical size, arable land inventory, landscape and environmental heterogeneity

The Republic of Guatemala, with an area of 108,900 km², lies within the Central American Isthmus just South of Mexico. It can be divided into 3 main topographic regions: the rainforest lowlands (in the North, bordering on Mexico and Belize): the highlands (in the South-Central portion), and the Pacific lowlands (in the South). The Sierra Madre mountain range, an extension of the Rocky Mountains, contributes to highly diverse terrain with many microclimates and life zones. Indeed, the country boasts a total of 14 life zones in spite of its relatively small area (de la Cruz, 1982). The mountains are bordered in the South by a chain of 30 volcanoes, including the 4,220-m Tajumulco, the highest peak in Central Americas. The fertile volcanic soil is a boon to Guatemalan agriculture, especially from the downslopes and to the Pacific lowlands, supporting cultivation of sugar cane, rubber and palm oil among other export crops.

The South-Central highlands contain most of the population of the country, including the capital of Guatemala City, which holds about 30% of the country's population in its metropolitan area. The northern lowlands lie on limestone with unfertile soils, which were mainly covered with forest until the 1970's when the government implemented an internal migration campaign to occupy those lands. Subsistence agriculture quickly gave way to cattle ranching, which is currently the main land use, although recently there has been an increase in palm oil plantations. The northern part of these lowlands is still covered with dense forest and is under conservation as the largest protected area in the country: the Mayan Biosphere Reserve.

According to the last land-use map for the year 2012 (GIMBOT, 2014), 34% of the country is still covered with forest, down from over 60% 40 years ago; 38% of the land is dedicated to agriculture, including 15% for cattle ranching, and 11% each for permanent and seasonal agriculture. Finally, 23.5% of the land shows a combination of secondary forest and shrub, growing on degraded soils or dry areas, with the remaining 4.5% including inland water, wetlands and urban areas.

b. Demographic characteristics and future trends

The country is divided politically in 22 departments, which in turn are divided into 340 municipalities. Guatemala is by far the most densely populated country in Central America with over 16 million people (INE, 2016). The population growth is rapid at 2.5% in the last decade, resulting from a high fertility rate (3.1 according to the last estimate). These demographic data are estimates derived from the last census in 2003; the government has promised a long-awaited census for 2017.

The census bureau estimates that the country crossed the landmark of 50% urban population about 7 years ago, with 2 million living in the capital, Guatemala City (density: 1,600 persons/km²) and a total of 5 million in the metropolitan area. The development of middle-size cities has recently been identified as an important development strategy for the country. At the other extreme, the northern department of Petén is sparsely populated with a density of only 21 persons/km². This region was practically uninhabited 50 years ago, when the central government started an internal migration campaign to populate this area.

Despite the urbanization trend, fertility rates remain above 5 in the rural population. Twenty-four languages are spoken in Guatemala, with Spanish the official tongue; additionally, there are 21 Mayan groups, as well as *Xinca* and *Garifuna*. Indigenous groups show the lowest socioeconomic indicators in the country.

[1] Noel W. Solomons, Scientific Director. Center for Studies of Sensory Impairment, Aging and Metabolism (CESSIAM).Guatemala Country Representative to IANAS, cessiam@cessiam.org.gt **[2] Edwin Josué Castellanos,** Co-Director. Center on Environment and Biodiversity (CEAB), Universidad del Valle de Guatemala, ecastell@uvg.edu.gt **[3] Florencio Rolando Cifuentes Velásquez,** Director. Center for Agricultural and Food Studies (CEAA), Universidad del Valle de Guatemala, rcifuen@uvg.edu.gt **[4] Silvana Maselli Conde,** Head. Plant Genetic Resources Unit, Center of Agricultural and Food Studies (CEAA), Universidad del Valle de Guatemala, smaselligua@gmail.com **[5] Mónica Ninnette Orozco Figueroa,** Director. Center for Atitlán Studies (CEA), Universidad del Valle de Guatemala, mnorozco@uvg.edu.gt **[6] Pamela Marie Pennington,** Director. Center for Biotechnology Studies (CEB), Universidad del Valle de Guatemala, pamelap@uvg.edu.gt **[7] Jack Clayton Schuster,** Co-Director. Center for Environmental Studies and Biodiversity (CEAB), Universidad del Valle de Guatemala, jschuste@uvg.edu.gt **[8] Gamaliel Giovanni Zambrano Ruano,** Director of the Center for Industrial Processes (CPI). Universidad del Valle de Guatemala, zambrano@uvg.edu.gt

Recently, extensive emigration to the US has been the norm, particularly from the impoverished highlands. It is estimated that at least 10% of the Guatemalan population now live in the US, with remittances accounting for 11% of the country's Gross Domestic Product (GDP) (IOM, 2013).

Population projections by the Population Observatory at ECLAC (2015) forecasts a population of 24 million by 2050, with a large urban component. With the relatively modest GDP growth rate of 3% observed in the last years, and the high inequality in income (ECLAC, 2010), it is expected that around 50% will remain in poverty through the coming years, leaving the country with the lowest Human Development Index in the region (UNDP, 2010).

c. Fraction of the population suffering from food and nutrition insecurity and the FNS trajectory

More than half of the Guatemalan population suffers from food and nutrition insecurity as measured by the 8-point Latin American and Caribbean Household Food Security Scale (ELCSA); it is more prevalent in rural areas and among the poor. Acute food security is present in the central and western highlands of Guatemala, as assessed by the satellite-based Famine Early Warning (FEWS NET). After a "stressed" condition in 2016, the prospects of the next highest state of "crisis" in terms of risk of crop failure and famine have been raised for 2017.

d. Agricultural modes

Agriculture contributes approximately 14% of the GDP. It is the major source of employment and contributes about 40% of the total foreign exchange through exports (CAMAGRO-Agrequima, 2015). The major agricultural modes include peasant subsistence, semi-commercial and export agriculture. However, based on access to land, size of land, access to credits, insurance, technology, market and education, agriculture is classified in Guatemala as infra-subsistence, subsistence, surplus and commercial agriculture (MAGA, 2016). About 93% of the producers hold a farm of a maximum of 1.6 hectares (ha) (IARNA_URL and IICA, 2014). According to CAMAGRO-Agrequima (2015), the major crops and sectors linked to agriculture include banana, sugar cane, coffee, oil palm, rubber, cardamom, staple crops, cash crops (snow peas, green beans and broccoli), potato, mango, papaya, livestock (meat and dairy products) and the porcine sector.

e. Is the country self-sufficient in agriculture?

The major crops and agricultural products are presented in **Table 1**. It is clear that the country is self-sufficient in some food products, but there is a shortage in others. The county is not capable of satisfying the demand for most staple crops and animal products. The internal demand is complemented through the importation of commodities. Even though the main diet of most Guatemalans relies on maize (mainly white) and black beans, the production is not enough to supply the demand. Most of the rice, wheat and yellow maize are imported. Some of the factors that influence the volume of maize and black bean production include very low productivity, weak agronomic management, plant varieties, pests and irregular rainy seasons in the last years. The main driving force for the rest of staple crops is the extension of the land surface dedicated to those crops. Most of Guatemalan agriculture is dryland agriculture that depends on rainfall.

f. Major export/import crops and markets

The major exports include our traditional crops like coffee, sugar, banana, cocoa and cardamom. The target market includes the US and some Central-American, European and Middle-Eastern countries (**Table 1**). The coffee and sugar market is more diverse since it also includes some Asian countries. Non-traditional export crops started during the 1980s and their specific contribution to the GDP increases annually. Some of those crops include vegetables (snow peas, broccoli, green beans, mini-vegetables) and fruits (lime, mangoes, pineapple, cantaloupe, plantain, strawberries and blackberries). Except for snow peas, whose main market in Europe, the bulk of this produce goes to the US and Central-American markets.

g. Potential sources of Food and Nutrition Security (FNS) instability

Food Nutrition Security (FNS) Guatemala is at risk. Although several potential sources of instabili-

Table 1. Major Agricultural Products of Guatemala

Crop	Production (MT)	Yield (t/ha)	Imports (I)		Exports (E)		Commercial Balance (I/E)
			MT	Country	MT	Country	
Traditional export crops							
Bananas	3,248,215	46.4	9,418	Honduras (85%) and USA (12%)	1,968,939	USA (90%) and Honduras, El Salvador and Italy (6%)	0.0
Cocoa	12,412	2.9	720	Nicaragua (81%) and Honduras (17%)	37,233	El Salvador (62%) and USA (17%)	0.0
Coffee	251,660	1.0	26	Vietnam (91%)	219,624	USA (43%), Japan (15%), Canada (9%) y Germany, Belgium and Italy (19%)	0.0
Sugar cane	27,546,560	95.0	27	USA (73%) and Venezuela (18%)	1,799,341	Several countries (48%), USA (12%), South Korea (11%), Chile (9%), China (9%) and Ghana (6%)	0.0
Cardamom	36,344	0.5	107		34,226	Saudi Arabia (28%), United Arab Emirates (20%), Syria (6%), Jordan (6%) and other countries	0.0
Fruits							
Avocado	101,437	10.2	2,653	Mexico (99%)	3,346	El Salvador (66%) and Honduras (32%)	0.8
Lime	121,683	16.9	127	Mexico (91%) and USA (7%)	7,220	USA (78%), Netherlands (7%) and Saudi Arabia (5%)	0.0
Mangoe	115,883	12.2	129	Mexico (53%), Vietnam (32%) and USA (11%)	21,031	USA (88%) and Honduras (7%)	0.0
Apples	24,103	3.5	14,827	USA (53%) and Chile (46%)	1,594	El Salvador (83%), Nicaragua (11%) and Honduras (6%)	9.3
Peaches	32,714	11.8	918	USA (56%) and Chile (44%)	1,205	El Salvador (99%)	0.8
Cantaloupes	538	21.8	220	Honduras (75%) and USA (11%)	419	USA (97%)	0.5
Oranges	792,717	26.9	38,719	Honduras (97%)	20	El Salvador (92%)	1,936.0
Pineapple	245,674	27.4	76	USA (38%), Vietnam (21%), Honduras (21%) and Costa Rica (19%)	21,766	USA (64%) and El Salvador (33%)	0.0
Plantain	223,771	18.2	1,118	Mexico (45%), Vietnam (26%) and USA (25%)	146,143	USA (55%) and El Salvador (38%)	0.0
Vegetables							
Snow pea	43,173	5.6	16	USA (64%) and Belgium (35%)	35,449	Reino Unido (73%), Netherlands (11%) and Belgium (10%)	0.0
Broccoli	75,833	13.4	267	China (85%) and Ecuador (6%)	42,670	USA (64%) and El Salvador (27%)	0.0
Onion	130,641	28.6	26,313	Mexico (95%)	28,629	USA (64%) and El Salvador (27%)	0.9
Bell pepper	53,781	23.4	32	Honduras (76%), Peru (16%), El Salvador (6%)	9,755	El Salvador (71%) and USA (24%)	0.0
Potato	516,520	25.1	3,648	Canada (60%) and USA (39%)	64,945	El Salvador (99%)	0.1
Tomato	318,210	35.3	180	Honduras (99%)	66,914	El Salvador (80%) and USA (17%)	0.0
Carrots	76,585	28.8	12	Mexico (54%) and USA (34%)	31,170	El Salvador (70%), Honduras (19%) and USA (8%)	0.0

Table 1. Major Agricultural Products of Guatemala

Crop	Production (MT)	Yield (t/ha)	Imports (I)		Exports (E)		Commercial Balance (I/E)
			MT	Country	MT	Country	
Staple crops							
Rice	32,437	3.0	95,379	USA (95%)	930	El Salvador (42%), Costa Rica (28%), Nicaragua (14%) and Honduras (8%)	102.6
White corn	1,776,408	2.1	44,260	USA (92%)	6,921	El Salvador (99%)	6.4
Yellow corn			740,580	USA (82%), Brazil (9%) and Argentina (85%)	8	El Salvador (72%) and USA (27%)	92,572.5
Black beans	227,945	0.9	11,133	China (43%), USA (29%) and Argentina (11%)	1,414	Costa Rica (46%) and El Salvador (38%)	7.9
Red beans			1,641	El Salvador (32%), USA (28%) and Nicaragua (19%), Argentina (95%)	482	El Salvador (38%), USA (31%) and Honduras (18%) and Costa Rica (13%)	3.4
Wheat	1,560	2.1	515,637	USA (91%)	563	Belice (71%) and Honduras (22%)	915.9
Animal products							
Beef	3,423,800 (1)	941,800 (2)	7,505	USA (67%), Nicaragua (15%), Costa Rica (13%)	3,406	El Salvador (77%) and USA (22%)	2.2
Pork	2,763,400 (1)	394,400 (2)	8,306	USA (98%)	210	Honduras (54%) and El Salvador (45%)	39.6
Chicken meat	199,715,400 (1)	123,296 (2)	69,874	USA (96%)	3,302	El Salvador (66%) and Hong Kong (China) (32%)	21.2
Eggs	4,854,657,600 (1)		794	USA (91%) and El Salvador (7%)	69	El Salvador (100%)	11.5
Liquid milk	490,126,280 (3)		37,430	Costa Rica (61%), Honduras (21%) and Mexico (13%)	65	Honduras (79%) and Costa Rica (19%)	575.8
Powdered milk			13,029	Nicaragua (34%), Costa Rica (22%), New Zealand (22%) and USA (7%)	181	Honduras (28%), El Salvador (25%) and Belice (21%)	72

(1) Number of units, (2) Slaughtered animals and (3) Non-processed milk.

ty have been identified, on a short-term basis the most important ones include the direct and indirect impact on the climate-change phenomenon.

Climate change includes irregular rainy seasons, with excess and shortage of water and floods alternating with droughts, frosts, hailstorms, high variation of temperature and relative humidity that allows the proliferation of arthropod pests and crop diseases, loss of agrobiodiversity as well as the loss of productive infrastructure. As an example, the effect of the prolonged drought in the last 3 years in Guatemala resulted in negligible maize and bean production in several areas of the dry corridor in eastern Guatemala. Since corn and beans are planted as part of Guatemalan dryland agriculture and no irrigation is available in the region, crop production was drastically reduced. The social and economic conditions of the rural population and postharvest losses are currently problematic. The most vulnerable population segment, constituting 60% of rural families, includes those having no land and infra-subsistence and subsistence farmers.

Other sources of FNS instability on the mid- and long-term basis include the change on the use of land from forest to crop production (deforestation), soil erosion due to cropping on steep slopes with no soil conservation practices, gradual loss of soil fertility and soil quality, desertification, genetic erosion (causing the loss of native corn and bean varieties), low use of improved varieties in staple

Box 1. Summary Chronology in Agriculture Research in Guatemala

- **1944:** The National Agricultural Institute (IAN) as a cooperative organization between the Guatemalan Government and the US Department of Agriculture was established. The research agenda included corn, beans, rice, wheat, coffee and rubber production.
- **1954:** The Inter American Cooperative Service for Agriculture (SCIDA) was created and replaced IAN. The new research center was financed and administrated by the US, making important advances in the modernization of the Guatemalan agriculture. With the creation of the new research center the Agricultural Extension Service was also born.
- **1970:** The Agricultural and Science Technology Institute (ICTA) was created, and the official launching took place in 1973. ICTA is the National Agricultural Research Center financed by the government of Guatemala and other donors and its name remains to the present. Since its creation, ICTA has been working on staple crops, vegetables, fruits and minor animal species. Their major activities are focused on peasant agriculture. At present, ICTA has five major research centers in the country.
- **1980–1990:** Agricultural research started in several organizations of the private sector, private universities, international organizations and NGO. The contribution of the National University (Universidad de San Carlos de Guatemala) started in 1950 when the College of Agronomy was created. Agricultural research in private universities also began since the creation of their Colleges of Agriculture (Agronomy Department at Universidad del Valle de Guatemala in 1977 and the College of Agricultural and Environmental Sciences in 1976).

crops, weak policies and weak participation of the agricultural public sector in assisting small-scale growers through effective extension and agronomic research programs, limited irrigation programs even though surface and subsurface water is available, high dependency on the use of chemical fertilizers and pesticides that are imported, low educational level of the producers, lack of effective programs to link growers to high-value chains for crop diversification, low number of associations and co-ops linked to the international market, and high dependence on foreign remittances.

h. Major agricultural challenges

Agriculture is one of the most important sectors in Guatemala for FNS and economic reasons. Some of the challenges that this sector faces in the development of the country include a growing population, the high level of hunger, poverty and malnutrition, as well as the factors for FNS mentioned in the previous section, in addition to the worldwide demand for high-quality products and an increase in competitiveness in a globalized market, the need for alternate energy sources that may compete for the use of land for food, the strength of rural development and the innovation of peasant agriculture. With those issues in mind, science, technology and innovation become an important engine for a constant increase in productivity and product quality. The major goal is to procure sustainable and climate-smart agriculture in harmony with the environment, natural resources, biodiversity and the quality of life of human beings. In response to those challenges, an important program in agriculture focused on the innovation of peasant agriculture is being promoted by the Ministry of Agriculture.

II. Institutional setting

a. National agricultural research systems

Although agricultural education began in Guatemala in 1877, it took over half a century for the establishment of the first research center. The National Agricultural Chemistry Institute was established to teach mineralogy, geology and soil fertility. Over the eight intervening decades, the institutional aspect of agricultural research has evolved, as summarized in **Box 1**.

An important aspect to be pointed out is that in 1990 the agricultural extension service was canceled by the government, and it was not until 2008 that a new extension system, named National System of Rural Extension (SNER) was relaunched in 2008.

i. Are research capabilities in need of further development?

Some of the major needs include the recognition by government, industry and policy-makers of the importance of education and human capital for research and innovation in the development of the country as a whole and agriculture and nutrition in particular. Strengthening post-graduate studies and accessing mainstream scientific journals and state-of-the-art technology is also critical. The latter should be coupled to an appropriate extension system for training and technology transfer.

ii. Areas of local strength

At present several institutions participate in the development and transfer of agricultural and forestry technologies. These include the National Agriculture Research Center (ICTA), which focuses its work on peasant agriculture and deals with staple crops, vegetables and fruits. Research centers of the colleges of agriculture of the different universities whose main lines of research include not only agriculture (peasant and export agriculture) but also environmental, biotechnology and biochemistry areas. We have different organizations of the private industry that focus their research on specific crop areas such as coffee (ANACAFE), sugar cane (CENGICAÑA and the 18 sugar mills), the rubber industry (Gremhule), and international organizations and the National Coffee Association (ANACAFE). Other sectors of the private industry such as oil palm, cantaloupe, banana and the Association of Non-Traditional Export Crops (AGEXPORT) have their own research and development departments. The contribution of some international organizations like the International Center for Tropical Agriculture (CIAT), Inter-American Institute for Cooperation in Agriculture (IICA) and the Center for Tropical Agriculture and Higher Education, along with international universities and NGO implement research and extension activities either by themselves or in cooperation with local organizations and institutions is also important. They usually work in a broad range of areas dealing with peasant agriculture and natural resources. Although agriculture in its extended concept includes crops, forest, animal science and food processing, most research subjects have been focused on crop production for local and international markets. As indicated by the National Council for Science and Technology (CONCYT), approximately 20% of the funds for research have been allocated to projects dealing with agriculture. Research on forestry, animal science and food processing needs to be strengthened.

iii. Networks of scientific collaboration inside and outside country

At the local (domestic) level, interinstitutional cooperation exists, but is weak and in need of strengthening. Each individual research center has its own collaborative network outside the country. This includes some Consultative Group for International Agricultural Research (CGIAR) centers, foreign universities, and international foundations and specific donors, including private industries and industry consortia.

iv. Access to and maintenance of the databases tracking agricultural systems

There is limited curating of and access to public databases in different government ministries, the CONCYT and the National Statistics Institute (INE). Fees can be required for data-bases. Even more limited are data-bases generated in universities, and even more so, those of private-sector institutions.

b. Universities and research institutes

i. Scientific development and infrastructure

Guatemala's National Science and Technology System (SINCYT) combines institutions and entities from the public, private and academic sectors. CONCYT, the core of the system, and its operative arm, the National Secretariat of Science and Technology (SENACYT), organize and link scientific activities with the SINCYT. Together they promote science, technology and innovation in the country, including administrating the National Fund for Science and Technology (UNESCO, 2010). CONACYT is also supported by sectoral and intersectoral technical commissions, integrated by public, private and academic institutions with common scientific and technological interests aimed at contributing to Guatemala's social and economic development. (UNESCO, 2010; SENACYT, 2015)

The nation's 15 universities play a major role in conducting scientific and technological research activities. The Universidad San Carlos de Guatemala (the only public university in Guatemala) runs 37 research centers and institutes located on several external campuses throughout the country. Only six private universities have research centers/institutes, headed by Universidad del Valle de Guatemala with 10 research centers, followed by Universidad Rafael Landívar with six. Another 10 public and private centers operate outside the higher education system and conduct research on specific topics of human health (CeSSIAM, Funadanier, INCAP, INVEGEM, National Laboratories for Health), agriculture (CENGICAÑA, IGCC, Cedicafé, ICTA), economy (ASIES, CIEN) and the social sciences (CEUR, FLACSO).

The country's public investment in scientific research and technological development through the SINCYT is extremely low compared to other countries in the region. For example, from 2007 to 2012, the government's investment in research and development ranged from US$ 18.1 to 23.5 million annually, representing 0.04% and 0.06% of the national GDP, respectively. Funding investments include natural sciences, engineering, medical sciences, agriculture, social sciences and the humanities (SENACYT, 2015).

Nonetheless, external funding from international public and private institutions, as well as NGO from the US, the European Union, Japan and Germany, among others, enable local research institutions to obtain funding for small-, medium- and large-scale projects.

III. Resource ecosystem characteristics

a. Water resources and challenges over the next fifty years

Guatemala's water resources exceed by far its demand for water: 97.1 billion m³ of available surface and groundwater, of which only 9.6 billion m³ are employed in consumptive and non-consumptive uses (Gabinete Específico del Agua, 2011); however, growing population demands, climate change, water pollution, water disputes (Basterrechea, 2013) and poor management by national and municipal government entities (IARNA, 2015) threaten this resource.

The total annual demand for water reached 20 billion m³ in 2005, consumed mostly by the industrial and agricultural sectors, followed by the hydroelectric energy production segment. Domestic uses only represent 3% of the total demand for water in the country (IARNA, 2015). Guatemala still faces major challenges in providing universal and high-quality coverage of drinking water and sanitation for all the population, especially in the neglected rural areas of the country. Such services represent cost-effective solutions to reduce poverty, chronic malnutrition, morbidity and maternal-child mortality, not to mention the impacts on the health and welfare of the general population as well as on the well-being of the environment (Gabinete Específico del Agua, 2011).

Social unrest surrounding water resources has increased recently due to a growing water demand from the agriculture and mining, as well as concomitant water-pollution concerns. Along with severe adverse climate events that have affected the country during the last two decades, there are threats to Guatemala's fragile hydrologic system. Attempts to design and implement multi-sector national legislation for the administration and regulation of the water resources have repeatedly failed, mainly because there is a lack of consensus among the sectors.

b. Soil resources and challenges over the next fifty years

The genesis of most soils of the country is from limestone, volcanic material, marine deposits at low altitudes, shale, serpentine and other igneous, sedimentary and metamorphic rocks, as well as from volcanic material transported by water that is eventually deposited downstream. The specific parental material and soil development depends on the geology, geomorphology and climate of each of the eleven physiographic and geomorphology regions into which the country has been divided.

The first soils' classification map was developed by Simmons et al. (1959) and was based on the genetic aspects of the soil. International systems used in Guatemala include the FAO-UNESCO system that allowed the identification of 10 of the 26 units identified by the system in the world, some soil taxonomic studies and a few technical-classification reports based on soil fertility. Based on soil taxonomy, soils have been classified in the sugar cane cropping system, soils of the South region of the coffee industry, and soils of the departments of Chimaltenango, Sacatepéquez and Sololá developed by the Ministry of Agriculture (González-Martínez, 2013). Other soil taxonomy studies have been implemented on specific areas of the country. Although soil taxonomy studies have not been developed for the entire country, based on some soil correlation between the study implemented by Simmons et al. (1959)

and the soils' taxonomy system, major soil orders identified for the country include those indicated in previous sections.

The topography of the land used in agricultures ranges from plains to steep slopes in the highlands (DIGEGR-MAGA, 2005). As indicated the natural vocation of most soils is for forestry. However, because of the land pressure and the high poverty level of most of the growers, agriculture is practiced even in class VIII of the USDA soil classification system. The distribution of the soils based on the land-use capacity system is presented in **Figure 1**. According to a Ministry of Agriculture classification by land-use, in 2000, the distribution of the land surface of Guatemala was classified as follows arable lands suitable for cultivation (34.2%); arable lands for grazing (16.8%); forest cover (41.1%); protected reserves (7.1%) and bodies of inland water (0.3%) with a small fraction of constructed urban centers. The major challenges over the next 50 years include reduction of soil erosion through implementation of soil conservation practices, use of land according to its capacity, completing the taxonomic classification of the soils for the entire country, conservation of water through appropriate soil management, and restoring marginal soils and increasing the soil-fertility level and quality of soils through climate-smart agricultural practices that promote organic carbon accumulation in the soil.

Over the next 50 years, Guatemala faces major challenges, centered on building resilience to adverse climate events and climate change, ensuring appropriate and equitable distribution of water to all the population segments, based on a human rights approach, and protecting the underground recharge zones and water sources from overexploitation and contamination.

c. Energy challenges

According to the World Factbook (CIA, 2016), Guatemala has an energy consumption estimate of 0.21 quadrillion Btu per year and the following potentials: wind potential of 3,445 km² class 3-7 wind at 50 m; solar potential of 328,690,840 MWh/year; 83,070,000 bbl of oil reserves and 2,960,000,000 m³ of natural gas reserves.

One in 10 Guatemalans is currently without a household electricity supply. Current national production is 10 billion kWh of electricity. The installed generating capacity was 3.73 million kW (2015) but some 61.9% coming from fossil fuels and 29.1% from hydroelectric plants with only 8.9% from renewable sources. National production of crude oil is 10,040 bbl/day with imports of refined petroleum products of 100,400 bbl/day. There are also carbon dioxide emissions from the consumption of energy of 13 million metric tons (mt).

Box 2. Main energy-associated challenges

- Reduction in fossil-fuel use
- Laws favoring the use of biofuels and renewable energies
- Reduction in the irresponsible use of biomass from wood and firewood
- Increase efficiency in energy use in industry, offices and residences
- Utilization of natural resources such as rivers, wind, thermal and solar energy
- In addition to the necessity of being more efficient and responsible in energy use, there is also a need to reduce emissions

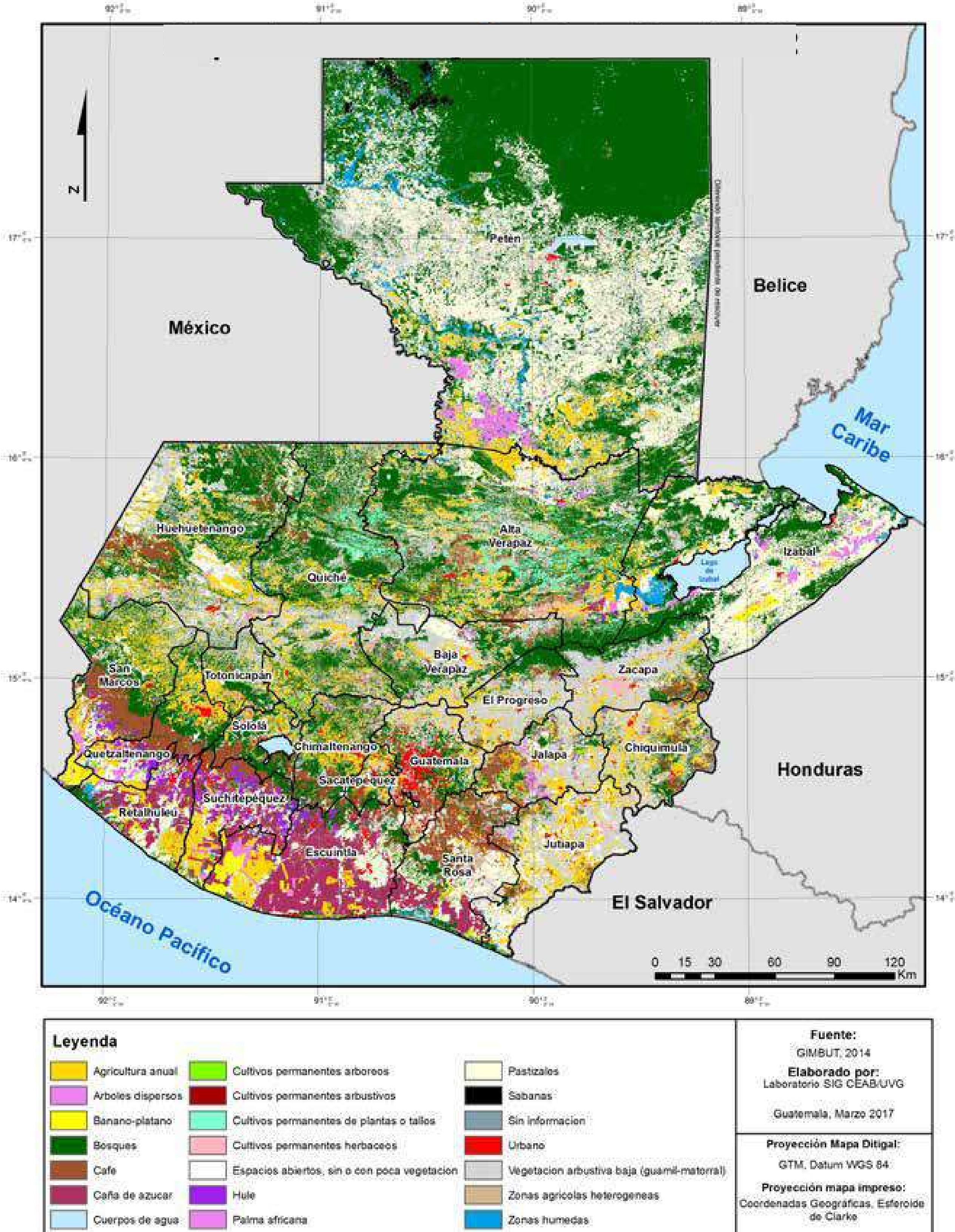
d. Biodiversity conflicts and challenges

The main threats to Guatemalan biodiversity have been described as recurrent in the last decades (CONAP, 2014), including the most recent official data for forest-cover lost: 146,112 ha (years 2006-2010), which corresponds to the 3.4% of the annual deforestation rate in the country. Deforestation is directly related to agroindustry monocultures, e.g., oil palm, sugar cane and grasslands. Other main threats to biodiversity are the 1,422 reported invasive exotic species, forest fires and climate change, with more frequent and intense hydrometeorological phenomena (CONAP, 2014), such as storms and drought, that result in agrobiodiversity loss, affecting the country's food security.

Environmental degradation is directly related to the lack of effective political instruments and to overlaps and gaps in regulatory frameworks (MARN, 2013). The value of agro- and biodiversity, their economic potential and their contribution to food security has not been fully recognized by the political class.

The implementation of the National Policy on Biodiversity, with its Strategy and Action Plan 2012-2022, that according to CONAP (2013), seek

Figure 1. Guatemalan Forest Cover and Land-Use Map for 2012



to develop political, juridical, social, financial and institutional conditions to ensure the conservation and sustainable use of biodiversity, including the fair and equitable sharing of the benefits arising for the use of biodiversity components and ecosystem services, remains the main biodiversity challenge to transcend.

i. Problems associated with overexploitation

The appropriate strategy for Guatemala is to limit or avoid overexploitation of land area for agriculture that will result in the destruction of native habitat and the extinction of species, as is currently happening in the rainforest area in the Petén, as discussed elsewhere. In addition to destruction of habitat, and consequently native species, the extension of chemicals used increases the probability of extinction, both in the natural areas as well as within the fields. The quality of agricultural practices also affects biodiversity, even in natural areas, e.g., drift of insecticide from agricultural fields to protected areas. Combined with monoculture, vulnerability to crop-specific disasters occurred in Guatemala with the introduction of foreign pests, such as with coffee (cherry borer and coffee rust), and citrus fruits (Huanglongbing). Guatemala requires a surveillance and monitoring system in which invading pest species are recognized comprehensively and early for timely control.

ii. Depletion of genetic diversity

As mentioned earlier, Guatemala has been recognized as a megadiverse country; that belongs to the Mesoamerican Center of genetic diversity. Plant genetic resources of worldwide economic importance, and their wild relatives, are found in the Guatemala, including the genera of *Zea, Phaseolus, Cucurbita, Capsicum, Manihot, Persea, Lycopersicon* and *Solanum*. The country is also very rich in underutilized species of high nutritional value (Orellana, 2012; Azurdia, 2016) and is a diversification center for the *Pinus* genus. The importance and contributions of these genera to food security and to the country's economy, as well as the urgent need for their sustainable use and conservation (ex situ and in situ) have been highlighted by national universities and international institutions in the last decades (CONAP, 2008; FAO, 2008; Maselli, 2013). These institutions have made important contributions to the World's Plan of Action (FAO, 2011) activities for the conservation and sustainable use of the plant genetic resources, to raising awareness of the depletion of genetic diversity of the Guatemalan agrobiodiversity (crops and their wild relatives, nutritional underutilized species, and fruits), and of Guatemalan forest genetic resources (INAB, 2012). Threats to agrobiodiversity are common to those of biodiversity in Guatemala and include the threat of genetic erosion. Studies on developing methods to measure genetic erosion have been conducted by Universidad del Valle de Guatemala (Maselli, 2014).

e. Implications of forestry trends

Despite that one-third of the Guatemalan territory remains under forest cover (the highest in Central America), the deforestation process has been intense in recent decades. As recently as four decades ago, forest covered two-thirds of the Guatemalan territory. The key factor in a 50% reduction since then is the internal immigration process to populate the northern territory of the Petén Province promoted by the central government in the 1970s. This policy initiated a strong deforestation process, the effects of which are still seen today, with the advancement of an agricultural frontier. Net deforestation rate was estimated at 1.7% for the 1991-2001 period; that rate was reduced to 1% for the last period of analysis available (2006-2010) (INAB et al., 2012). This was not the result of a reduction in deforestation, but rather a significant increase in afforestation coming mainly from three processes: new plantations established through the National Forest Incentive Program (PINFOR); regeneration of burned areas not converted into croplands and regeneration of abandoned agricultural areas, particularly in the highlands. The abandonment of agricultural land may be related to the strong immigration to the US coming mainly from small farmer communities in the highlands (Aguilar-Stoen et al., 2014).

The amount of gross deforestation has remained at around 100,000 ha per year for the 1991-2010 period; at the same time, the gain in forest cover has been increasing steadily in the same period. As a result, the net forest loss reported for the last period evaluated (2006-2010) was 38,600 ha per year (INAB et al., 2012).

f. Potential impacts of climate change

The entire region of Central America has been characterized as a region with high exposure to geo-climatic hazards due to its location and topography. The region has been identified as the most responsive tropical region to climate change (Giorgi, 2006). A series of extreme-weather events, e.g., hurricanes and droughts, in the recent years have resulted in various studies ranking Guatemala and other countries in Central America among the most vulnerable to climate change. For example, the World Risk Report prepared by United Nations University (2015) ranked Guatemala in fourth place among countries with the highest risk of suffering a natural disaster. The Global Climate Risk Index 2017 published by Germanwatch (2016) ranked Guatemala as number nine among the 10 countries most affected by climate events from 1996 to 2015, with 75 events occurring during that period resulting in a loss of 0.47% of the GDP.

The chapter on Central and South America from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change IPCC (Magrin et al., 2014) concluded that for Central America, the expected temperature increase through the end of the current century will be between 0.6 and 2.0°C for the most optimistic scenario and between 3.6 and 5.2°C for the most pessimistic projection. This increase in temperature will be accompanied by a decrease in rainfall of up to 25%. This long-term trend of less precipitation will be accompanied by increasing variability of rainfall resulting in periods of extreme rain and extreme drought. Other modeling efforts show similar trends, with warming in the range of 2 to 4°C and a precipitation reduction of 10 to 25% (ECLAC, 2010; Imbach et al., 2012; Sáenz-Romero et al., 2010). Beyond these long-term trends, local farmers report that the timing of rainfall has been increasingly variable, making it extremely difficult to recognize the start of the rainy season and optimal planting time (Eakin et al., 2013).

g. Building resilience to extreme events

The approach to disaster management in Central America has focused on developing early warning systems and emergency response for extreme events (Saldaña-Zorrilla, 2008), rather than on strengthening local organizations and cooperatives, which could increase adaptive capacity among farmers through increased access to soft credits and information on global markets, as well as new technologies (Eakin et al., 2011). The experience of coffee growers in the Mesoamerican region (Castellanos et al., 2013) indicates that diversification in production systems and income generation is of utmost importance to reduce the vulnerability of rural communities to a highly variable environment.

h. Future outlooks

Due to its geography and topography, melting ice, rising oceans and oceanic acidity would seem to be less important going forward than rising temperatures, changing patterns of precipitation and especially the frequency and intensity of natural extreme adverse events. The exact scenario is beyond prediction.

IV. Technology and innovation

a. Role of biotechnology

i. Plant agriculture

The regulated, area-wide use of transgenic corn with insect-resistant traits could lead to pest suppression and prevention of resistance, as has been observed after several decades of application in the US (Hutchinson et al., 2010). In addition, it has been shown that Bt-maize can have reduced levels of fumonisin mycotoxins (Ostry et al., 2010). Contamination of corn-based products with these fumonisin toxins can adversely affect human health (Torres et al., 2013). Thus, this biotechnology has the potential to reduce the regional application of insecticides as well as the level of mycotoxin contamination in Guatemala's main staple. However, Guatemala has not regulated/licensed the use of transgenic crops, making this technology currently inaccessible in the country.

ii. Animal agriculture

According to Guatemala's National Council for Protected Areas (CONAP), in 2010 there were 27 laboratories associated with the use of biotechnology and/or safety in biotechnology in the country. Four of them were government, eight were private and the rest were academic institutions working on a total of 106 projects/programs. These programs were focused basically on the transformation and transference of resistant genes to common plant viruses and on the control of human vectors and diseases. So far, there are no reports of studies being conducted in higher organisms, such as animals (CONAP, 2010). Nonetheless, private companies are processing semen and bovine embryos to enhance the genetic pool of the local bovine breeds, thus to improve yields in meat and dairy production (BASA, 2008).

iii. Pests and diseases

The large-scale use of traditional chemical pesticides affects beneficial insects and biodiversity, in turn affecting agricultural sustainability (Whitmee et al., 2015). The biopesticide industry, as an alternative to chemical pesticides, is expected to grow over the next decade (Bergin 2016). Biotechnology for the control of insect pests has been part of several successful area-wide integrated pest-management programs in Guatemala. One such example is the control of insect pests of sugar cane using entomopathogenic fungi (COMIP, 1998). Another highly successful biotechnological application is the sterile insect technique for the screwworm eradication program, with Guatemala being declared in 1994 free of this important cattle pest (Wyss 2006). The sterile insect technique is also a central part of the Mediterranean fruitfly program that led to the elimination of this horticultural pest on the northern border with Mexico (Lynch 2002). Area-wide applications of biotechnological products are, therefore, an important component of the arsenal against insect pests for sustainable agriculture in the region.

b. Prospects for novel agricultural products

If Guatemala is to reach the second Sustainable Development Goal, i.e., "to eliminate hunger, achieve food security and improved nutrition and promote sustainable agriculture" (United Nations, 2016), the country will need to develop policies to ensure available agricultural biotechnologies are adopted to protect the environment, biodiversity and human health. To ensure the well-being and improved nutrition of future generations, Guatemala will need to intensify area-wide agriculture through a combination of integrated pest management that includes biological control methods and genetically-modified crops (Whitmee et al., 2015). It should be noted that highly-efficient, area-wide strategies are only possible with investments in multi-institutional agreements and research programs on pest biology. The adoption of these technologies also depends on the implementation of country-wide, participative strategies that include professionals from the fields of public health and the nutritional, environmental and agricultural sciences (Whitmee et al., 2015).

c. Opportunities for and obstacles to new management technologies

Many opportunities exist for new technology looking for adequate resource use, and of course, innovation is required. The use of organic waste and by-products can be employed as fertilizers, after being digested for the production of biogas. Where possible, the use of rainwater and treated water for irrigation, processes and domestic use will increase water availability. To facilitate processes, the use of natural treatment systems such as biofilters, wetlands, cascade aeration, among others, is imperative.

In terms of obstacles, the removal of hazardous pollutants is expensive and requires sophisticated technology. The use of natural systems requires time and in the case of wetlands, large extensions of land for implementation. Appropriate microorganisms and plants belonging to the environment must be handled to prevent the propagation of alien species.

d. Development of aquaculture/ marine resources

Fisheries are not, as yet, a fully-developed economic activity in Guatemala, contributing only 0.03% to the country's GDP. Nonetheless, they contribute significantly to the food security and economic welfare of many Guatemalans, mainly those living in the coastal areas of the country. This activity takes place primarily within Pacific and Atlantic Ocean waters. There is, however, an important sector working in artisanal fisheries in continental (inland) waters throughout the territory, producing approximately 15,500 mt of hydrobiological products per year. On the Pacific Coast, the leading activities are artisanal and industrial fisheries (small-, medium- and large-scale), which center on the catch of shrimp and associated marine fauna. On the Atlantic Coast, the majority of efforts are aimed at the catch of fish and shrimp with artisanal and small boats. Overall, annual ocean-fisheries production is approximately of 32,000 mt of hydrobiological products such as tuna, several types of fish (shark, mahi mahi, groupers, snappers, sardines, etc.), crustaceans (crab, shrimp and lobster), and mollusks (clams, squid, oysters and snails). In 2003, total exports reached approximately 23,000 mt, representing incomes of between US$ 50 and 80 million to the country (FAO, 2005).

Recently, a noteworthy reduction on the catch of marine resources has been reported, not only within the jurisdictional waters of the country, but beyond them, in Central American and Mexican waters as well. The possible factors are associated to climate change, which has disturbed the natural patterns and distribution of the marine species, the lax control of the artisanal and industrial fishers' activities, and the degradation of the marine floors (FAO, 2005). Inland, waters have been polluted by monocrops such as the palm oil and sugar-cane industries (EJA, 2014; ActionAid, undated), as well as mining (GHRC, undated) and other industrial and anthropogenic activities that impact the abundance and biodiversity of the freshwater species. Industrial activities, specifically the food and beverage sectors, which are largely responsible for the degradation of freshwater sources, accounted for 71.4% of emissions of organic water pollutants (UNEP, 2000).

The aquaculture activities center on the production of shrimp and tilapia (FAO, 2005), but there is little information regarding the volumes of production, uses and statistics that would allow measurement of the contribution of this activity to the national economy and food security.

V. Increasing efficiency of food systems

i. Prospects for technology-based increases in agricultural production

A major hurdle to be overcome, in terms of sustainable human development, is social inequity. For the sector of export-based cash crops, the producing and exporting community has the wherewithal to apply evolving technologies; a system of regulation and licensing will be needed for all forms of biotechnology to be applied. The food-production sector has been stagnated in time within the traditional peasant infra-subsistence and subsistence context. Agricultural cooperatives have a potential role to play. Technology is intrinsically important for this activity as well, but the source of investment has not been visualized. Both sectors will run into the negative consequences of climate change and the other factors related to soil and water.

ii. Infrastructure needs

As with most countries, with farming as a rural pursuit and markets in cities, transportation infrastructure (roads and bridges) lead the list of needs in that sector. To the extent that export of products is to be maintained or expanded, seaport facilities in the harbors and wharves in the ports need improvement and expansion.

b. Issues for food utilization and minimizing waste

Postharvest losses can reduce food utilization by 30-50% from setting to setting. A precise estimate for Guatemala is not available. International agencies for development have implemented a series of strategies to improve the production of horticultural products in Guatemala; however, the lack of infrastructure (above) is a factor in their not getting to markets and consumers and efficiency-of-use is poor. Refrigeration systems in internal transport and storage will be needed to begin to impact waste.

iii. Conflicts between food production and production of energy and fiber

Use of specific crops that do not harm food security is a requirement for the production of biofuels. Plant species have to be selected to assure that their tissues, fruits, seeds and other components can be processed in a profitable way for the extraction of oils, alcohol, fibers, cellulose, or the residues thereof for obtaining biomass, biogas, among others. The selection of areas for the cultivation of these plants should be done in a way that does not affect food-producing crops or perhaps alternating with them.

Government and laws should encourage the cultivation of plants for various purposes, as well as encourage the use of biofuels, while ensuring the food security of Guatemalans. It is also the obligation of the government to regulate emissions, while assuring an adequate energy supply.

VI. Health considerations

The primary aspects and linkages of agriculture to health are via the consumption of food; five important levels are listed in the Insert **Box 3**. The basis of the contemporary Guatemalan diet is constituted by the traditional elements of the Mayan cuisine of antiquity, namely maize, beans and squash. In recent centuries, the primary beverages have been coffee, hot gruels derived from the grains and seeds, and natural fruit drinks. Flesh from livestock, farm animals, hunting and fishing have been variable complements. The lactase non-persistent phenotype of the Amerindian and Mediterranean ancestors of contemporary Guatemalans limits the demand for and tolerance of dairy products with regular lactose content.

b. Foodborne diseases

Food- and waterborne diseases have historically been widely endemic, life- and health-threatening in Guatemala. This was one of the sites for the formulation of the "weanling diarrhea" paradigm, of the explosion of diarrhea once complementary foods are added to the diet. The prolonged contact with the hands in elaborating tortillas would be a factor in fecal–hand–oral transmission. Historically, latrinization and treated piped water have been rare in rural areas, but both elements of infrastructure have expanded greatly over the last decade. Overall under-5 mortality rates have declined from 124 to 35 per 1,000, from 1980 to 2000, and diarrhea disease accounts for 14% of mortality in this group (WHO, 2017).

Waterborne or soil-transmitted parasites are commonly found in rural Guatemalan communities. In a Western Highlands survey among school children, roundworms (*Ascaris*) were found in 18%, amebas (Entamoeba) in 16% and giardiasis in 11% of the 5,000 stool samples analyzed (Cook et al., 2009). Mycotoxins are a serious contaminant of maize (Torres et al., 2013). Aflatoxins have recently come into prominence as a possible contributor to poor growth (Prendergast & Humphrey, 2014).

c. Overconsumption/malnutrition

i. Undernutrition

If we embrace malnutrition in all of its forms, the concern for undernutrition supersedes that for overnutrition in Guatemala within the public health agenda. The condition-of-interest is that of early-life growth retardation and low stature (stunting), often termed "chronic malnutrition." The Hunger Zero Pact (SEGEPLAN, 2013) was dedicated to focusing on its prevention in the first 1,000 days of life. Guatemala has the highest prevalence of stunting in children under 5 years of age in the Western Hemisphere, at 49% in the 2008-9 DHS survey, falling only to 46.5% in the follow-up in 2014-15 (MSPSA-ENSMI, 2015). Currently, the prevalence of the indigenous subsegment of the population has a 61.2% stunting rate. Stunting is not a full-fledged undernutrition disorder, as the lower limbs are specifically affected out of proportion to the upper body and head (Bogin and Varela-Silva, 2009).

The international response to reduction in stunting has followed the line of assuring an adequate diet and providing multiple micronutrients, but efficacy trials of both modalities have not shown impressive results. Environmental stress is

Box 3. Linkages Between Agriculture and Healthy via Issues of Food Consumption

- **Food safety:** Microorganisms, toxins and contaminants in the food supply.
- **Nutritive value:** The quantity, density and bioavailability of essential macronutrients and micronutrients.
- **Energy balance and diet profile of consumption:** An individual's energy intake and expenditure must be in balance, and the pattern of health-protective and health-noxious foods and constitutents.
- **Fuels for cooking:** Forestry and fiber implications of the fuels used for cooking.
- **Monetary income for food acquisition:** Agricultural labor or sale of production for purchase of food and health-related items.

likely to be a more important determinant in Guatemala, in a truly multi-factorial situation (Solomons et al, 1993). The foodborne illness scenarios discussed earlier are part of the causality. In a major new epidemiological analysis covering 137 developing countries conducted by the Harvard School of Public Health, Danaei et al. (2016) conclude: "FGR (Fetal Growth Retardation) and unimproved sanitation are the leading risk factors for stunting in developing countries. Reducing the burden of stunting requires a paradigm shift from interventions focusing solely on children and infants to those that reach mothers and families and improve their living environment and nutrition."

In addition, micronutrient malnutrition is a concern in Guatemala and the Central-American region. These include vitamin A, iodine, iron, zinc, vitamin B12, vitamin E, vitamin D and omega-3 fatty acids. A three-decade, stable national program of sugar fortification with retinyl palmitate and salt fortification with potassium iodate since the 1950s have both been effective interventions. Trace-element nutrients, iron and zinc, are not highly bioavailable from the corn and bean diet. Weekly supplementation with iron is provided by government clinics for selected subsegments of the Guatemalan population. Nutritional-sensitive agriculture needs to consider the unmet micronutrient gaps in the diet in forward planning.

ii. Overnutrition

Sixty-seven percent of Guatemalans aged 15 and above are overweight, among whom 29% are obese [World Bank, 2017]. The breakdown by gender and age is not available. This classifies Guatemala with one of the ten highest prevalence values for excess weight in adults. A reflection into adulthood of the early short-stature is an increased susceptibility to excess body weight. In any event, overweight and obesity represent a public health problem in this nation with a 50% rural residency.

The other contextual risk for overconsumption is that for vitamin A. With the fortification of table sugar with this vitamin, dietary-intake surveys have documented daily consumption chronically exceeding 1,500 µg of the preformed vitamin, a risk-level for bone demineralization, and occasionally exceeding the 3,000-µg level for fetal birth-defects risk.

d. Expected changes in consumption patterns

Guatemala has been in a phase of rapid nutritional transition over recent decades, with a Westernization of the dietary pattern driven by urbanization, improved transport to the rural areas and opening of North-South food trade. Bermúdez and coworkers (2008) demonstrated a reduction in the diversity of "traditional" foods and a rise in "modern" foods in recent food-intake surveys. The precise nature of future development is so multi-factorial and contingent on local and international factors as to be unpredictable. The maize and bean culture is deeply rooted in the Guatemalan populace, but movement from home-prepared to ready-to-use tortilla flours and packaged, cooked beans exemplifies a change toward convenience solutions. Mechanization of household, industrial and agricultural pursuits should further reduce average daily-energy expenditure, hopefully to be accompanied by a concomitant or greater decrease in caloric intakes.

e. Understanding and incentivizing behavioral change

Guatemala has been a leading setting for cultural anthropology, including aspects of food and diet. The understanding of the cultural basis of attitudes and practices, including food taboos and avoidances is profound (Cosminsky, 1977). Much of the behavioral concern has been around maternal eating habits in pregnancy and lactation, which are deeply ingrained. Moreover, rather than intervene and guide a change in practices, respect for the "wisdom of the Mayans" has been the watchword in both anthropology and public heath.

As mentioned, fortification programs, which do not require diet change for effectiveness, are instituted in Guatemala. Where behavioral change might emerge to become a strong public health consideration is in maintaining energy balance with growing overweight and obesity, and in the control of saturated fat, sodium and sugar intake. Traditionally fat intakes are low, as maize preparations do not require frying. One rural study in an indigenous community showed low sodium intakes (Melse-Boonstra et al., 1998); this, however, might not reflect the corresponding urban reality. As a sugar cane-producing country, sugar is abundant and relatively inexpensive. Curbing the "sweet-tooth" of Guatemalans in a sea of sugar, however, will represent a major challenge.

VII. Policy Considerations

a. Distortions created by subsidies and other outmoded agricultural policies

Outmoded is a term in the eye of the beholder and, in agricultural policy, and with respect to the slow advancement of the basic structure, harmony among measures might require retention of older modes. Concessional fertilizer distribution was a visible governmental policy of the administration of 2000-2004, but it has generally been judged as more of a public-relations ploy for popularity among the rural populace than a concerted strategic policy. No other susidization programs are widely recognized.

b. Promoting nutrition-sensitive agriculture to provide healthy and sustainable diets with associated issues for resource use and food prices

Nothing as comprehensive or integrated as outlined in the heading exists for Guatemala. An extensive quotation from the 2014 FAO Fact Sheet on trends in agricultural policy for this nation describes the enunciation of relevant government policies, "The National Policy on Integrated Rural Development (2009), which has the overall objective of: "achieving a progressive and permanent progress in the quality of life of the priority subjects [...] through the equitable and sustainable use of productive resources for integrated human development in rural areas; ii. The National Agricultural Policy 2011-2015 has the goal of creating the conditions for productive actors to generate an equitable and sustainable economic development, fostering employment and reducing poverty and inequality. It prioritizes the promotion of rural economies, indigenous and peasant communities, in order for them to become surplus producers and to invigorate local economies". (FAO, 2014).

c. Policies that foster technological innovation

On the broadest scale, for agriculture and other pursuits, the research-granting mechanism of the CONCYT has participation from the Ministry of Economics and a point-assignment for the potential to develop a patentable product is employed. The government collaborates with the offering of international study fellowships for students to study advanced technology in Korea and Taiwan in many fields of engineering and technology, some of which may be applicable to the agrosector upon their return.

d. Policies to build human resources (e.g., education, gender, equity)

As noted, Guatemala is one of the 10 most inequitable countries with its GINI coefficient of 48.7. Gender equity in basic schooling has been a theme in Guatemala since the mid-1980s, and major success has been made in closing the gap; however, the overall state of public education for both sexes is currently in serious decline.

e. Policies that seek to redesign the agricultural ecology (land use, bioeconomy, etc.)

Policies of the nature of redesign in land use, for historical reasons that date to the Revolution of 1944 and the counter-revolution of 1954, would be beyond the purview of a Ministry or Administration, and require legislation. The legislature is currently in a cumbersome impasse, and the theme of redesign is far from consideration.

f. Policies to promote consumption of healthy food

The format of inquiry for action on healthy foods, promoted across the world by the International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support (INFORMAS) (Swinburn et al., 2013), based at INCAP. This inquiry has the backing of the Guatemalan SENACYT. Movement toward the public discussion conducted in February, 2017, but the process is a long way from producing legislation or ministerial regulations.

g. Comparative advantages of Guatemala in agriculture

The availability of low-cost agricultural workers, an anachronism in labor policy, is an advantage for labor-intensive production. Water resources, if well managed according to the principles outlined previously, are superior to most tropical countries. The traditional climate, to the degree that it resists climate change, has year-round growing seasons in most of the arable regions.

h. International trade issues

Guatemala is a co-member of the Central American Free Trade Agreement (CAFTA). Currently, the instability and ineptness of formulating trade policies, mainly in the US, and other countries that might join a protectionist and exclusionist approach, would be an unpredictable barrier.

i. Market challenges

For internal commerce, the infrastructure of roads and waterways for transport are the challenges. Internationally, airport and port facilities for export of crops to overseas markets is deficient.

VIII. Conclusions

a. Some potential national scenarios for agricultural production over the next fifty years

Three distinct sectors would be the players in this scenario interplay: peasant subsistence agriculture; expanded mechanized production for national consumption, and expansion and diversification of cash-crop (exportation) productions. The scenarios involve the parallel and co-equal persistence of each, or the emergence of two to the exclusion of the third or the dominance of only one to the reduction of the other two. The peasant sector seems the most likely to head toward extinction.

b. Highest priority actions to achieve agricultural sustainability

This review would suggest that resolution of water tenency issues, conserving arable land and instituting environmentally-sensitive agricultural and land-use practices would be the priority actions, whatever be the actual scenarios going forward.

References

ActionAid. No date. Water at Risk: The impact of biofuels expansion on water resources and poverty. 39 pp. Accessed: http://www.actionaid.org/sites/files/actionaid/water_at_risk-actionaid-proof3_0.pdf

Aguilar-Stoen, Mariel, M. Taylor and E. Castellanos. 2014. Agriculture, land tenure and international migration in rural Guatemala. Journal of Agrarian Change. Doi: 10.1111/joac.12091

Azurdia, C. 2016. Plantas Meosamericanas subutilizadas en la alimentación humana. El caso de Guatemala:una revisión del pasado hacia una solución actual. Consejo Nacional de Áreas Protegidas y Universidad de San Carlos de Guatemala. Dirección General de Investigación. Documento técnico No. 11-2016.

Basterrechea M. 2013. Status of Water in Guatemala. In: Diagnosis of Water in the Americas. Jiménez-Cisneros B and Galizia-Tundisi J. (Editors). Interamerican Network of Academies of Sciences. 565 pp.

Biotecnología Animal, S.A. (BASA). 2008. Biotecnología Animal en Guatemala. Accessed at: http://biotecnologia-animal.blogspot.com/2008/07/biotecnologa-animal-sa-basa.html

Bergin J. (2016). Agricultural Biotechnology: Emerging Technologies and Global Markets - BIO100B. Bccresearch.com. Retrieved 19 December 2016, from http://www.bccresearch.com/market-research/biotechnology/agricultural-biotechnology-technologies-markets-report-bio100b.html

Bermúdez OI, Hernández L, Mazariegos M, Solomons NW. 2008. Secular trends in food patterns of Guatemalan consumers: new foods for old. Food and Nutrition Bulletin 29(4):278-287.

Bogin B, Varela-Silva MI. 2010. Leg length, body proportion, and health: a review with a note on beauty. International Journal of Environmental Research and Public Health. 7(3):1047-1075.

Castellanos E., Tucker CM, Eakin H, Morales H, Barrera JF, and Díaz R. 2013.. Assessing the adaptation strategies of farmers facing multiple stressors: Lessons from the Coffee and Global Changes Project in Mesoamerica. Environmental Science and Policy 26:19-28.

COMIP 1998. Manejo integrado de la chinche salivosa de la caña de azúcar. Guatemala: CENGICAÑA.

CONAP. 2014. V Informe Nacional de cumplimiento a los acuerdos del Convenio sobre la Diversidad Biológica. Guatemala. Documento técnico No. 3-2014.

CONAP. 2013. Política Nacional de Diversidad Biológica (Acuerdo Gubernativo 220-2011). Estrategia Nacional de Diversidad Biológica y su Plan de Acción (Resolución 01-16-2012). La década de la vida y el Desarrollo. 112 pp. Políticas, Programas y Proyectos No. 03 (01-2013).

CONAP. 2008. Guatemala y su biodiversidad: Un enfoque histórico, cultural, biológico y económico. Consejo Nacional de Áreas Protegidas, Oficina Técnica de Biodiversidad. Guatemala. 650 pp.

CONAP. 2010. Situación Actual de la Biotecnología en Guatemala. Accessed at: http://www.bchguatemala.gob.gt/el-ciisb/situacion-actual-de-la-biotecnologia-en-guatemala

Cook DM, Swanson RC, Leggett DL, Booth GW. 2009. A retrospective analysis of prevalence of gastrointestinal parasites among schoolchildren in the Palajunoj Valley of Guatemala. Journal of Health and Population Nutrition 27:31-40.

Cosminsky S. 1977. Alimento and fresco: nutritional concepts and their implications for health care. Human Organization. Summer. 36(2):203-207.

De la Cruz, J. 1982. Clasificación de zonas de vida de Guatemala a nivel de reconocimiento. Instituto Nacional Forestal; Guatemala. 23 p.

Danaei G, Andrews KG, Sudfeld CR, Fink G, McCoy DC, Peet E, Sania A, Smith Fawzi MC, Ezzati M, Fawzi WW. 2016. Risk factors for childhood stunting in 137 developing countries: a comparative risk assessment analysis at global, regional, and country levels. PLOS Medicine 3(11):e1002164.

Eakin H, Tucker CM, Castellanos E, Díaz-Porras R, Barrera JF, and Morales H. 2013. Adaptation in a multi-stressor environment: perceptions and responses to climatic and economic risks by coffee growers in Mesoamerica. Environment, Development and Sustainability. DOI: 10.1007/s10668-013-9466-9

Eakin H, Bojórquez-Tapia LA, Monterde Díaz R, Castellanos E, and Haggar J, 2011. Adaptive capacity and social-environmental change: theoretical and operational modeling of smallholder coffee systems response in Mesoamerican Pacific Rim. Environmental Management 47(3):352-367.

ECLAC (CEPAL). 2015. Observatorio Demográfico. Proyecciones de población. LC/G.2675-P. Santiago de Chile. 138 p.

ECLAC (CEPAL). 2010. Latin America and the Caribbean in the World Economy 2009-2010. A Crisis Generated in the Centre and a Recovery Driven by the Emerging Economies. United Nations; Santiago, Chile. 164 pp.

ECLAC (CEPAL). 2010. La Economía del Cambio Climático en Centro América. Santiago, Chile. 145 pp.

Environmental Justice Atlas (EJA). 2014. Sugarcane cultivation and oil palm plantation in Polochic Valley, Guatemala. Accessed at: https://ejatlas.org/conflict/sugarcane-cultivation-and-oil-palm-plantation-in-polochic-valley-guatemala.

FAO/MAGA. 2008. Segundo Informe Nacional sobre el estado de los recursos fitogenéticos. Guatemala. 101 pp.

FAO Guatemala: Country Fact Sheet on Food and Agriculture Policy Trends 2014. http://www.fao.org/3/a-i4124e.pdf Accessed February 4, 2017.

Food and Agriculture Organization of the United Nations (FAO). 2005. Resumen Informativo sobre la Pesca por Países: Guatemala. 52 pp.

Food and Agriculture Organization of the United Nations (FAO). 2011. Segundo Plan de Acción Mundial para los recursos fitogenéticos para la alimentación y la Agricultura. Comisión de Recursos Genéticos para la Alimentación y la Agricultura. Roma, Italia. 104 pp.

Gabinete Específico del Agua. 2011. Política Nacional del Agua en Guatemala y su Estrategia. 48 pp.

Germanwatch. 2016. Global Climate Risk Index 2017. Bonn, Germany. 31 p.

GIMBOT (Grupo Interinstitucional de Monitorio de Bosques y Uso de la Tierra). 2014. Mapa de Bosques y Uso de la Tierra 2012. Documento Informativo, Guatemala. 16 p.

Giorgi F. 2006. Climate change hot-spots. Geophysical Research Letters 33:L08707.

Guatemalan Human Rights Commission (GHRC). No date. Goldcorp's Mining In San

Miguel Ixtahuacán. Accessed at: http://www.ghrc-usa.org/AboutGuatemala/Goldcorp.htm#Environment

Hutchison W, Burkness E, Mitchell P, Moon R, Leslie T, and Fleischer S, et al. 2010. Areawide suppression of European corn borer with Bt maize reaps savings to non-Bt maize growers. Science, 330(6001):222-225. http://dx.doi.org/10.1126/science.1190242

Imbach P, Molina L, Locatelli B, Roupsard O, Mahé G, Neilson R, Corrales L, Scholze M, and Ciais P. 2012. Modeling potential equilibrium states of vegetation and terrestrial water cycle of Mesoamerica under climate change scenarios. Journal of Hydrometeorology 13(2):665-680.

Instituto de Agricultura, Recursos Naturales y Ambiente (IARNA). 2015. Balance hidrológico de las subcuencas de la República de Guatemala: Bases fundamentales para la gestión del agua con visión a largo plazo. 65 pp.

INAB (Instituto Nacional de Bosques), Consejo Nacional de Areas Protegidas, Universidad del Valle de Guatemala y Universidad Rafael Landívar. 2012. Mapa de Cobertura Forestal de Guatemala 2010 y Dinámica de la Cobertura Forestal 2006-2010. Editorial Serviprensa; Guatemala. 111 pp.

INAB y IARNA-URL (Instituto Nacional de Bosques e Instituto de Agricultura, Recursos Naturales y Ambiente de la Universidad Rafael Landívar). 2012. Primer Informe Nacional sobre el Estado de los Recursos Genéticos Forestales en Guatemala. Guatemala, XX. 186 pp.

INE (Instituto Nacional de Estadística de Guatemala). 2016. Indicadores en línea. http://www.ine.gob.gt/index.php/estadisticas/tema-indicadores

Lynch L. 2002. Migration of exotic pests: phytosanitary regulations and cooperative policies to protect US ecosystems and agricultural interests. In Fernández L and Carson RT (Editors). The Economics of Non-market Goods and Resources. Both Sides of the Border Transboundary Environmental Management Issues Facing Mexico and the United States. Dordrecht: Kluwer Academic Publishers. 478 pp.

Magrin GO, Marengo JA, Boulanger J-P, Buckeridge MS, Castellanos E, Poveda G, Scarano FR, and Vicuña A. 2014. Central and South America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; Cambridge, United Kingdom and New York. pp. 1499-1566.

MARN. Ministerio de Ambiente y Recursos Naturales. 2013. Informe Ambiental del Estado 2012. Guatemala.

Maselli S. 2014. Reporte final de proyecto "Establecimiento de una red preliminar de bancos comunitarios de semillas en regiones vulnerables del país, para disponer de semilla en caso de desastres naturales". Universidad del Valle de Guatemala.

Maselli S. 2013. Recursos fitogenéticos: elementos clave para el desarrollo y la seguridad alimentaria. Revista 26 de la Universidad del Valle de Guatemala.

Ministerio de Salud Pública y Asistencia Social. 2015. VI Encuesta Nacional de Salud Materno Infantil (ENSMI 2014-2015) Informe de Indicadores Básicos. Guatemala City.

Melse-Boonstra A, Rozendaal M, Rexwinkel H, Gerichhausen MJ, van den Briel T, Bulux J, Solomons NW, West CE. 1998. Determination of discretionary salt intake in rural Guatemala and Benin to determine the iodine fortification of salt required to control iodine deficiency disorders: studies using lithium-labeled salt. American Journal of Clinical Nutrition 68(3):636-641.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura (UNESCO). 2010. Lemarchand E (Editor). Sistemas nacionales de ciencia, tecnología e innovación en América Latina y el Caribe. 324 pp.

OIM (Organización Internacional para las Migraciones). 2013. Perfil Migratorio de Guatemala 2012.OIM Guatemala. 242 pp.

Orellana A. 2012.Catálogo de hortalizas nativas de Guatemala. Instituto de Ciencia y Tecnología, Agrícolas, ICTA. Guatemala. 100 pp.

Ostry V, Ovesna J, Skarkova J, Pouchova V, and Ruprich J. 2010. A review on comparative data concerning Fusarium mycotoxins in Bt maize and non-Bt isogenic maize. Mycotoxin Research 26(3):141-145. http://dx.doi.org/10.1007/s12550-010-0056-5

Prendergast AJ and Humphrey JH. 2014. The stunting syndrome in developing countries. Paediatric and International Child Health 2014 Nov 34(4):250-265.

Rotterdam Convention 2016. Pic.int. Retrieved 20 December 2016 from: http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

Saldaña-Zorrilla S.O. 2008. Stakeholders' views in reducing rural vulnerability to natural disasters in Southern Mexico: hazard exposure and coping and adaptive capacity. Global Environmental Change 18:583-597.

Sáenz-Romero C, Rehfeldt G, Crookston N, Duval P, St-Amant R, Beaulieu J, and Richardson B. 2010. Spline models of contemporary, 2030, 2060 and 2090 climates for Mexico and their use in understanding climate-change impacts on the vegetation. Climatic Change 102:595-623.

Secretaría Nacional de Ciencia y Tecnología (SENACYT). 2015. Indicadores de actividades científicas y tecnológicas Guatemala 2011-2012. 81 pp.

Secretaría de Planificación y Programación de la Presidencia (Segeplan). 2013. Hambre Cero: Retos para Guatemala. Gobierno de Guatemala. http://www.mineduc.gob.gt/portal/contenido/menu_lateral/programas/seminario/docs13/PACTO%20HAMBRE%20CERO.pdf

Solomons NW, Mazariegos M, Brown KH, Klasing K. 1993. The underprivileged, developing country child: environmental contamination and growth failure revisited. Nutrition Reviews 51:327-332.

Swinburn B, Sacks G, Vandevijvere S, Kumanyika S, Lobstein T, Neal B, Barquera S, Friel S, Hawkes C, Kelly B, L'abbé M, Lee A, Ma J, Macmullan J, Mohan S, Monteiro C, Rayner M, Sanders D, Snowdon W, Walker C; INFORMAS. 2013. INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. Obesity Reviews 14(Suppl 1):1-12.

Torres O, Matute J, Gelineau-van Waes J, Maddox J, Gregory S, and Ashley-Koch A,. et al. 2013. Urinary Fumonisin B1 and estimated Fumonisin intake in women from high- and low-exposure communities in Guatemala. Molecular Nutrition & Food Research 58(5):973-983.

United Nations (2016). Transforming our World: The 2030 Agenda for Sustainable Development. Sustainabledevelopment.un.org. Retrieved 20 December 2016, from: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication

United Nations Development Programme (UNDP, 2010. Regional Human Development Report for Latin America and Caribbean 2010. Acting on the Future: Breaking the Intergenerational Transmission of Inequality. San José, Costa Rica. 208 pp.

United Nations Environment Programme (UNEP). Division of Technology, Industry and Economics. 2000. Guatemala: Investment and Environment Outlook. 1st edition. Accessed at: http://www.unep.fr/shared/publications/pdf/WEBx0043xPA-GuatemalaOutlook.pdf

United Nations University. 2015. World Risk Report 2015. Institute for Environment and Human Security. Bonn, Germany. 68 pp.

Victorino L. No date. Food System Analysis of Guatemala. MGD 150 Methodology Practicum #1: Guatemala. Saint John's University. Accessed at: https://www.academia.edu/23417546/Food_Systems_Analysis_of_Guatemala

Whitmee S, Haines A, Beyrer C, Boltz F, Capon A, and de Souza Dias B, et al. 2015. Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Foundation–Lancet Commission on Planetary Health. Lancet 386(10007) 1973-2028.

World Health Organization (2014). Guatemala – Neonatal and Child Health Profile. http://www.who.int/maternal_child_adolescent/epidemiology/profiles/neonatal_child/gtm.pdf Accessed February 4, 2017.

World Bank. 2015. Guatemala. Nutrition at a Glance. http://siteresources.worldbank.org/NUTRITION/Resources/281846-1271963823772/Guatemala.pdf Accessed February 4, 2017.

Wyss J. 2000. Screwworm eradication in the Americas. Annals of this New York Academy of Sciences 916(1):186-193.

Box 3

Insects as a food source

Jeremy N. McNeil, Distinguished University Professor, and The Helen Battle Professor of Chemical Ecology, Department of Biology, University of Western Ontario, Canada.

As the human population increases and the demand for food grows, we will need to consider alternative food sources. One such possibility is an increased use of insects, both as a food source for humans and as feed for many of the domesticated animals we exploit.

Entomophagy (human use of insects as food) is quite common in many parts of the world, and it is not uncommon to see a variety of species (such as beetles, caterpillars, wasps, crickets and grasshoppers) on sale in local markets (See Figure). Yet, when asked about the idea of eating insects, a large proportion of the world's population would respond with a resounding "How disgusting".

However, as pointed out in the 2013 FAO publication "Edible insects: Future prospects for food and feed" 1 there are a number of very compelling reasons why insects should be considered an important component of meeting the dietary needs of the growing global population.

Insects are significantly better than commonly reared farm animals at converting their food. A cricket will produce one kilo of "meat" for two kilos of food consumed, compared with four for pigs and eight for cows. Furthermore, if one considered the relative amount of an animal that can be eaten (80% for crickets versus 40% for beef) the difference in yield is even greater1. Another difference is that certain insects can be reared using "waste" material as a food source, and thus could provide a partial solution to the disposal of unwanted by-products from other activities. In addition, rearing insects results in far less emission of greenhouse gases, and require a smaller area/kilo produced than livestock.

The protein, lipid, mineral and vitamin content of insects will vary with species, specific life stage and rearing conditions. However, the levels reported to date compare favourably with many animals currently used for human nutrition and thus could be used as part of a balanced diet. One of the major hurdles to be overcome will be the psychological and cultural barriers to eating insects that are prevalent in many societies. Ento, a company in the UK working to introduce insects into the human diet found that people were more accepting if the insects were not clearly visible in the dishes provided2. Thus, the visual presentation of insect-based foods will be important when working to increase their acceptance by the general public.

While getting humans to accept insects as a food source may take some time, the possibility of using insects as a feed source for farm animals such as chicken, as well as in the aquaculture industry may be more readily applicable. Insects would certainly provide the necessary nutrients and both the economic and environmental costs of production, would certainly be lower than for many of the current animal food sources. These possibilities are being considered by international consortia, such as PROteINSECT in the EU.

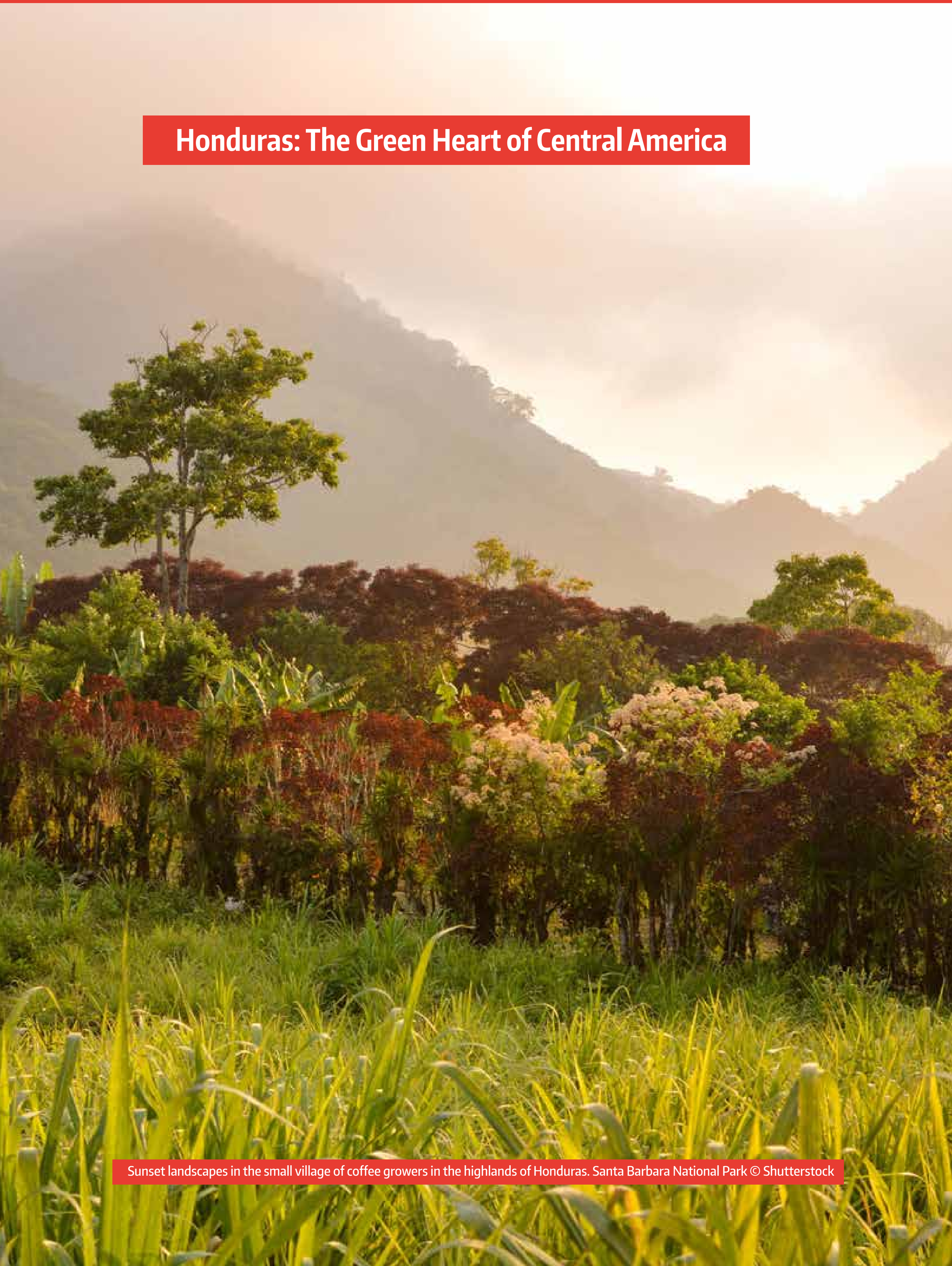
The use of insects as a staple as food or feed offers great promise, including the generation of job opportunities for those involved in the production process. However, there are still a number of aspects that must be addressed as we move forward. At present the majority of insects used as food are produced commercially on a small scale or are collected from natural populations. In the latter case availability could vary with the season and if the demand increases there is a danger that the sources will be overexploited, resulting in ecological problems. Clearly, the alternative is to develop "insect farms" to mass produce species that provide high quality products all year round. Currently there are a few such enterprises internationally, but as the field expands it will require a concerted effort between entomologists, dieticians and entrepreneurs to determine which species and conditions will provide the best quality products at the most reasonable cost in different regions of the world. Furthermore, new research on the possibility of the transfer to humans of pathogens present in insects, on the impact on humans of insect toxins used for defence and on new allergies will be required, as this information is necessary to develop the regulatory guidelines relating to security of insect based food sources. There will also be a need for creative chefs to prepare dishes that appeal to those who find a plate of clearly recognisable insects unpalatable.

References

Van Huis, A., J. Van Itterbeeck, H. Klunder, E. Mertens, A. Halloran, G. Muir and P. Vantomme. 2013. Edible insects: future prospects for food and feed security. FAO Forestry Paper 171. FAO Rome

Chung J. & J. Aguirre-Bielschowsky. 2012. Ento: Introducing edible insects into the Western diet . Antenna 38 (1). 10-15.

Honduras: The Green Heart of Central America



Sunset landscapes in the small village of coffee growers in the highlands of Honduras. Santa Barbara National Park © Shutterstock

Honduras

[1] Carolina Alduvín Sainz
[2] Napoleón Molina
[3] Dinie Espinal
[4] Carlos Almendares

Food insecurity in Honduras affects 72% of the population, mainly in rural areas, because of its extreme poverty conditions, coupled with the degradation of natural resources, climate change, low productivity levels, low education levels, the use of obsolete, inefficient technology, economic constraints on obtaining access to food and uncoordinated state policies.

Summary

Food insecurity affects 72% of Honduras's population, mainly in rural areas, since over half the population lives in extreme poverty. This situation is linked to the degradation of natural resources, climate change, low productivity levels, low educational attainment, the use of obsolete and inefficient technology, economic constraints on access to food and uncoordinated state policies.

There is a vicious circle among agriculture, degraded natural resources and poverty. Extreme poverty and lack of education have led peasants to clear forests to provide farmland which, however, has a forest vocation. This puts pressure on the land, degrades soils and destroys wildlife habitats, reduces forest cover, increases the risk of landslides and floods and exacerbates vulnerability to climate change.

Agriculture consumes agrochemicals and large amounts of water. Climate change puts food security at risk and is expected to cause reduced water availability, increased landslides, a decline in fish stocks and lower agricultural productivity due to rising temperatures. Although Honduras's food security and climate-change policies are designed to address these threats, problems associated with the use of agrochemicals are not a priority. A major challenge is the lack of effective technology and knowledge transfer to peasants. The problem should be addressed by all the sectors, and the following measures implemented: facilitate equitable access to food for the most vulnerable groups; promote agroforestry development to improve food; encourage the use of environmentally- friendly farming practices; promote scientific research focused on national agricultural productivity problems and the use of new biotechnologies to improve this, and reduce the use and waste of harmful agrochemicals through natural organic solutions.

National characteristics

Honduras is one of the poorest, most unequal countries in Latin America. Its average income is US $4,243.00 per capita per year, and a population of 9.4 million. Although the national economy recovered slightly following the global economic crisis of 2008-2009, its finances declined in 2012 and 2013, due to a lack of fiscal discipline, higher current expenditure and high payments for debt service.

The fiscal deficit increased from 2.8% of GDP in 2011 to 7.6% in 2013, slowed growth and increased public debt. Since 2014, measures adopted by the current administration have led to fiscal consolidation. The 2015 World Bank Review notes the country's greater tax collection, better expenditure control, progress in tariffs, and adjustments to subsidies. Last year, the fiscal deficit fell to 4.4% of GNP and poverty rates declined. Nevertheless, 66% of Hondurans live in poverty, 46% in extreme poverty. Poverty in the countryside accounts for 70% of overall poverty and 58% of extreme poverty.

The most depressed rural areas are located in the west and south of the country where rains are scarce and irregular. The Global Climate Risk Index identifies Honduras as the country most severely affected by extreme weather events.

The agricultural sector accounts for nearly 40% of overall employment and the majority of rural employment. Nevertheless, Honduras relies heavily on imports to meet its food needs. Almost half the population lives in rural areas, while 72% of rural households obtain their livelihood from subsistence farming on small parcels. Despite this, the country imports almost all its maize and rice, while beans are produced locally almost every year.

Territorial size

Honduras lies between 12°58' and 16°02' of North latitude, and between 83°10' and 89°22' of West longitude. Its island territory extends to 17°30' of North latitude and 82°30' of West longitude. It has an area of 112,492 km², with a 2,401-km perimeter, 1,597 km of which are borders and 804, shores. It has the following islands: Islas de la Bahía; Islas del Cisne and the Crescent Moon Reefs in the Caribbean, and Isla de Zacate Grande and Isla El Tigre in the Gulf of Fonseca. To the North, it is bounded by the Caribbean Sea; to the East and South: Nicaragua; to the South: Gulf of Fonseca and El Salvador, and to the West, Guatemala.

Its relief consists of Caribbean lowlands, occupying 16.4% of the country. This region has narrow alluvial plains that are constantly flooded, with branches leading into the interior, following the depressions between the mountain ranges. The Pacific lowlands, accounting for 2% of the territory, encompass the Gulf of Fonseca coastline, with mangrove forests and narrow plains of fragmented dry forest. The valleys and highlands of the interior occupy 81.7% of the country's surface, 79% of which corresponds to the mountain system. Honduras consists of 37% of flat land and 63% of mountainous areas, most with a forest vocation. The terrain includes mountains with gradients of over 25 degrees, plains, valleys, rivers and other bodies of fresh water. The highest point is Celaque Mountain, with a height of 2,849 masl (meters above sea level).

Climate

Honduras has a warm tropical climate in the lowlands, which gradually changes to temperate in the higher areas. It has an average temperature of 26°C up to an altitude of 600 m on the Caribbean side. between 16 and 24°C between 600 and 2,100 m, and less than 16°C above 2,100 m. The South has a dry climate and an annual average temperature of 28°C. Rainfall varies considerably throughout the country, ranging from 900 to 3,300 mm depending on the region.

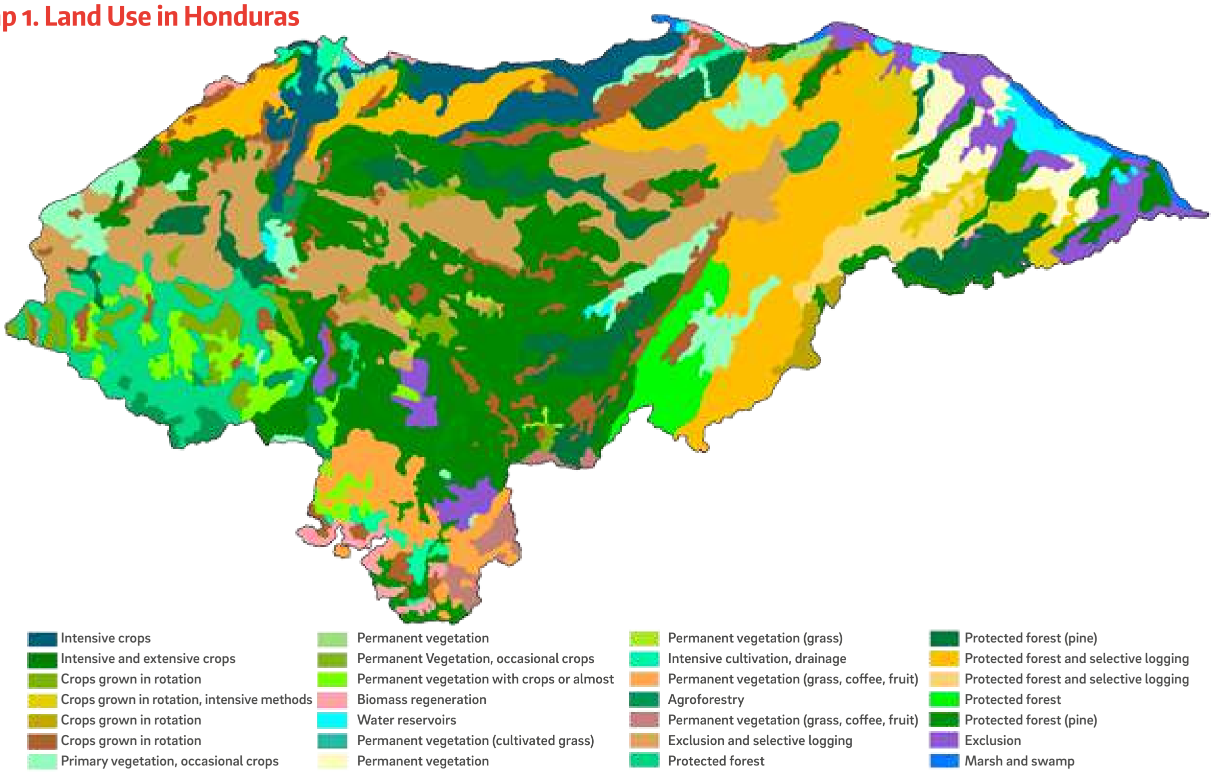
Its tropical location between two oceans and its topography create a wide variety of habitats, from cloud forest to coral reefs, with an enormous diversity of flora and fauna. It has 43,352 km² of forests. Wooded areas are steadily declining due to the felling and burning of their vegetation, which reduces biodiversity and limits the water sources on which the population depends.

Water Resources

Honduras has a water surface of just 200 km². It comprises 21 hydrographic basins, 15 of which flow into the Caribbean and six into the Gulf of Fonseca. In a normal year, they discharge an average of 92.813 million cubic meters of precipitation, at a rate of 1,524 m³/s. Water availability is 11,500 m³/inhabitant/year. There is unequal water access, however, due to distribution problems. The scarcity of drinking water is due to the population increase, a shortage of investment in infrastructure for water collection, purification

[1] **Carolina Alduvín Sainz,** Coordinator. Sc.D, Profesora e investigadora de la Universidad Nacional Autónoma de Honduras, carolinalduvin46@gmail.com [2] **Napoleón Molina,** Sc.D., Project Coordinator, Heifer International Hondura, napomg@gmail.com [3] **Dinie Espinal,** MSc, Professor at the Department of Agricultural Science and Production / Zamorano University, drueda@zamorano.edu [4] **Carlos Almendares,** Sc.D., Head of the Department of Seed Certification, SENASA, Ministry of Agriculture, calmendares81@yahoo.com

Map 1. Land Use in Honduras



Source: Secretariat of Agriculture and Livestock, Info@agro, Directorate of Agricultural Science and Technology DICTA/SAG. Cartographic descriptors Datum WGS 1984 Zone 16N, Geographic units UTM, Units of mapping MTS, Units of measurement Km.

and distribution, as well as lack of maintenance. Moreover, a percentage of the water in the supply systems is lost through leaks, illegal connections and vandalism.

Land

Twenty-four percent of the national territory has agricultural soils, while 76% are for forest use. Nevertheless, over half the country is under cultivation. In fact, 30.5% of the territory is used for agriculture, despite its forest vocation, due to the demographic pressure to obtain land to produce food and guarantee food security, as well as opportunity costs, incentives and entry barriers to alternative land uses, which make forest activities less attractive as income generators.

Forests

In 2011, the Forest Statistical Yearbook estimated forest coverage of 6,598,289 ha, or 59% of the national territory, distributed as follows: 57% of broadleaf forest with 3,747,913 ha; 38% of coniferous forest or 2,579,153 ha; 2% mangrove with 130,894 ha; 2% of mixed forest and 1% of dry forest with 25,017 ha.

Characteristics of Resources and Ecosystems

Honduras has the following bioregions: broad-leaved tropical forest; conifer forest; temperate broad-leaved forest and mangroves. Its habitats include: montane forest; Atlantic Forest; Pacific dry Forest; pine-Oak forest and Caribbean and Pacific wetlands. There are eight life zones: low montane humid forest lm-HF; subtropical humid forest st-HF; low montane very humid forest lm-VHF; subtropical dry forest st-df; tropical rainforest tf; subtropical very humid forest st-vhf; very dry tropical forest vd-tf and dry tropical forest dtf.

The National Map of Honduran Plant Ecosystems, drawn up in accordance with the UNESCO classification system, reports 70 ecosystems, including lagoons, estuaries, reef systems and cities. Working with an ecosystem approach is as yet in its infancy. Through the National System of Protected Areas (SINAPH), the aim is to have a minimum of 12% of each ecosystem under some form of conservation.

Biodiversity

Honduras has a high degree of biodiversity in relation to its size. According to the National Biodiversity Strategy and Action Plan (ENBPA), there are 718 bird species, 59 that are endangered within the country and five on the International Union for the Conservation of Nature (IUCN) endangered list; 228 mammal species, six endemic and 19 under threat; 211 reptile species and 111 amphibian species 36 endemic; 672 fish species, and 2,500 insect species, 14 endemic. There are no systematic records of other groups such as mollusks, or of arthropods other than insects.

In flora, 7, 524 vascular plant species have been recorded, 170 with limited distribution, 134 endemic and 35 with endangered habitats. The registration of fungi, algae, non-vascular pteridophytes or any kind of microbes has not been systematized. Knowledge of biodiversity and research on its components is developed through studies of local and regional flora and fauna, especially in protected areas.

Demographic characteristics and future trends

Of the estimated 9.4 million inhabitants, 52% are concentrated in cities and the rest in rural areas; 38.1% are under the age of 14, 58.3% ages 15 to 64 and 3.6% 65 or older. The country has a population growth rate of 2%, a birth rate of 27/1,000, a mortality rate of 5/1,000, net migration of 2/1,000; infant mortality of 24/1,000 (27% for boys and 21% for girls); a life expectancy of 70 years and a fertility rate of 3 children per woman.

The Economically Active Population (EAP) is approximately 3 million, while agriculture contributes 39.2% of GDP, industry 20.9% and services 39.8%. The unemployment rate is estimated at 27.8%, public debt accounts for 21% of GDP, the inflation rate is 11.9%, the investment rate totals 31.5% of GDP; and economic growth stands at 4%. Ethnically, the 2013 census reports that: 90% of the population are mestizo, 7% indigenous, 2% black and 1% white. The country has a literacy rate of 80% and an average of 11 years' schooling, while 3.8% of the GDP is assigned to education. There are nine distinct ethnic groups within the mestizo population with an estimated population of 600,000.

Lack of food and nutrition security

The World Bank's Food Program estimates that 60% of Hondurans experience some form of food insecurity. One in four children is malnourished, meaning that their lives are cut short. In the most depressed regions, 58% of children under 5 suffer from chronic malnutrition, characterized by low weight, low height, insufficient breastfeeding and complementary breastfeeding practices. A high priority for the Honduras Government is to eradicate poverty and increase food and nutrition security.

Farming Modalities

In Honduras, family farming coexists with medium- and large-scale private farms with plantation crops and industrial crops such as sugar cane and African palm. Since colonial times, the land ownership regime has been the main source of inequality in the income and living conditions of the country's inhabitants.

Agriculture is the primary source of income and food security for the rural population. Productivity, however, is low, inefficient and extremely vulnerable to external factors. In 2012, it accounted for 14% of GDP and 70% of exports. The agricultural sector lost almost a third of its purchasing power in the past two decades, due to the fall in prices of export crops. It has improved productivity in the lowlands by exporting nontraditional products such as fruit and vegetables, and diversifying rural economic activities such as tourism, handicrafts, fishing, sustainable wood production and processing, and environmental services.

Small and medium producers are excluded because of sharp differences within the rural sector and the challenges they face. Most grow low-value crops, for on-farm consumption and local markets. Women farmers face additional challenges: less access to capital, training, inputs and markets. Women with access to land have smaller plots on less fertile soils, with less potential to grow export crops than men.

Quesungual

This is an ecologically friendly agroforestry system that has improved the living conditions of small farmers with scant resources. In Honduras, nearly 78% of the land used in agriculture is on slopes, where there are problems of safe water supply and soil erosion, which have been exacerbated by climatic variability and change. For generations, traditional agriculture has had a negative impact on livelihoods, food production and the environmental quality of the surrounding communities.

Two decades ago, peasants in the south-western part of the country - with the help of FAO - began to develop the system. Previously, the slash-and-burn method was used, which involved felling part of the forest and burning the waste. Parcels were cultivated from one to three years, until yields declined together with soil moisture and fertility. Farm workers were subsequently forced to move to a new plot of land to repeat the destructive cycle.

It was an inadequate, inefficient way of cultivating sloping land with fragile acid soils, which progressively depleted resources and food security. *Quesungual* consists of: 1) No slashing and burning: partial, selective and progressive vegetation management; 2) Permanently covering the floor: continuous depositing and distribution of the biomass coverage of native vegetation and crop residues; 3) Minimum soil disturbance: zero tillage and direct planting; 4) Efficient fertilizer use: accurate application regarding time, amount and form.

This system is used to cultivate maize, beans, sorghum, vegetables and soybeans. Farmers now clear the vegetation by hand. Trees that were

Box 1. Coffee growing as a feature of food security

Maritza Midence, Highland Coffee of Honduras, highland@cablecolor.hn

Honduras's coffee vocation is determined by its mountainous topography. This was first recorded in the 18th century, when the production of "abundant harvests of such excellent quality such as "moka" was already mentioned.

In 1974, devastating Hurricane Fifi affected crops in the high mountains to a lesser extent, and coffee was identified as a strategic cash crop. International prices suddenly rose by over 300% in 1975, as a result of the crippling frost that destroyed over 70% of Brazil's coffee plantations, which supplied approximately 40% of the world market at the time. Spurred by this incentive, Honduras exported its first million quintals in 1981. The minimum price guaranteed by the international quota system increased Honduran coffee production. In 1989, and the world coffee market changed to "free market" conditions, which have remained to this day.

Even without the quota system, Honduran coffee production continued to grow as a result of training producers, adopting new varieties and growing methods, and finding a market in Northern Europe, the US and Japan. Coffee exports grew exponentially from 1974 to 2001. In 2004, the first Cup of Excellence was held. As a result of this contest, the country committed to quality growth and is now the third largest producer in Latin America. It is also recognized as a producer of special and differentiated or gourmet coffee with international certification, accounting for 25% of total coffee exports.

Approximately 110,000 registered producers depend directly on coffee and generate jobs that occupy nearly a third of the EAP according to the National Institute of Statistics (INE 2016). Coffee is grown in almost 300,000 ha in 15 of 18 of Honduras' departments. Exports from the 2016/17 crop are expected to generate $1.2 billion USD in foreign exchange. Income depends on the quality and/or volume of production, the system used and its level of organization to pay for certification. There are guaranteed minimum prices when selling coffee certified by the Fair Trade Organization (conventional and organic). Specialist coffees generate much higher income than generic coffees, which provides more purchasing power for farmers to be able to meet their nutritional needs.

The Honduran Coffee Institute (IHCAFE), created in 1970 as an autonomous government agency, was privatized in 2001, and since then, has belonged to the producers. IHCAFE controls Honduras's coffee policy. In less than 50 years, coffee production has increased the value of farmworkers' labor. In Lempiras (L.), wages rose from L. 3.50/day ($1.75 USD) in 1970 to L. 10/day ($ 5.00 USD) in 1990, to L. 70/day ($4.67) in 2000, to L 120/day (US $6.32) in 2009 to L. 165/day ($7.17 USD) in 2017. It has also increased the price of their land which, according to the region of the country in which they are located, has risen from L. 14,000/ha ($7,000 USD) in 1970 to L. 214,000/ha ($9,300 USD) today.

previously cut and burned constitute a source of fruit, firewood and furniture wood, in addition to providing a fresh microenvironment for their crops. A typical plot contains approximately 20 large timber and fruit trees, in addition to hundreds of small trees and shrubs. They are regularly pruned to allow the passage of light and a period of recovery and thereby promote growth. This permits year-round cultivation on the same plot of land. By improving soil quality and management, the *Quesungual* system increases production, requires less labor, retains moisture better, is low-cost and has reduced greenhouse gas emissions and retained more carbon.

Major crops

According to the National Agricultural Survey, crops such as banana, plantain, sugar cane, African palm and pineapple are grown on more than 30,000 farms, with a cultivated area of 227,326 ha, producing 8,404,460 MT. Citrus fruits, coconut, papaya, mango and other fruit trees are common in family orchards, even in urban areas. Annual crops such as melon, watermelon, tomato, potato, chili and onion are produced at 8,840 farms covering 19,580 ha, with a productivity of 508,263 MT. Basic grains such as maize, beans and rice are planted on 117,647 ha, of which 80% are technified, the remainder involving subsistence farming.

Livestock

Extensive livestock production is carried out on 9.7% of the territory, on the best valleys and coastal plains, driving many small subsistence farmers onto the slopes. Preference is given to dairy and beef cattle, pigs and poultry and to a lesser extent, goats, sheep and bees.

Fishing

Most fishing is carried out using small artisanal boats, which catch shrimp and lobster, as well as fish, while aquaculture produces tilapia and shrimp.

Industries

The main industries are sugar, coffee, honey, preserves, textiles, woods, clothing, crafts, food processing and tourism.

Is the country self-sufficient in agriculture?

Definitely not. Domestic food production expanded in the 1980s and 1990s but has declined in recent years and is still insufficient to meet the needs of a growing population. A negative trend in per capita food production has therefore been observed that is exacerbated by the fact that postharvest losses are significant, despite the efforts undertaken made by specific projects. This is turn is compounded by inefficient marketing, transportation and storage.

Food and nutrition security

Food and nutrition security only exists when all people have access at all times to sufficient, safe and nutritious food to meet their nutritional needs and cultural preferences for leading a healthy, active life. Food availability in Honduras is related to the national capacity to produce it and allocate it for families' consumption. Agriculture is a major source of employment, income and foreign exchange that provides food and indirectly contributes, through imports, to supporting the country's food supplies.

Basic grains are crucial to the country's food security. They are produced by thousands of families who have historically inhabited the worst hillside lands. Their contribution, particularly of maize and rice, is declining. The balance between domestic production and total demand is negative for maize, the crop with the highest production and consumption. Since the 1990s, its production has steadily declined, registering a deficit of over 250,000 MT.

The country's food availability is therefore increasingly reliant on the international market, meaning that export crops and other sectors of the national economy become increasingly strategically important. Import capacity is a key element for guaranteeing Food and Nutrition Security. Measures are needed to intensify agricultural and rural development and thus increase food availability.

Food Access

This is the most important component for combating food insecurity. In the fight against poverty, facilitating access to food involves two aspects- The first involves producers, by promoting access to means of production such as land and property deeds, technical assistance, improved seeds, environmentally-friendly fertilization, agroforestry, irrigation, year-round roads, markets, postharvest treatments, competitive prices and everything else required to make them efficient. The second entails stimulating the rural economy by generating more sources of employment and income, with access to credit for micro and small enterprises in depressed areas, and large agribusiness projects, to export vegetables and fruits and to produce bioenergy from sugar cane and oil palm in the most productive valleys and plains, without forgetting better market conditions.

Urban and rural poverty

Several factors are responsible for rural poverty in Honduras, particularly lack of access to and insecurity in land tenure, the abandonment of food production and the constant deterioration of the terms of trade for raw materials and agricultural foodstuffs, due, on the one hand, to the lower prices paid to the producer and, on the other, to the inflationary effects of the rise in oil prices, such as the sliding devaluation of the currency.

Non-coffee exports are neither constant nor uniform, which negatively affects the wages of the national labor force, which, in turn, undermines the food security of large segments of the rural and urban population. The crisis in the sector forces the rural population, especially young people, to migrate to cities and the US in search of job opportunities. Thus, poverty extends to urban areas, where it acquires new features and changes consumption patterns.

The surplus non-migratory labor force that does not migrate is located in the urban informal sector, expanding micro, small- and medium-sized enterprises, which account for nearly 34% of the EAP and produce approximately 25% of GDP. Although they suffer from the same limitations of the formal economy and threats to the passage of free trade agreements, companies on these scales are regarded as a decisive factor in the family economy of the urban poor and a source of hope for reviving the rural economy by creating new non-agricultural jobs. New interventions should consider these profound changes if food and nutrition security is to be achieved.

Unequal food access

The cost of the basic food basket for a family of five in the early 1990s was L. 10.04 and L. 34.00 in 1995. In 2010, it stood at L. 6,400.00, when the minimum wage was L. 5,500.00. At present, the cost is L. 7,700.00, well above the income of the poorest families. The price of the basic food basket changes on a monthly basis. Price instability and variability are due to low production, intermediation, scarcity, speculation and unemployment. Rising food prices, speculation and hoarding pose constant threats to Honduras' weak economy.

Remittances contribute to reducing the food and nutrition insecurity of the senders' dependents. In 2014, the impact of this type of income on the 284,000 households that declared receiving them was US $ 3,465 million, of which 53% are not poor and are the ones that support the country financially.

Main export/imports

The agri-food trade balance in Honduras has shown a downward trend, in which food imports are growing at a faster rate than agri-food exports. This trend has intensified since the 1990s, when the country adopted a policy of trade liberalization, as part of its agreements with international financial institutions - and expanded its Free Trade Agreements (FTA), especially with the US, and other trade liberalization mechanisms such as the Central American Customs Union.

There is increasing food dependence on the international market, especially regarding cereals. The exacerbation of these trends as a result of the Central American Free Trade Agreement (CAFTA) prompted the need for an agri-food strategy that would consider the impacts on the national economy, especially on agriculture, since a gradual tariff reduction program was only established to temporarily protect a group of sensitive agricultural products, such as white maize, rice, beef and pork, and milk and dairy products.

Impact of environmental vulnerability on food production

In recent years, the country has experienced growing environmental vulnerability with serious repercussions on the quality of life, especially regarding its population's food security. A key factor is the conflict between the current use and productive capacity of the soils. This is one of the country's main environmental challenges, since agriculture has been practiced on unsuitable where as early as the late 80s, it was estimated that 22,682 km² were overexploited.

Annual droughts, due to the El Niño Southern Oscillation (ENSO) phenomenon, cause recurrent food crises in the southern, central and western regions of the country, home to the largest peasant population, which depends on the production of basic foodstuffs. The rule is that during these years, over ¾ of the area under cultivation is lost.

Possibility of achieving MDG targets

Table 1 summarizes the status of the indicators used to assess the results of efforts in the country to achieve the goal of reducing poverty and hunger in the Millennium Goals (MDG). The results are positive for the chronic malnutrition indicator yet insufficient for overall child malnutrition.

Main agricultural challenges

1) Invest in women: Protect and strengthen women's capacity to provide food, health and nutrition security for their families. 2) Increase year-round access to and availability of foods with high nutritional value. 3) Improve knowledge of nutrition in rural households with an emphasis on dietary diversity. 4) Incorporate explicit nutritional goals and indicators into agricultural investments.

Priority objectives of nutritionally sensitive social protection

1) Focus activities on the populations with the greatest nutritional vulnerability such as pregnant women and children aged two or under. 2) Include nutritional education and counseling in social intervention programs to raise awareness about health care and seeking behaviors. 3) Integrate nutritional services into social protection interventions, which improve the quality and quantity of diets. 4) Reduce the acute long-term negative financial impacts of external financing, price and climate shocks by stepping up programs at times of crisis and focusing on impacted areas.

Priority objectives for improving nutrition through the health sector

1) Reduce micronutrient deficiencies. 2) Reduce anemia in pregnant and breastfeeding women. 3) Promote good food and nutrition practices. 4) Prevent and treat diseases. 5) Reduce low birth weight. 6) Improve reproductive health and family planning. 7) Correct moderate and severe malnutrition in children.

Table 1. Summary of indicators used

Indicators	Unit	1990-92	2004-05	Gap	Progress	2015
Overall child malnutrition (P/E)	%	21.4	18	-7.3	Insufficient	10.7
Chronic child malnutrition (T/E)	%	42.4	30	-8.8	Positive	21.2
Acute infant malnutrition (P/T)	%	1.8	2	-1.1	Negative	0.9
Proportion of undernourished persons	%	22	23	1	Negative	11
Undernourished persons	Persons	1.11	1.61	-0.62	Negative	0.99
Productivity in basic grains	Qq/mz	26	23.6	-2.7	Negative	n.a.
National food deficit (maize)	MT	49,992	271,276		Negative	0
Agrifood trade balance	USD	568	97		Negative	0
Total population	millions	5.03	7			9

Notes: NA = Not Applicable, there is no goal for the indicator. Although there was no target for 2015 for the maize deficit and agri-food trade-balance indicators, they should ideally have zero sum balances.

Institutionality

In 2009, the Law for the Establishment of a Country Vision and the Adoption of a National Plan for Honduras was approved, thereby institutionalizing the process of strategic planning for the country's economic, social and political development. Both include socioeconomic development initiatives to achieve food and nutrition security goals. In 2010, an Executive Decree was approved that resulted in the 2010-2038 Country Vision, which declares the food and nutrition security of the Honduran population a national priority, framing the Long-Term Food and Nutrition Security Policy (PSAN) and its Implementation Strategy (ENSAN) within the objectives, goals and strategic guidelines established.

The Country Investment Plan for the Agri-Food Sector (PIPSA) was also approved to expand the agricultural sector. This decree transforms the institutional Food and Nutrition Security framework by stating that the Food and Nutrition Policy is multisectoral and that its Implementation Strategy should be implemented by all the State Secretariats. At the same time, the Technical Unit for Food and Nutrition Security (UTSAN) was institutionalized as a national technical body for the coordination, planning, monitoring, evaluation and formulation of methodological procedures of the PSAN and ENSAN. The Interinstitutional Technical Committee on Food and Nutrition Security (COTISAN) was also confirmed as a consultative body that brings together public and private institutions and external cooperation agencies involved in this issue.

The coordination of international cooperation is overseen by the Technical Cooperation Secretariat (SETCO); programming and budgeting by the Ministry of Finance (SEFIN); the implementation and supervision of productive projects, by the Secretariat of Agriculture and Livestock (SAG); land tenure and legalization by the National Agrarian Institute (INA) and marketing and distribution, by the Secretariat of Economy (SE). Civil society participates through NGO, the Association of Municipalities of Honduras, municipal governments and their communities.

Public programs and projects related to Food and Nutrition Security

Table 2 summarizes the main programs and projects identified. Most projects distribute food, provided by USAID and WFP in the rural poorest departments of the country's West, South and Central

Table 2. Major government programs linked to Food and Nutrition Security

Program / project	Duration	Sponsor	Amount
Comprehensive Assistance to Vulnerable Groups	2003-2007	Government PMA	L. 20'000,000 L. 3'142,340
Atención Integral a la Niñez en la Comunidad AIN-C	2006-2010	World Bank Government	12'000,000 L. 3'000,000
Maternal and Child Coupon	2005 -	Government	L. 21'719,600
Integral Women's Development	2005 -	Government BANPRAF	17'200,000 30'301,750
Technical Assistance in Nutrition and Social Protection	2005 -	World Bank Government	1'000,000 L. 19'000,000
Rural Forestry and Productivity Project	2004-2006	World Bank Government	18'000,000 L. 4'000.000
Healthy Schools Program	Continua	G. Taiwan PMA	17'510,000 L. 29'870,000
Food and Nutrition Support Program	2006-2009	European Union	E. 13'500,000
Food Security/CA Regional Program	2006-2010	European Union	E. 12'000,000
Food Security-Honduras Special Program	2000-2007	AECI-FAO Government	2'664,759 L. 10'739,325
Approximate total			**123'229,987**

regions. They are implemented by national NGO and international NGO such as CARE, World Vision and Plan International (**Table 3**).

A state agency is required to direct and coordinate Food and Nutrition Security programs and projects. For the time being, they are implemented with a lack of integration, very little accountability and scant guidelines for a national policy and long-term strategic plan that would clearly and decisively reflect the will of the Honduran State to achieve the MDG Goals

Agricultural research

Agricultural research is scarce and largely unrelated to national development, particularly Food and Nutrition Security. It is carried out by the central government, through the Secretariat of Agriculture and Livestock (SAG), which has the Directorate of Agricultural Science and Technology (DICTA). In the public academic sector, it is undertaken by the National Autonomous University of Honduras (UNAH), the National University of Agriculture (UNA) and several mid-level agricultural technical schools. In the private academic sphere, it is carried out by Zamorano University and the University of San Pedro Sula (USPS). In the private sector, research is conducted by the Honduran Foundation for Agricultural Research (FHIA) and several fruit and agroindustry companies.

SAG-DICTA

A leader in the scientific and technological development of the country's agri-food sector, it implements public policies at the national level and provides services for producers. Its mission is to design, direct, regulate and implement programs of research, technology transfer and promotion to family agriculture that will enhance producers' innovation capacities in order to develop the agricultural sector and food security.

At its offices and central laboratories, as well as its 11 regional headquarters, it develops breeding programs for maize, sorghum, beans, rice, chili, tomato, potato, avocado and cassava, a plant and livestock production program, and a national seed, plant and fruit tree system. In the livestock sector, it promotes the production of pigs, poultry and fish farming. In technology transfer, priority is given to the training of technicians, the productive solidarity bonus and promoting household orchards.

It has implemented the National System of Phylogenetic Resources by officializing the National Committee for Phylogenetic Resources of Honduras (CONAREFIH), comprising public, academic and private institutions. With the help of FAO, it has produced the National Diagnosis of Phylogenetic Resources for Food and Agriculture. It established the National Information Exchange Mechanism (MNII), as a follow-up to the Global Action Plan adopted by 150 countries with regard to the International Treaty on Phylogenetic Resources for Food and Agriculture.

DICTA is a member of the Central American Integration System for Agricultural Technology (SICTA), the International Potato Center (CIP), the International Center for Tropical Agriculture (CIAT), the Inter-American Institute for Agricultural Cooperation (IICA) (FAO) and other regional programs. DICTA holds the rotating presidency of the Central American Cooperative Program for Crop and Livestock Improvement (PCCMCA), with the motto: "Let Us Generate Technology to Harvest Development".

Table 3. Major government programs linked to Food and Nutrition Security

Program / project	Duration	Financial entity	Amounts
Food Security PL80 Title II	2005-2009	USAID-CARE	5'500,000
Food Security in Santa Bárbara	2005-2009	USAID-ADRA	3'242,514
Rural Management in Food Security	2005-2010	USAID-Save the Children Honduras	3'008,176
Food Security Improvement and Risk Reduction in Western Honduras	2005-2009	USAID-World Vision	4'236,712
Approximate total			**15'987,402**

UNAH

This institution is responsible for higher education and professional training, as well as for undertaking teaching, research and outreach activities. In the agri-food sector, it offers professional degree programs in Agronomy Engineering, Forestry Engineering, Aquaculture Science and Coastal Marine Resources, Agroindustrial Engineering, Biology, Microbiology and Nutrition. At the technical level, short degree programs are available in Dairy Processing, Agricultural Production, Livestock Production, Food Technology, Food and Beverage and Coffee Quality.

Few university professors undertake research and not all of them publish for various reasons, the main one being the lack of recognition of the extra effort involved in publishing. Those who decide to research face challenges such as the lack of financial and logistical support. They also fear being constricted by institutional and customs bureaucracy, and working with inadequate, obsolete and insufficient equipment, if indeed it exists. There are no incentives such as a National System of Researchers and they barely earn some of the hundreds of points needed for their promotion every few years.

National University of Agriculture

This university offers degree courses in Agronomic Engineering, Veterinary Medicine, Food Technology, Natural Resources and Environment, and Agricultural Business Administration. It is located in the center of the country, in one of the richest, most productive departments regarding agriculture. Its mission is to contribute to the scientific, technological and socioeconomic development of Honduran society with an emphasis on the rural sector, through the training and improvement of professionals in agricultural and related sciences.

It has an Agro-Food Social Inclusion Observatory that conducts research to promote innovation and sustainable agro-food development in Honduras. It is equipped with a virtual library on health and other programs to protect natural resources and the environment and is supported by other universities and cooperation and research agencies such as IICA and the German International Cooperation Agency (GTZ).

Zamorano University

This university began as a Pan American Agricultural School in 1941 as a legacy of a transnational fruit company. It is located in Yeguare Valley, in the East of the country, and trains professionals to leverage the productive potential of the agricultural sector of tropical America. On the basis of the motto "Learn by Doing," it has trained 71 classes of agronomists, and engineers in agricultural science and production, agroindustry, agribusiness and socioeconomic development and environment.

It has the best facilities and laboratories in the country for studying biological sciences. The teaching staff and students are mostly Hondurans accompanied by colleagues from other countries in the region, North America and Europe. It has large tracts of land for crops, livestock facilities, workshops, greenhouses, ponds, warehouses, as well as forests and other ecosystems to undertake all the field practices required to produce food and manage natural resources.

All the students are boarders with permission to leave on some weekends. Students grow and process much of what they eat, in addition to marketing the surplus on campus. They have a strict schedule that include classes, laboratory and field practices, study hours and personal activities. In the last year, they go to other areas or countries to collaborate with companies or communities as part of their training and write a thesis on a research topic developed by their tutors.

FHIA

FHIA began as the research department of a fruit company. It is still private, yet willing to collaborate with the public and academic sectors. It is located in the North of the country, adjoining large plantations. It is dedicated to the improvement of tropical crops, especially export fruits such as bananas, citrus fruits, coconuts, pineapples and others. Another field of study is the fight against the different diseases that plague crops by studying the mechanisms of interaction between plants, vectors and pathogens. With its well-equipped laboratories and highly qualified technicians, the results of its research are the property of those who finance the operations, meaning that special permission must be obtained to publish them. The government and private individuals have the option of contracting research or specific services within the scope of their interests and capacities.

National School of Forestry Sciences

This school trains foresters and engineers for the management and use of Honduran forests. It provides training in agroforestry and forestry to various groups of farmers. It is located at the entrance to the city of Siguatepeque, on the North Highway, in the center of Honduras.

Research capacities

Research capacity is limited in quality and areas-of- interest. Educational institutions have an enormous accumulated deficit in terms of laboratories, equipment, material and specialized professionals, budget and training programs. This is very difficult gap to close since, although education is considered a national priority, research is not always part of the training process.

Local areas of strength

In the country, nearly everything has yet to be done or established, meaning that all initiatives are welcome; what is needed is support and recognition. Many efforts have gone unrecognized because they have not been published in indexed journals, yet they can be used as a basis. A great deal of information is scattered in various sources, which much be collected, organized and validated to foster a new research culture.

Scientific collaboration networks inside and outside the country

The Secretariat for International Cooperation, the Secretariat of Science and Technology and its Honduran Institute of Science, Technology and Innovation (IHCIETI), SAG, the Secretariat of Health (SS) and others keep documents and data on their respective interventions. The main higher-education institutes have some means of promoting scientific research. However, the most efficient form of collaboration is achieved through the personal contacts each active researcher has established abroad.

Another form is scientific networks, such as the Latin American Network of Biological Sciences (RELAB), under the aegis of UNESCO, sponsor courses, scientific meetings, internships, training and other forms of assistance. Since 1975, it has helped scientists from less developed countries participate more frequently in programs and refresher courses in the most advanced countries with respect to biotechnology, bioinformatics, biodiversity management and other leading-edge topics. Although Honduras joined in 1990, it has scarcely participated in these activities. FAO's REDBIO is concerned with agricultural research issues across the continent, and other networks on more specific issues. IANAS, which brings together the Academies of Sciences, is the best example and a network could be created for Food and Nutrition Security. IANAS is concerned with various issues such as water, energy and Food and Nutrition Security.

Access to and maintenance of databases for monitoring farming systems

We have regular access to SIMPAH, INFOAGRO through the Internet.

Development of trained workforce and status of national education systems

This is carried out at the institutions mentioned earlier, as well as at the intermediate level. It is essential to increase their budgets, quality and quantity in order to transfer practical and theoretical knowledge, and sensitize and strengthen farmers, regardless of the scale at which they operate. It is vital to analyze their needs and gaps, allocate resources to close them and implement strategic plans to improve their services and bring them to the entire population.

There are radio programs that share good agricultural practices and advice on the rational and proper use of agrochemicals. They provide criteria for the selection and preparation of food to provide the greatest benefits and ensure a balance of all the nutrients. They operate in conjunction with existing broadcasts and improve the state's agricultural outreach services. It is essential to link university centers to value chains and to adapt the courses offered by these centers to the demands of the producers, processors, merchants and exporters that comprise them.

Energy challenges

Honduras is among the 30 countries with the lowest per-capita energy consumption in the world, equivalent to 0.6 tons of oil. The country meets half its energy needs with internal sources. It has the potential to be energy self-sufficient, since it has abundant natural resources serving as renewable energy sources.

The energy matrix comprises fossil fuels and the use of biomass. There is a small wind farm with generators to meet the demand of municipalities and hamlets a few kilometers South of the capital. Fuel wood generates 43% of domestic energy and at the residential level accounts for more than 87% of the fuel used. This is followed by fossil fuels, used to produce 62% of the country's electricity. A total of 84% of households are connected to the national electricity grid. The main cities have been electrified, while fewer than half the households in remote regions have coverage. Plans are underway to provide 2GW by 2022, through 40 projects, including renewable energy.

Economic energy is wasted. Every year, coffee produces 90,000 MT of waste, which would guarantee 10 times the country's electricity needs. Although livestock and poultry waste have the potential to produce 72 MW biogas power, they are not used either. Solar energy production is as yet incipient, with just one program for 6,000 families in the South of the country sponsored by the World Bank, which currently does not exceed 25 kW. Zamorano University has just inaugurated the largest solar-energy park in Latin America, with the capacity to produce 1,500 MW hours, equivalent to 30% of the electricity demanded by the university campus.

Development of aquaculture and marine resources

This subsector includes artisanal and industrial fisheries, and the Caribbean, Pacific and mainland regions. It generates over 55,000 positions, mostly in the industrial aquaculture export sector. This subsector accounts for 4% of national exports to the US and German markets.

The viability of fishing is threatened. The industrial fleet has shrunk by 30% this century. Boats date from the 1980s and do not meet current quality, efficiency or hygiene standards. There is a higher incidence of overfishing in territorial waters, because non-adult specimens are not returned to the water. The varieties under the greatest pressure are lobster, shrimp, giant snail and coastal sharks. External regulations such as CITES attempt to mitigate certain practices, which mainly affect artisanal fishing.

The ecological quality of coastal waters has declined due to organic contamination from sewage and agroindustrial waste, heavy metals and non-biodegradable material. The problem of land waste is exacerbated by the temperature increase caused by climate change, which decreases the amount of oxygen dissolved and affects the growth of fish. Increased acidity reduces the availability of calcium for the formation of fish bones, forcing the more susceptible species to migrate to cooler waters. Honduras lost half of its 150,000 ha of mangroves between 1980 and 2005, due to the expansion of shrimp farms. Continental aquaculture offers more sustainable long-term production, although at present, this sector creates fewer than 10% of the jobs in the subsector. The main type of fish produced is tilapia in factories, in addition to several domestic mini-farms or those attached to highway restaurants. Trout farms have not flourished.

Measures to take advantage of food and minimize waste

Hondurans in the countryside tend not to waste food. SAG promotes the construction of artisanal silos to minimize postharvest losses. Bt maize is authorized and released throughout the country. Since it is not bitten by pests, it maintains greater integrity and is therefore able to resist fungus attacks.

Conflicts among food, energy and fiber production

Conflicts are virtually non-existent since maize is used entirely to feed either livestock or humans; so far it is not used to produce ethanol or fibers. The same is true of other food crops.

Main infectious diseases

The main diseases are caused by food or water contamination: bacterial diarrhea; hepatitis A, and typhoid fever; vectors: dengue and malaria, Zika and chikungunya; acute respiratory infections, caused by sudden changes in temperature and contact with water, leptospirosis.

Food regimen

Honduras is regarded as a malnourished country due to the population's deficient intake and generally unbalanced diet. An average of fewer than 3,000 kilocalories is consumed per day per person and is estimated that 70% of these calories come from relatively low-carbohydrate foods such as corn, cassava, rice, beans, potatoes, potatoes, bananas, sugar and wheat. Cereals provide over 50% of protein, and there is a significant deficit of animal protein. Fish consumption is still low in relation to the national potential.

There are deficiencies in calcium, iodine, iron and sodium chloride requirements; while cases of geophagy have been reported among peasants. High temperatures cause excessive perspiration, which increases the demand for salt. There are also significant vitamin deficiencies due to ignorance and the fact that people are not used to including fresh vegetables in their diet. Most of these deficiencies occur in rural areas. Forty percent of the population suffers from malnutrition, which is particularly acute in infants.

Biological use and consumption of food

A person's health status is determined by what s/he eats, while a balanced diet enables him or she to take advantage of all the nutrients contained in food. Health is influenced, among other things, by nutritional status, nutritional and health knowledge, the care received and the health conditions of households and communities. In order for food intake to produce desirable results, the body must be free of disease, particularly infections that negatively impact nutrient and food energy utilization.

Global malnutrition

Also called moderate-to-severe underweight, the official indicator for measuring the MDG Goal is defined as: "The number of children under 5 with lower than normal weight". The country's rate global nutrition rate has varied since it began to be measured in 1990, although in the past two years, it has remained stable at around 18%.

Chronic malnutrition or stunted growth

This is measured by the delay in growth in relation to chronological age. In Honduras, it affects 31% of children ages 0 to 5 and has irreversible effects on people's development. It is related to long-term conditions, including chronic food shortages, frequent infections, incorrect dietary practices and extreme poverty.

Spatial distribution of malnutrition

Geographically, child malnutrition is concentrated in rural areas, where it doubles the chronic prevalence of urban areas, decreasing in larger cities, and increasing in smaller ones. The areas with the highest incidence of undernourished children are the West, South and Center, in that order.

Per-capita consumption of simple vs. processed foods

Honduras is undergoing a process of food transition that it shares with neighboring countries. The growing urbanization and diversification of the Honduran population's sources of income and greater exposure to the consumption patterns of industrialized countries, as well as the aggressive transnationalization of agri-food chains, trigger a series of changes in consumption and the national food culture. Simple foods from peasant agriculture are being replaced by foods with a higher degree of processing, derived from agroindustries.

This food transition requires rethinking food-security strategies and interventions in order to significantly reduce food-insecurity indicators, particularly in urban areas, which involves addressing a two-fold challenge: persistent hunger in the population living in extreme poverty on the one hand, coupled with the rapid increase in the number of non-communicable diseases associated with dietary habits such as obesity, hypertension and diabetes in the urban population.

Consumption patterns and their changes, and the implications of food imports

The pattern of food consumption in a population refers to the set of foods most commonly used by the majority of the population. In urban areas, 17 products are used by 75% or more of households, whereas in rural areas, only five are consumed, namely: eggs; rice; beans; sugar and salt. The number of foods used by 50% of the population totaled 31 in the cities and 20 in the countryside. These differences show that food diversification is not the same in urban and rural areas. The greater the diversification, the better the quality of a person's diet. **Table 4** shows the percentage of households using the most common foods at the national, urban and rural levels.

In urban areas, more animal protein is consumed whereas in the countryside, only cheese, eggs and poultry are eaten. In rural areas, 85% of households use vegetable shortening, compared to only 58% in cities; the remainder consume oil or margarine. Beans are commonly used in about 90% of households, as is sugar. Over 50% of households eat rice, pasta and pastry; corn seed is only reported in the western and eastern regions, whereas fewer than 50% of households in the Central region consume tortillas. Both juices and soft drinks are mainly consumed in the Central region.

In rural areas, the number of food products used in households is noticeably lower, which reduces the dietary quality of their inhabitants. The greatest diversity of food is consumed in the Central region and the smallest in the western region. The basic basket consists of 31 products for the cities and 20 for the countryside. The most commonly used vegetables are onions, tomatoes and potatoes, while the most popular fruits are bananas, plantains and oranges. Food consumption is affected by poverty levels. Non-poor households consume 31 products, those living in relative poverty use 29 while those in extreme poverty ingest 20.

Food quantities

Household purchases, or apparent consumption, are indicators of food availability. The unit is gross gram available per capita per day; values are expressed as medians. Six categories are created and corn seed is expressed in grams of tortilla (**Table 5**).

Table 4. Proportion of households using each food by area

Food	National	Urban	Rural
Refined sugar	94	95	94
Eggs	91	93	88
Rice	91	93	90
Beans	91	91	92
Salt	81	80	82
Cheeses	78	90	65
Poultry	81	89	73
Bananas and plantains	76	83	68
Tomato	67	82	51
Onion and similar	72	82	62
Sauces and dressings	69	81	56
Pasta	74	80	68
Potatoes and tubers	67	78	55
Condiments	68	78	58
Pastry and similar	73	77	69
Citrus fruits	74	77	72
Dehydrated soups	74	75	73
Vegetable shortening	71	58	85
Cream	59	74	43
All kinds of chile	55	71	38
Sod		70	42
Liquid milk	56	70	42
Juices and soft drinks	52	66	38
Sausages and ham	47	67	26
French bread and similar	47	64	30
Breakfast cereals	45	63	27
Margarine	46	60	31
Vegetables for salad	46	59	32
Tortillas	37	59	15
Boneless beef	41	57	25
Avocado	39	51	26
Squash and christophenes	50	48	52
Corn kernels	48	22	74
Carrot and beet	32	47	17
Vegetable oils	29	44	13
Cornmeal	35	43	27
Pork	33	43	22
Various desserts	37	41	33
Beef with bone	31	41	21
Fish and shellfish	34	39	28
Tropical fruits	24	34	13
Powdered milk	26	32	20
Apples and the like	17	24	9
Other vegetables	19	21	17

Table 5. Daily amount available per capita and in each food group

Name	National	Urban	Rural
Number of households	**7438**	**5076**	**2362**
Products of animal origin			
Liquid milk	0	48	0
Fresh cheese	8	11	0
Thin cream		11	0
Eggs	26	29	22
Boneless beef	0	8	0
Beans	38	38	43
Cereals			
Rice	50	50	45
Tortilla	128	96	340
Pasta	8	8	6
Sugar and fats			
Sugar	47	46	47
Vegetable shortening	14	10	18
Vegetables and fruits			
Tomato	18	22	4
Onion	7	9	4
Potato	19	23	0
Green and ripe banana	39	42	30
Green and ripe plantain	12	35	0
Oranges/lemons	9	15	2
Other			
Sodas	48	71	0
Salt	9	8	11
Herbs	15	8	4

Nutritional Sufficiency of Food Availability

Here we analyze the available amount of energy and nutrients per capita and per day, in addition to its relation to Daily Dietary Recommendations (DDR), expressed as percentage of adequacy. The DDR are proposed by INCAP.

By area of residence

Average energy availability, expressed in kilocalories per capita, is slightly higher in urban areas with 2,234 Kcal, whereas in the countryside it drops to 2,177 Kcal. Both cover 95% of the population's average needs. About 20% of both areas have a 30% or more deficit in energy adequacy, meaning that they are in a critical situation, which could be called "undernourishment".

In both urban and rural settings, most energy is obtained from cereals. As for the contribution of macronutrients to total energy, it has been found that the contribution of carbohydrates is greater in rural areas, where it amounts to 66%, than in the cities, where it totals 58%. The reverse occurs with fats, the consumption of which is higher in urban areas, 30%, than it is in the countryside, where it is 23%. In proteins, the contribution to total energy is similar in both areas.

Minerals

The average per-capita calcium availability in cities covers 89% of DDR, whereas in the countryside, the figure is 55%, and as low as 30% in the case of severe deficits. Per-capita iron availability, in both urban and rural settings, covers 100% of DDR. There is a zinc deficit across with board, with adequacy levels of 75%. In cities, 60% of households have a deficit of over 30%, whereas in the countryside, rates can be as high as 43%. Only 15% of households have an acceptable level of this mineral. Low zinc availability is complicated by high fiber intake, which hampers its absorption.

Vitamins

The vitamins included in the study are adequate in both areas, but when distribution of households is analyzed by level of adequacy, a proportion of households have a deficit of every vitamin. For riboflavin, 20% of rural households and those in the East and West have levels of below 70%, which is in itself a deficit. As for Vitamin C, both areas of residence and the three regions have average adequacy of 120%. However, analysis of households by percentage of adequacy shows that in the countryside and the East, over 30% of households have a deficit of over 30%. With respect to Vitamin A, the consumption of fortified sugar means that on average, availability more than meets DDR, with over 150% adequacy. Fortified sugar accounts for 60% of Vitamin A availability.

Policy considerations

The first step is to acknowledge malnutrition and food insecurity, and the main challenges to reducing both are: 1) the complexity of intersectoral coordination; 2) the lack of awareness among top-level decision-makers of the scale and magnitude of the problem, particularly its social and economic consequences in the near future; 3) the lack of social pressure and commitment from within the country to eradicate malnutrition; 4) limited financial resources for implementing programs of the correct scale and duration, and 5) limited availability of qualified personnel in developing countries to adequately address the problem.

Distortions created by subsidies and other agricultural policy models

Price stabilization mechanisms and actions to improve food security are in place, which the government uses to reduce distortions in the domestic market. Honduras supports the elimination of distortions in the agricultural sector and within the framework of the Doha Round, it has called for continued negotiations on special safeguard mechanisms to ensure farmers' food security.

Since maize is the most important crop, its production is protected by a price band and purchase agreements between producers and agribusiness. This mitigates the effect of price fluctuations in the international market on the domestic market. The Honduran Institute of Agricultural Marketing (IHMA) is responsible for this process. The IHMA Executive Committee approves the band each year in January and submits it to the Agricultural Development Council.

The agreements allow maize to be imported with tariff preferences. For each quintal of national white maize, three tariff-free quintals can be imported and up to four if it is yellow maize. Products imported in this way must be processed and can be sold as whole grain on the national market to industries that are not part of the agreement.

Despite these protectionist measures, low levels of technology and profitability persist. An unintended result of the policy differentiating between white and yellow maize has been to distort the market. Freezing the prices of products in the basic food basket, usually decreed by the state, has debatable results, since it lacks the necessary information to set prices. This has caused market distortions for these products.

Promotion of nutrition-sensitive agriculture to provide healthy, sustainable diets associated with resource use and food prices

SAG-DICTA has developed biofortified strains of maize and beans. Biofortification naturally increases the concentration of nutrients such as iron, zinc and Vitamin A in staple crops in the basic basket. To achieve this, Honduras received support from the AgroSalud project, sponsored by the International Advisory Group on Agrarian Research (CGIAR) and the Canadian International Development Agency (CIDA). AgroSalud operates in 14 countries in Latin America and the Caribbean to benefit the most vulnerable segments. With the support of the International Maize and Wheat Improvement Center (CIMMYT), the Olanchano 03 maize variety was released. This strain of maize is characterized by a high content of the essential amino acids lysine and tryptophan. Lines of maize with significant zinc content have also been identified and are expected to be released in the near future.

In 2016, the Bean Research Program (PIF) at Zamorano University, in conjunction with SAG/DICTA's National Bean Research Program, released a variety of biofortified bean with a bright red grain known as "Honduras Nutritivo", characterized by its high iron and zinc content. It also has a high potential yield and is extremely adaptable to various environments. Resistant to the Bean Yellow Mosaic Virus (BYMV) and the Common Bean Mosaic (CBM), it is suitable for the country's low and intermediate zones. This variety was evaluated with the support of the AgroSalud project, Harvest Plus, the International Center for Tropical Agriculture (CIAT) and other institutions.

Policies that encourage technological innovation

The Law for the Promotion and Development of Science, Technology and Innovation created the National Science, Technology and Innovation System, which in turn established the Secretariat of

Science, Technology and Innovation (SENACIT) and the Honduran Institute of Science, Technology and Innovation (IHCIETI). Much work remains to be done to create an economic and institutional environment that will foster innovation and competitiveness in the country. Honduras currently ranks as one of the countries with the lowest competitiveness and innovation in America.

The National System of Agro-Food Science and Technology (SNITTA), led by SAG, was created for the purpose of developing and encouraging technological-agro-food innovation. In terms of Central- American Agricultural Policy, SNITTA supports instruments involving technological innovation and public investment within the framework of competitiveness.

The Central American Agricultural Policy promotes conditions to develop a modern, competitive, equitable, regionally linked Central-American agriculture. One of its six priority areas is technology and innovation. Honduras forms part of FONTAGRO, a cooperation mechanism between Latin America and Spain, which promotes innovations in family agriculture, competitiveness and food security. It supports projects and initiatives involving strategic issues, through calls for submissions, contests and seed funds.

Policies that develop human resources: education, gender, equity

The Basic Law on Education guarantees the human right to education and establishes the principles, guarantees, aims and general guidelines of national education. It defines the National Education System structure. Decree No.34-2000 for the Law on Equal Opportunity for Women is designed to integrate and coordinate the actions that the state and civil society must implement to eliminate all forms of discrimination against women and obtain equality between men and women. The 1999-2015 Policy for Gender Equity in Honduran Agriculture establishes the basis for achieving sustainable development with gender equity and alleviating poverty, the root cause of food insecurity.

Policies to promote the consumption of healthy foods

The Food Guide for Honduras was sponsored by FAO, PAHO, INCAP, the Secretariat of Health, Presidential Office, Pedagogical University and World Vision. It acknowledges the fact that the national diet is monotonous and that most of the population lacks information that would allow them to make the best use of available foods. It is an educational tool that promotes the consumption of healthy, varied and culturally acceptable foods. It is self-taught with extremely precise instructions reinforced by illustrations.

It recommends the daily consumption of foods from all the macronutrient groups, emphasizing fruits and vegetables to prevent diseases. Meat, fish or offal should be included at least twice a week, the consumption of fried foods and sausages should be reduced, while processed foods should be avoided as much as possible, as well as excess salt. The consumption of bottled soft drinks and sweets should be limited, at least eight glasses of water should be drunk a day and a daily half-hour walk is recommended. The guide helps to select and combine foods in order to prevent disease and recommends the best cooking and preparation methods. Its distribution is free, although real or functional illiteracy prevent it from being fully applied.

Comparative advantages of national agriculture

National agriculture has two comparative advantages: the country's geographical location and its climatic diversity. Honduras is in a privileged geographical position that gives it access to the markets of Mexico, the US and Canada. This also allows it to serve as a distribution base in Central America. It has the conditions to build deep water ports on both coasts.

Honduras has an interesting climatic diversity and a variety of ecosystems. Its climatic conditions include semi-dry Caribbean islands, tropical humid conditions in the North and dry tropical conditions in the South, while its ecosystems encompass different types of forests and important marine-coastal resources.

References

Anguiano, R. (1804). Anuario Estadístico 1804. Tegucigalpa, Honduras.

Consejo Agropecuario Centroamericano (CAC) y Sistema de Integración Centroamericana (SICA) (2007). Política Agrícola Centroamericana, 2008-2017. Tegucigalpa, Honduras.

Cruz, D. (2006). Estado de la Seguridad Alimentaria y Nutricional en Honduras. FAO. Tegucigalpa, Honduras.

FAO y Gobierno de Honduras (2010). Estrategia Nacional de Seguridad Alimentaria. Tegucigalpa, Honduras.

Global Water Partnership (2011). Situación de los Recursos Hídricos en Centro América. Tegucigalpa, Honduras.

INCAP (2013). Guía Alimentaria para Honduras. INCAP, FAO, Visión Mundial. Tegucigalpa, Honduras.

La Gaceta (2012). Ley Fundamental de Educación, Decretos 262-2011. Miercóles, Febrero 22, 2012 No. 32,754. Tegucigalpa, Honduras.

Menchú, M.T. and H. Méndez (2012). Análisis de la Situación Alimentaria en Honduras. Tegucigalpa, Honduras.

Palerm, J.; Florez Payarez, E.; and H. Nusselder (2013). Perfil Ambiental País de Honduras. Tegucigalpa, Honduras.

Secretaría de Agricultura y Ganadería (2001). Política para la Equidad de Género en el Agro Hondureño. UPEG, ASDI, PNUD, PAGS. Tegucigalpa, Honduras.

SERNA (2012). Estrategia Nacional de Cambio Climático. Tegucigalpa, Honduras.

The World Bank (2015). Corredor Seco Food Security Project. Tegucigalpa, Honduras.

The World Bank (2013). Improving Nutrition Through Multisectorial Approaches. Tegucigalpa, Honduras.

Universidad Nacional Autónoma de Honduras (2016). Seguridad Alimentaria y Nutricional en Honduras 1999-2015. Tegucigalpa, Honduras.

World Trade Organization (2016). Trade Policy Review Body on Honduras. WT/TPR/S/336. Tegucigalpa, Honduras.

Food and Nutritional Security in Mexico: Major Challenges for the Twenty First Century

Family from Quintana Roo and a sample of the enormous diversity of foods found in the market. Many Mexican families supplement their diet with food planted for on-farm consumption. Photography © Fulvio Eccardi

Mexico

[1] Sol Guerrero Ortiz
[2] Agustín López Munguía
[3] Natalhie Campos Reales
[4] Elizabeth Castillo Villanueva
[5] Luis Herrera Estrella
[6] Sol Ortiz García

Mexico is rich in natural and human resources, but owing to a complex topography has limited arable land. **Mexico is now a net food importer, dependent on other countries for food security** and vulnerable to climate change, especially in desert and coastal regions. **Scientific and technological institutions are very good, but further investment is needed** as well as a closer linkage between public and other agricultural sectors. Evidence-based public policies will be more important than ever in combatting these challenges

Summary

Mexico is the thirteenth largest country worldwide. It has enormous environmental heterogeneity, due to its physiographic complexity, intricate geological history and varied climates. It also has vast cultural wealth due to its indigenous peoples, who have interacted for thousands of years with the country's vast biological diversity. This interaction has resulted in the description of 5,500 species of useful plants, and the domestication of over 200 species of economic importance. Cropland accounts for 55% of Mexico's total area, while 14% corresponds to arable land, limited by both dry climates and the steep slopes of its terrain. In terms of food and nutrition security, Mexico ranks 15th in the Food Sustainability Index and tenth in Sustainable Agriculture (Food Sustainability Index, 2016), and therefore still has significant areas of opportunity to meet the challenges of the next 50 years. The country has vast natural resources, diversified agricultural capacity, operational institutional infrastructure and competition in scientific, technological and innovation development. There are state policies focused on addressing the main problems of agriculture, nutrition and the environment. However, these are usually implemented in piecemeal fashion and with little continuity, under an incipient transversality scheme.

The major challenges facing the nation for its food and nutrition security require the coordination of various sectors and actions aimed at implementing strategies for adaptation and mitigation of climate change. These challenges require the strengthening of programs for the conservation and sustainable use of biodiversity and genetic resources. There is also an urgent need to boost effective investment for the development of the countryside through alliances between the public and private sectors and academia, in order to generate innovations that meet the needs of the various strata involved in food production.

I. National characteristics

a. Physical size, inventory of arable land, environmental and landscape heterogeneity

Mexico is located in the northern hemisphere of the American continent, with most of its territory in North America and the rest in Central America. It has coasts in both the East – the Gulf of Mexico and the Caribbean –and the West - Pacific Ocean and Gulf of California–. Mexico has 1,959,248 km² of mainland and 5,127 km² of islands, comprising a total area of 1,964,375 km². Its maritime area covers 5,109,168 km² corresponding to the patrimonial sea (territorial sea, contiguous zone and exclusive economic zone).

Mexico's agricultural land accounts for 55% of its total area, whereas its arable land is limited by both the dry climate and the steep slopes accounting for 14% of its total territory (World Bank, 2016). According to the National Agricultural Survey (ENA 2014, SAGARPA-INEGI), the total agricultural area of the production units is 27.5 million ha, equivalent to 25.2% of a total of 109.3 million ha. The remaining 81.8 million haa correspond to the area of summer pastures (for cattle), farmland or fallow land.

Mexico has enormous environmental heterogeneity, due to its physiographic complexity and intricate geological and climate history. The physiography of Mexican territory is the result of the interaction of five tectonic plates: North American, Pacific, Rivera, Cocos and Caribbean (Ortega et al., 2000). Their joint action has created seven mountainous systems, two large coastal plains and a plateau. Moreover, the funnel shape of Mexican territory -broad in the North and narrow in the South-, the mountain systems that converge in the South and the SE, the action of the trade winds and the seasonal oscillation of the subtropical high pressure belt contribute to a diverse climate pattern, so that all climates are represented in the country (Vidal-Zepeda, 2005): from very dry in the North, sub-humid and extremely humid in the South, to cold in the mountain peaks (>4,000 m altitude) (Espinosa et al., 2008). Additionally, due to its geographical position, Mexico is regarded as the border zone between the Neoarctic and Neotropical biogeographic regions. This transition permits the flow of species from one region to another (Luna-Vega, 2008), all of which results in an increase in the diversity of taxa present in the country.

b. Demographic characteristics and future trends

According to the results of the Intercensus Survey of the National Institute of Statistics and Geography (INEGI, 2015), Mexico has a total population of 119,530,753 inhabitants, with an annual growth rate of 1.4%. According to the population projections of the National Population Council (CONAPO) 2016, Mexicans have a life expectancy of 75.2 years.

The 2015 population pyramid is wider in the center and narrower at the base, meaning that the proportion of children has decreased while that of adults has increased. In 2015, the population under 15 accounted for 27% of the total, the 15-64 age group 65% and the elderly population 7.2%, **Figure 1** also shows the proportion of men and women.

This situation indicates that the population of working age is more important in relative terms, which translates into an opportunity for economic growth for Mexico. This is what has been called the demographic bonus, which happens when the volume of people of working age is greater than the number of economic dependents; thus, families can save more or productive investment can increase considerably, although there must be an economic context that favors this. In this respect, the use of the demographic bonus requires meeting various requirements,

[1] Sol Guerrero Ortiz, Fellow, Cornell Alliance for Science, solgo.guerrero@gmail.com **[2] Agustín López Munguía,** Department of Cellular Engineering and Biocatalysis, Institute of Biotechnology, National Autonomous University of Mexico City, agustin@ibt.unam.mx **[3] Natalhie Campos Reales,** Executive Secretariat of CIIBIGOMNAM, Mexico City, ncampos@conacyt.mx **[4] Elizabeth Castillo Villanueva,** Executive Secretariat of CIBIOGEM, CONACYT, Mexico City; Department of Microbiology and Parasitology, Faculty of Medicine, National Autonomous University of Mexico, ecastillo@conacyt.mx **[5] Luis Herrera Estrella,** Metabolic Engineering Group, Advanced Genomics Unit, National Laboratory of Genomics for Biodiversity (LANGEBIO) of the Center for Research and Advanced Studies, Irapuato, lherrerae@cinvestav.mx **[6] Sol Ortiz García,** Chapter Coordinator, Executive Secretariat of CIBIOGEM, CONACYT and Science Faculty, National Autonomous University of Mexico, sortiz@conacyt.mx

including, for example, prior investment in education, adequate structures to incorporate all these people into work and working conditions that ensure the stability needed to encourage savings. Some demographic specialists believe that unless this is done soon, Mexico will lose the opportunity to take advantage of this demographic bonus. They also warn of the need to take advantage of the gender bonus, in other words, to incorporate a higher percentage of women into the labor force (Alba et al., 2007; Giorguli, 2016).

c. Farming Modalities

Of the 27.5 million ha of agricultural land, 81.5% correspond to land that has been sown or planted, and the remaining 18.5% to non-cultivated land. According to the Agro-Food and Fisheries Information Service, a total of 21,938,184 ha (SIAP, 2016a) were planted in 2016.

Of the agricultural area, 20.3% is under irrigation (5.6 million ha) while the remaining 79.7% is rain-fed (21.9 million ha). The results of the ENA (2014) indicate that 66.3% of production units under irrigation with an area of between 0.2 and 5 ha occupy 14.3% of the agricultural area, while 31.3% of the units with more than 5 ha (commercial) cover 85.6%. As for rain-fed production units, 70.5% of those that measure up to 5 ha (self-consumption) occupy 20% of the agricultural area, while 6.1% of those with more than 20 ha (commercial) cover 49.9%. According to the Diagnosis of the Rural and Fisheries Sector carried out in 2012 (FAO-SAGARPA, 2012), agricultural production units are classified into six strata as shown in **Table 1**, so that profitable, dynamic, highly-technified units coexist alongside small producers, who tend to have areas of less than 5 ha with low productivity.

In Mexico, the use of improved seeds is not widespread among producers, since only 29% of production units use them, whereas 82% use criollo seeds. However, it is important to note that, in terms of area, 68% of the area planted with annual crops uses improved seeds. Only 0.2% corresponds to transgenic seed.

Figure 1. Population Pyramid 2015 (INEGI, 2015)

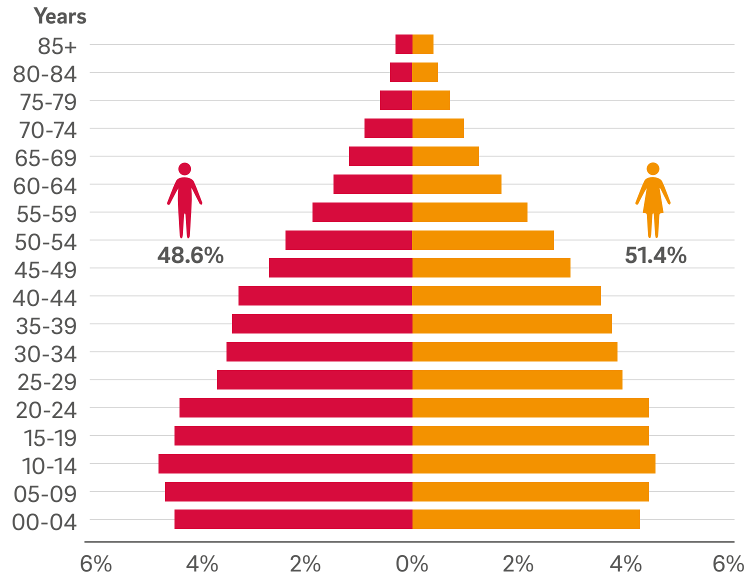


Table 1. Classification of Productive Agricultural Units (PAU) in Mexico

	Type	Number of Units	%
E1	Non-market family agriculture	1,192,029	22.4
E2	Family agriculture linked to the market	2,696,735	50.6
E3	In transition	44,370	8.3
E4	Unprofitable commercial agriculture	528,355	9.9
E5	Thriving commercial agriculture	448,101	8.4
E6	Dynamic commercial agriculture	17,633	0.3
	Total	**5,325,223**	**100**

i. Major Food Crops

Mexico also has enormous cultural wealth due to its indigenous peoples, who have interacted for thousands of years with the country's vast biological diversity. This interaction has resulted in the description of 5,500 species of useful plants (Caballero and Cortés, 2012), and the selection and modification (domestication) of over 200 species (Casas et al., 2007). The historically most important species were beans, chili, squash and mainly maize, whose domestication and genetic improvement are activities that probably date back over ten thousand years (Miranda-Colín, 2000).

Mexico's most important crop is maize with its 64 strains or native varieties (Sánchez et al., 2000) and numerous improved varieties. It is mainly planted in tropical sub-humid, temperate humid and sub-humid zones (Fernández-Suárez et al., 2013). In 2014, the area under maize was 7.4 million hectares (ha), 82.5% of which is rain-fed. Production for that year stood at 23.13 million tons (t). Although irrigated land accounts for only 17.5% of the total area under maize, average yields per ha are considerably higher; in land under irrigation, it was approximately 8.0 t/hectare (ha), whereas in rain-fed crops, the average was 2.3 t/ha (FIRA, 2015).

As for other agricultural products, in 2015, production of the 52 main crops was 4.7% higher than in 2012, mainly due to increases in fruit crops (14.4%), agroindustrial crops (7.9%), vegetables (11.6%) and grains (2.3%). The following increases were recorded by crop: rice (13.3%), corn (11.9%), asparagus (66.1%), broccoli (34.1%), lettuce (30.3%), onion (100%) and sugar cane (11.3%, SAGARPA, 2016a). Among annual crops, in addition to corn, the main crops were: beans, sorghum, wheat, barley, cotton and chili. The main perennial crops include: coffee, sugar cane, orange, alfalfa, mango, lemon, avocado, banana and cacao (ENA, 2014).

ii. Livestock production

Mexico produces cattle and goats (for milk and meat), pigs and sheep (for meat), poultry (for meat and eggs) and bees (for honey). Livestock production also includes aquaculture (fish farming) and rabbit breeding.

In 2015, record meat production was achieved with 6.2 million tons (in carcasses), equivalent to 276,000 t (4.6%) more than in 2012, due to the increase in pig farming (6.8%), poultry (6%) and cattle (1.3%). There was also a significant increase in the amount of egg, milk and honey obtained (14.5, 4.7 and 5.1%, respectively), and in aquaculture production (11% from 2014 to 2015). For all of the above, Mexico has positioned itself as a major producer of animal protein in the world, occupying seventh place (SAGARPA, 2016a).

d. Is the country self-sufficient in agriculture?

Food security has always been a priority in Mexican state policies. However, year after year, food security is extremely vulnerable to variations due to the climate, domestic agricultural policy and international economic conditions.

Mexico had been a net exporter before the 1980s, becoming a food and product importer in the late 20th century. From the mid-1990s to 2008-2010, agricultural imports increased by 201%. Self-sufficiency for maize, wheat, soybeans, cotton, rice, pork, beef and chicken has declined in recent years (UNCTAD, 2013). It was not until 2015 that a positive trade balance for agricultural exports was achieved (SIAP, 2016).

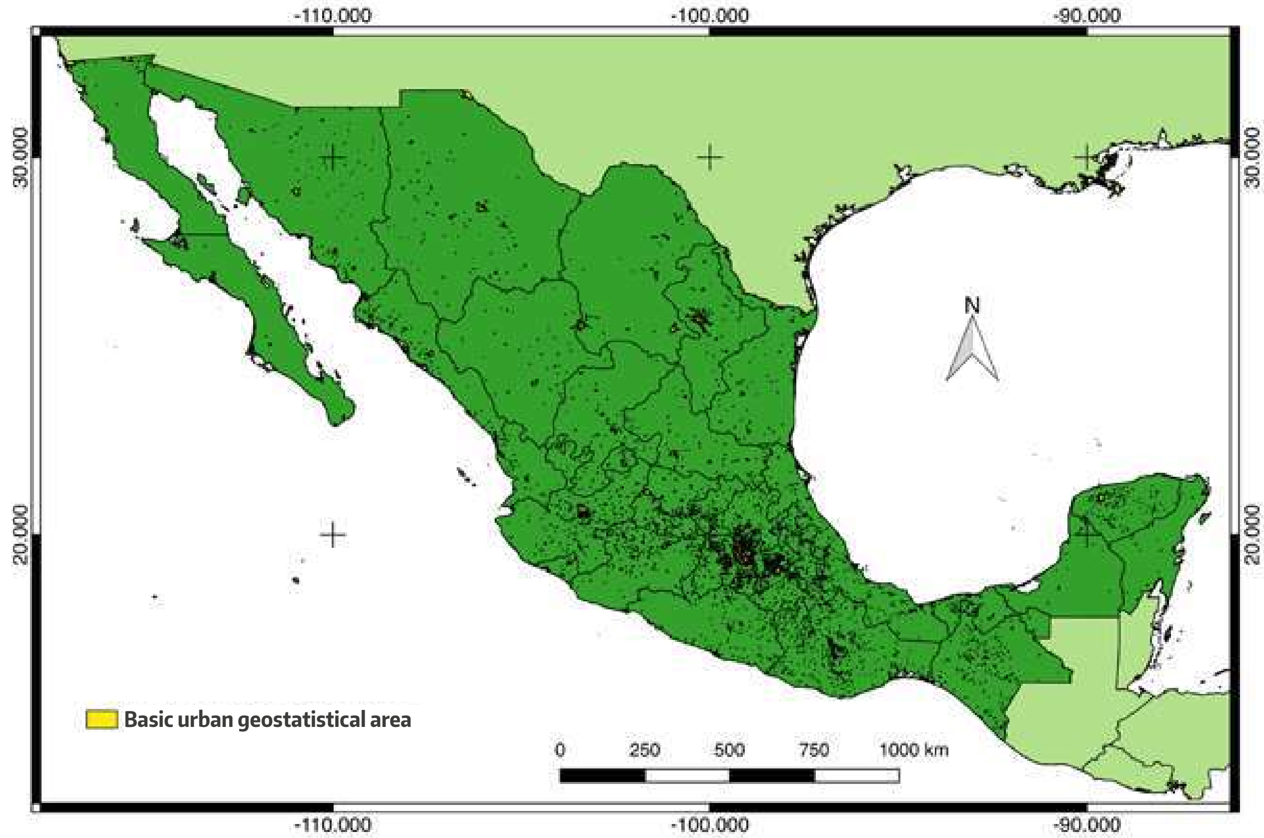
The agrifood trade balance reported by the Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) in 2015 indicates a surplus balance for Mexico. The main export products, in which the country is self-sufficient, are vegetables and fruits with 28% and 25% of the total export value (mainly tomato, cucumber, lime, avocado, chili, strawberries and berries, banana and watermelon). However, the country has a deficit of cereals, meat, seeds and oilseeds, which are imported mainly from the U.S. (SAGARPA, 2016b).

Domestic production of white maize - intended for human consumption - is considered sufficient to meet national demand. Per capita maize consumption in Mexico is approximately 10 times that of the U.S. (Serna-Saldivar and Amaya-Guerra, 2008), and in 2014, over 23.13 million t of maize were produced (FIRA, 2015). However, the production of yellow maize - mainly used as fodder and in industry - is insufficient. On average, more than 10 million t are imported annually, mostly from the U.S. (FIRA, 2015). The same happens with the soybean consumed in the country, since 91.9% is imported, representing about 3.9 million t destined for animal nutrition.

e. Trends in urbanization

In Mexico, urban growth involving changes in the area, population and density of cities can be described in three stages: 1) from 1900 to 1940, it was characterized by a strong rural predominance and relatively slow urban growth; 2) from 1940 to 1980, there was a rapid shift

Figure 2. Map of Mexico showing the territorial extension of urban localities (urban basic geostatistics area, constructed on the basis of INEGI, 2016)



to urban predominance with high levels of concentration; and 3) from 1980 to present, there was more moderate and diversified urban growth within the country (CONAPO-SEDESOL, 2012). The urban population is distributed among a set of 384 localities, comprising the National Urban System (SUN), varying in size and scope from small cities (between 15 and 99 thousand inhabitants) through intermediate cities (between 100 and 999,000 inhabitants) to large ones (one million or more inhabitants) (Sobrino, 2011).

Whereas in 1950, just under 43 per cent of the population lived in urban localities, in 1990, this percentage had increased to 71 per cent, and by 2010 almost 3/4 of the population (more than 86 million) lived in one of the cities comprising the National Urban System (**Figura 2**; Islas-Rivera et al., 2011). Mexico has obviously moved from being a rural and agrarian country to a predominantly urban one, through the demographic growth of cities due to the migration of the rural and indigenous population to large and intermediate cities (Rosas-Rangel, 2009).

f. Impacts of migration

Mexico has seen the massive displacement of rural labor to its cities and the U.S.. It is estimated that between 1990 and 2002, the Mexican rural population working in the U.S. increased from 7% to 14% (Mora et al., 2005). Rural migration has also increased. In 1995, the flow of people recorded by the Survey on Migration on Mexico's Northern Border (EMF-North) was 276,800, whereas in 2007, it was 542,100 (historical maximum at 12.6 million), decreasing to 328,300 people because of the U.S. crisis. According to estimates by the Pew Hispanic Center (PHC), there are currently 11.1 million Mexican migrants (Arrazola-Ovando and López-Arévalo, 2012).

Migrant agricultural workers are usually over the age of 30 and have low educational attainment. Most choose agriculture as a labor niche, since they lack English-language proficiency and, in some cases, have a poor command of Spanish – due to the growing participation of the indigenous population, mainly from the state of Oaxaca - and because they already have a certain level of specialization in agricultural activities. There are more male than female migrants, partly because of the tightening of U.S. migration policies (Zúñiga-Herrera, and Arroyo-Alejandre, 2006), while women who migrate are mainly hired to perform cleaning and housework activities (Rojas-Rangel, 2009).

These migratory flows (from the countryside to the cities or abroad) modify the dynamics of migrants' rural communities of origin. For example, women's access to land ownership has been increasing as a result of men's migration (SIAP, 2016). At best, migration can contribute to improving the living conditions of sending communities through the use of remittances and knowledge transfer (which the migrant provides to the community). However, when migration continues for longer periods, it can deprive rural areas of labor and lead to the loss of skills (Chávez and Campos, 2013).

g. Main export/import crops and markets

According to the Agri-food and Fisheries Information System (SIAP), Mexico is one of the countries that export the most agricultural products. Due to their variety and quality, agrofood exports generated an income of $26.714 billion USD in 2015, surpassing the revenue created by remittances, oil exports and foreign tourism. Moreover that same year, exports exceeded imports due to a positive trade balance of $960 million USD, not seen for 20 years.

The main exports are divided into four categories:

1. Agroindustrial: These correspond to 51.4% of exports. This classification includes products such as confectionery, tequila, beer, bread, chocolate, preserved fruits, sugar and fruit juices.
2. Agricultural: These account for 40.9% of exports, including avocado (Mexico is the world's leading avocado producer), tomato, cucumber, lime, chili, strawberry, zucchini, banana, blackberry, onion, watermelon and raspberry.
3. Livestock and beekeeping: These account for 4.3% of exports and include products such as pork, beef and honey.
4. Fish: These account for 3.4% of exports and include lobster, shrimp, tuna, sardine, crab and oyster.

The main countries to which Mexico exports its products are: U.S., Japan, Canada, Guatemala, Venezuela, Netherlands, the United Kingdom, Germany, Spain and Colombia. A network of 11 free trade agreements with 45 countries gives Mexico a potential market of 1,462 million people, which encourages the search for new opportunities and better conditions for sales of agricultural, livestock and fishing products.

Mexico imports an average of over 10 million t of maize annually (FIRA, 2015). In 2015, imports of this grain stood at 11.97 million t. Moreover, that same year, the country also imported other products such as wheat (4.2 million t), soybean (3.9 million t), paddy rice (876 thousand t), pork (750 thousand t), chicken meat (481 thousand t), apple (310 thousand t), grain sorghum (220 thousand t), barley (168 thousand t) and grain oats (142 thousand t). Imports mainly come from the U.S., China, Canada, India, Brazil, Argentina, Russia and Australia (SIAP, 2016).

h. Main agricultural challenges

The main problem of Mexico's agricultural sector is that it has not been developed in a sustainable manner. This is a consequence of the low growth in agricultural and fishing activity, the persistence of rural families' poverty, the degradation of natural resources in the sector, the unfavorable economic environment and the existence of a weak institutional framework to create policies that will contribute to the development of the sector. There is a low development of technical-productive and entrepreneurial capacities. This is compounded by poor technological innovation and limited funding for agricultural and fisheries activities. The economic environment is unfavorable, with distorted international prices and limited access to markets (FAO-SAGARPA, 2012).

In 2016, the United Nations Summit on Biological Diversity was held in Mexico. As a result of the high-level segment, the Cancun Declaration was adopted, which recognizes the importance of integrating biodiversity into different sectors of human activity. For the agricultural sector, COP-13 recognized the importance of biodiversity for food security, human nutrition, health and well-being, as well as its contribution to ecosystem processes and climate change mitigation.

II. Institutional environment

a. National Agricultural Research Systems

Mexico has a research and development system that can be divided into infrastructure for basic (or free) research and applied (or directed) research, as well as training programs in agronomy, agriculture and biotechnology, from the technical level to postgraduate programs in basic and applied aspects. SAGARPA has support programs for research and technological development projects that help both academic institutions and firms. SAGARPA also has an education and research system comprising the National Institute of Forestry, Agriculture and Livestock Research (INIFAP), eight regional research centers, five National Disciplinary Research Centers and 38 experimental fields and a research and postgraduate center (Postgraduate College), which, in turn, has seven campuses in various states and two universities dedicated to the training of human resources at the undergraduate and graduate level: The Autonomous University of Chapingo (UACh) and the Antonio Narro Autonomous Agrarian University.

In addition to the main agricultural research centers mentioned, the country also boasts: the Advanced Agricultural College of the State of Guerrero and the National Fisheries Institute, while the Public Centers of the National Council of Science and Technology (CONACYT) include the Yucatán Center for Scientific Research (CICY). All these institutions plan, organize, generate and transmit scientific knowledge and produce a faculty of professionals, teachers, researchers and technicians who guide the rational, economic and social use of agricultural resources and agro-food technological innovation.

Mexico is also the site of the International Center for the Improvement of Maize and Wheat (CIMMYT), which runs programs to improve these two crops and generate materials adapted to different parts of the world, particularly Latin America and Africa. CIMMYT is probably the only institution in Mexico to implement molecular and genomic markers for genetic improvement.

CONACYT has several funding programs for research projects that support research programs in academic institutions, some of which deal with agronomic and livestock aspects.

It has several sectoral funds, including one with SAGARPA for research and development in agricultural and livestock areas. The Intersecretarial Commission on the Biosafety of Genetically Modified Organisms (CIBIOGEM) also has a program for the development of biosafety and biotechnology that supports the research of Genetically Modified (GM) organisms, including crops.

Although there are various programs to support scientific research and technological development, there is no plan to integrate these programs or establish priority areas and desirable goals for periods of at least 10 years. It is also important to increase the transparency of the mechanisms to provide support, especially those implemented by SAGARPA.

i. Research capacities that require further development

There is an urgent need to strengthen the quantity and quality of breeding programs for plants and animals and increase the number of researchers working in this area who are able to incorporate the new molecular and genomic strategies that hasten genetic improvement. The number of researchers has declined in recent years and programs went from being highly competitive in the 1960s and 1970s, to being uncompetitive and productive in the last two decades, despite certain important yet isolated successes.

Although valuable work has been done in the area of phytopathology at various institutions, these have failed to be translated into effective diagnostic systems for producers. Most analyses are sent abroad or carried out by national commercial laboratories that use diagnostic kits imported from other countries. It is therefore necessary to strengthen research programs in the field of phytopathology not only to detect and characterize the pathogens affecting the country's main crops, but also to develop diagnostic kits that identify and differentiate local pathotypes.

Although Mexico boasts significant human and physical infrastructure in the area of biotechnology, this infrastructure is insufficient for effectively addressing all the problems of the country's main agricultural crops.

The area of animal biology lags significantly behind the agricultural sector, since until lately there were no laboratories working on the most modern of breeding and genetic engineering techniques in livestock species. In 2015, priority was given to the development of research and livestock technology transfer to develop projects such as the Center for Livestock Genomic Reference in Morelia, Michoacán, a benchmark laboratory with state-of-the-art technology in genomics. Its operation is expected to chart a new direction for livestock since its DNA analysis will make it possible to use genomic selection to improve livestock characteristics in a shorter time (SAGARPA, 2016a).

In the area of animal health, there are competent researchers and relevant research projects, yet without programs and schemes to design and produce vaccines for the main animal diseases occurring in the country. Although there are several groups initiating projects using new genomic editing technologies, Mexico must strengthen its programs in this area to take full advantage of the enormous impact they can have on both plant and animal genetic improvement.

ii. Local areas of strength

The most important research centers in molecular biology and plant genomics include the UNAM Institute of Biotechnology and Center of Genomic Sciences; the Irapuato Unit and the National Laboratory of Genomics for Biodiversity (LANGEBIO); the Center for Research and Advanced Studies (CINVESTAV); CICY; the San Luis Potosí Institute for Scientific and Technological Research; and state universities such as the Michoacán University of San Nicolás de Hidalgo, the Autonomous University of Morelos and the Autonomous University of Nuevo León. There are other universities and technological institutes with research groups that do significant work in the area, but these are isolated efforts rather than institutional programs.

Mexico's main strengths are: the study of the molecular biology of development processes in plants, the responses to environmental factors and the link with symbionts, nitrogen-fixing bacteria and mycorrhizae. There are also several leading groups working on the development of biofertilizers and bacteria that promote plant growth, which in some cases have created products marketed by domestic firms. An example of this is Biofábrica Siglo XXI, which commercializes biofertilizers developed at the UNAM Center of Genomic Sciences.

One area in which Mexico is a standout is the genomics of agricultural crops, both in the use of transcriptomic analyses to examine the biological processes of plants in response to adverse environmental factors, and the sequencing and characterization of the genomes of the country's native crops. LANGEBIO in Irapuato, Guanajuato has sequenced the genome of popcorn, the common bean, chili and avocado, among others.

iii. Scientific collaboration networks inside and outside the country

The various research centers in Mexico have collaboration programs at both the national and international level. Many Mexican institutions have collaboration agreements, mainly with American and European institutions. In agriculture, the UC-Mexus program grants scholarships and donations for collaborative research between researchers from Mexican institutions and those at various University of California campuses, as well as a number of collaboration programs through CONACYT agreements with American and European universities that provide funds for reciprocal visits in order to establish collaboration programs.

CONACYT's Thematic Networks promote interdisciplinary collaboration to address complex problems in issues of national interest in a coordinated fashion among academia, government and society. These networks bring together people interested in working together to address a key national problem. Each network is collegially coordinated by a Technical Academic Committee (CTA) in five main areas: Environment, Knowledge of the Universe, Sustainable Development, Technological Development, and Energy, Health and Society. Since 2017, the activities of CONACYT's 27 Public Research Centers have been reoriented to form 10 research and industrial development consortia, some of which focus on the agri-food sector (Adesur-Acapulco for the agri-food industry, Agro-Hidalgo, Pachuca oriented towards research and development, Intel-Nova, Aguascalientes and Mérida). There are expected to be 18 consolidated consortia by 2018.

iv. Access to and maintenance of databases for monitoring farming systems

SIAP, a decentralized body of SAGARPA, is responsible for the collection, integration, sampling, quantitative evaluation, organization, analysis and dissemination of statistical and geospatial information on the agri-food sector, in accordance with applicable legal provisions, as well as integrating and updating the corresponding documentary collection. It provides the population with a platform for browsing these databases. SAGARPA also promotes the use of technology through applications to document the information derived from agricultural activities, for which it has designed free-access applications on mobile devices that facilitate access to information in the sector.

b. Universities and Research Institutes

i. Scientific development and infrastructure

As for research infrastructure in Mexico, the most competitive research centers in the country have equipment and facilities similar to those of American or European institutions. CONACYT has a support program to strengthen research centers through the acquisition of state-of-the-art equipment or platforms, including the purchase of DNA sequencers, microscopes and mass spectrometry equipment.

ii. Inter- and transdisciplinary research capacities, modeling

This infrastructure, together with the training of personnel at doctoral and postdoctoral level abroad, has permitted the continuous development of the country's scientific capacities. However, Mexico has approximately 30,000 researchers registered, a very small universe for a country of 120 million inhabitants, particularly in comparison with the number of scientists per thousand inhabitants in developed countries. This means that there is an urgent need to promote the creation of new research and technological development centers to incorporate young people who are being trained at the master and doctoral level, at both national and foreign institutions, so that they can develop their capacities in an environment that encourages transdisciplinary research, an aspect that is still only marginally developed. There are also several universities and technological institutes in the country offering degree programs in agronomy, zootechnics and biotechnology.

c. Development of a trained workforce and the state of national educational systems

Mexico offers dozens of master and doctoral programs in agricultural and biotechnological specialties, including some that are internationally competitive, such as those offered by the UNAM Biotechnology Institute, CINVESTAV plant biotechnology in Irapuato, CICY and those of the San Luis Potosí Institute for Scientific and Technological Research. More traditional programs, but also of excellent quality, are offered by the College of Graduates, and the Autonomous Universities of Chapingo and the Antonio Narro University. Over 150 master and doctoral students graduate in these areas every year.

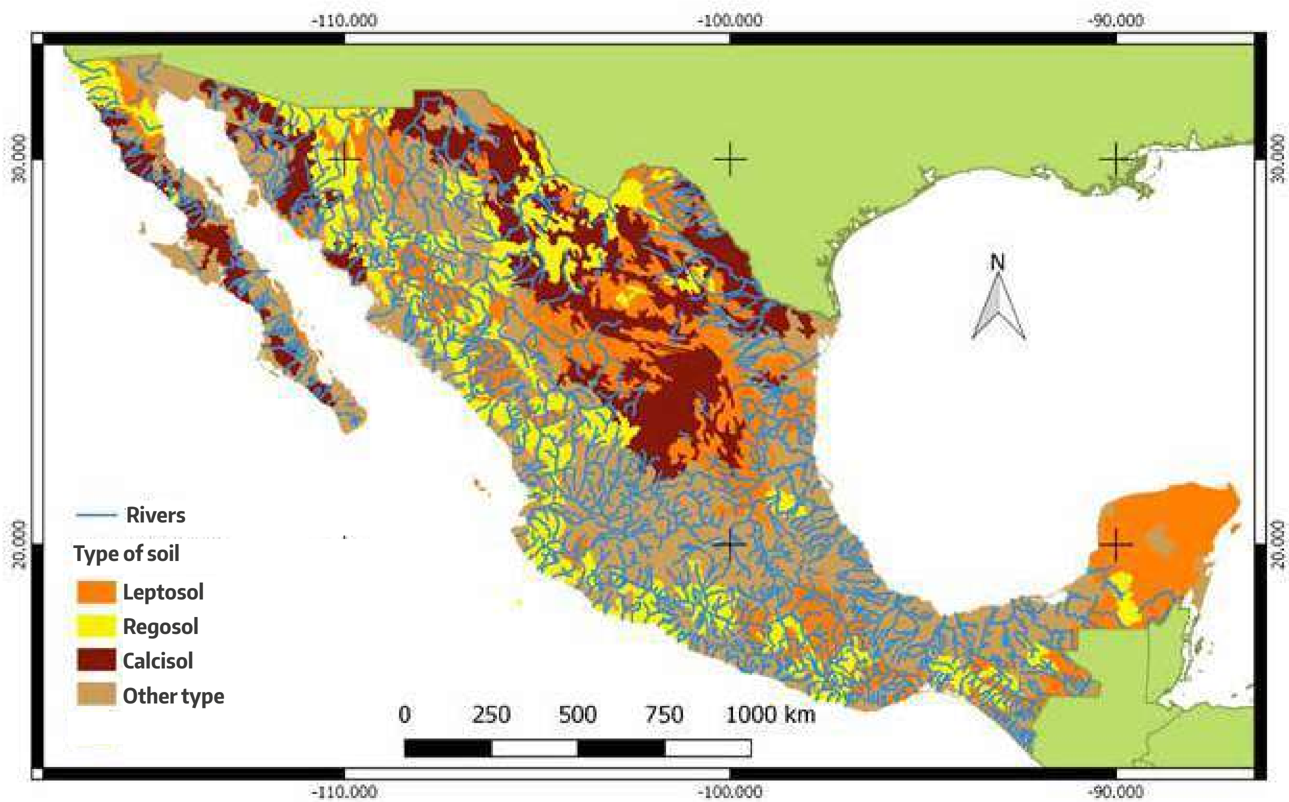
d. Contributions of the public and private sectors

Very few Mexican companies in the field of agriculture or agricultural biotechnology have their own research programs. National seed companies have their own breeding programs and develop their own varieties and hybrids. However, domestic seed companies only capture between 5 and 10% of the seed market, whereas multinationals control more than 90% of the market of the main crops grown in the country, including maize, sorghum, tomato and chili, (COFECE, 2015). Although the public sector provides most of the research programs, there are very few cases of technology transfer from academic institutions to the private or productive sector. This is due to a number of reasons, such as the following: the lack of a culture of intellectual property protection, an absence of interest on the part of researchers in doing their work beyond producing a publication, lack of knowledge on the part of the private sector about the importance of research, technological development and innovation to improve competitiveness at the national and international level, which is reflected in a low level of investment in these areas and the gap between research results and productive needs. This occurs despite the fact that there are several incentives from CONACYT, SAGARPA and other Federal Government agencies, as well as state governments that provide full or partial financing for companies to undertake their own research programs or fund those of public or private academic institutes.

e. Outlook for the future

Despite Mexico's shortcomings in strengthening its programs for the genetic improvement of plants and animals, vaccine production, the genetic engineering of agricultural and livestock crops, and other strategic areas for the country's development, the human and material infrastructure required to make rapid progress in these areas is already available. This requires the implementation of a State policy to define the strategic areas of opportunity and the short-, medium- and long-term plans to boost, consolidate and achieve international competitiveness in the sectors that impact the country's agricultural development. A strategic plan is needed to increase the federal government's current investment of 0.5% of the Gross Domestic Product in science, technology and innovation to at least 1%. This plan should include strategies to facilitate and promote the technological transfer of academic institutions

Figure 3. Map showing the main soil types present in Mexico (constructed from CONABIO, 2001), complemented with the hydrographic network (CONABIO, 1998)



to companies, and encourage the participation of scientists and technologists in the creation of new technology-based companies.

III. Characteristics of Resources and Ecosystems

a. Water and the challenges for the next 50 years

Mexico's mainland aquatic systems are extremely important from an ecological point of view (**Figure 3**). The country's geographical location and relief are two factors directly affecting the availability of water resources. For the purposes of national water management, the National Water Commission (CONAGUA) has defined 731 hydrological basins. Rivers and streams constitute a 633-kilometer-long hydrological network (**Figure 3**). Regarding groundwater, the territory is divided into 653 aquifers (CONAGUA, 2014; Toledo, 2010).

Mexico annually receives approximately 1.489 billion cubic meters of water in the form of precipitation. It is estimated that 71.6% evapotranspires and returns to the atmosphere, while 22.2% runs through rivers or streams and the remaining 6.2% is infiltrated underground and replenishes aquifers. As for the country's water consumption, the agricultural sector uses 76.7%; the public water supply 14.2%; (excluding hydroelectricity), electricity 4.9%, and industry, 4.2% (CONAGUA, 2015). Per-capita renewable water available at the national level is 3,736 m^3/inhab/year (in the range of 19,078 m^3/inhab/year and 150 m^3/inhab/year). However, as a result of population growth, renewable water per capita at the national level will decrease from 3,736 m^3/inhab/year to 3,253 m^3/inhab/year by 2030 (SEMARNAT, 2012; CONAGUA, 2015). It is estimated that in some regions, only levels approaching 1,000 m^3/inhab/year will be achieved, which is a condition of scarcity according to the Falkenmark index (OECD, 2013). Regions where levels are less than 500 m^3/inhab/year, considered a condition of absolute scarcity (CONAGUA, 2015), will be at greater risk. In order to reduce the declining trend in per-capita water availability in Mexico, it is essential to implement irrigation systems and avoid open irrigation.

Moreover, water scarcity can be exacerbated by the impact of climate change. In certain parts of the North of the country, rising temperatures would reduce residual moisture in the soil during the dry months. If there is a temperature increase of between 2 and 3°C by 2050, soil humidity could be halved. This condition would have serious implications for agriculture in the region, as it would require greater water extraction, thus, more overexploitation of aquifers (Magaña-Rueda, 2006).

b. Soil

Mexico has an enormous range of soils formed over thousands of years by the interaction of the climate, the orography of volcanic origin, the type of mother rock and living beings (**Figure 3**) (SEMARNAT, 2012). Due to the importance of soils in the global food strategy, their fertility is a priority issue. Mexico lacks a comprehensive national soil strategy. However, there are programs run by the Ministry of the Environment and Natural Resources (SEMARNAT), the National Forestry Commission (CONAFOR), SAGARPA and the National Commission for Arid Zones (CONAZA), which provide economic and technical support to producers to undertake conservation works, soil restoration, land management and erosion control (SEMARNAT, 2012).

Mexico contains 26 of the 32 recognized soil groups (IUSS, 2007). Leptosols predominate in 25% of the territory and are characterized by being shallow and extremely stony (**Figure 3**), are typical of arid mountainous areas, and are unsuitable for agriculture. The next group in importance is Regosols (19%), which are very shallow and are located in arid zones (**Figure 3**). Arid zones also have Calcisols (18%), which have calcareous contents and produce pastures, grasses and shrubs, making them suitable for grazing livestock. They can be used in rain-fed agriculture with drought-tolerant crops, although they require irrigation to exploit their agricultural potential (CEDRSSA, 2015).

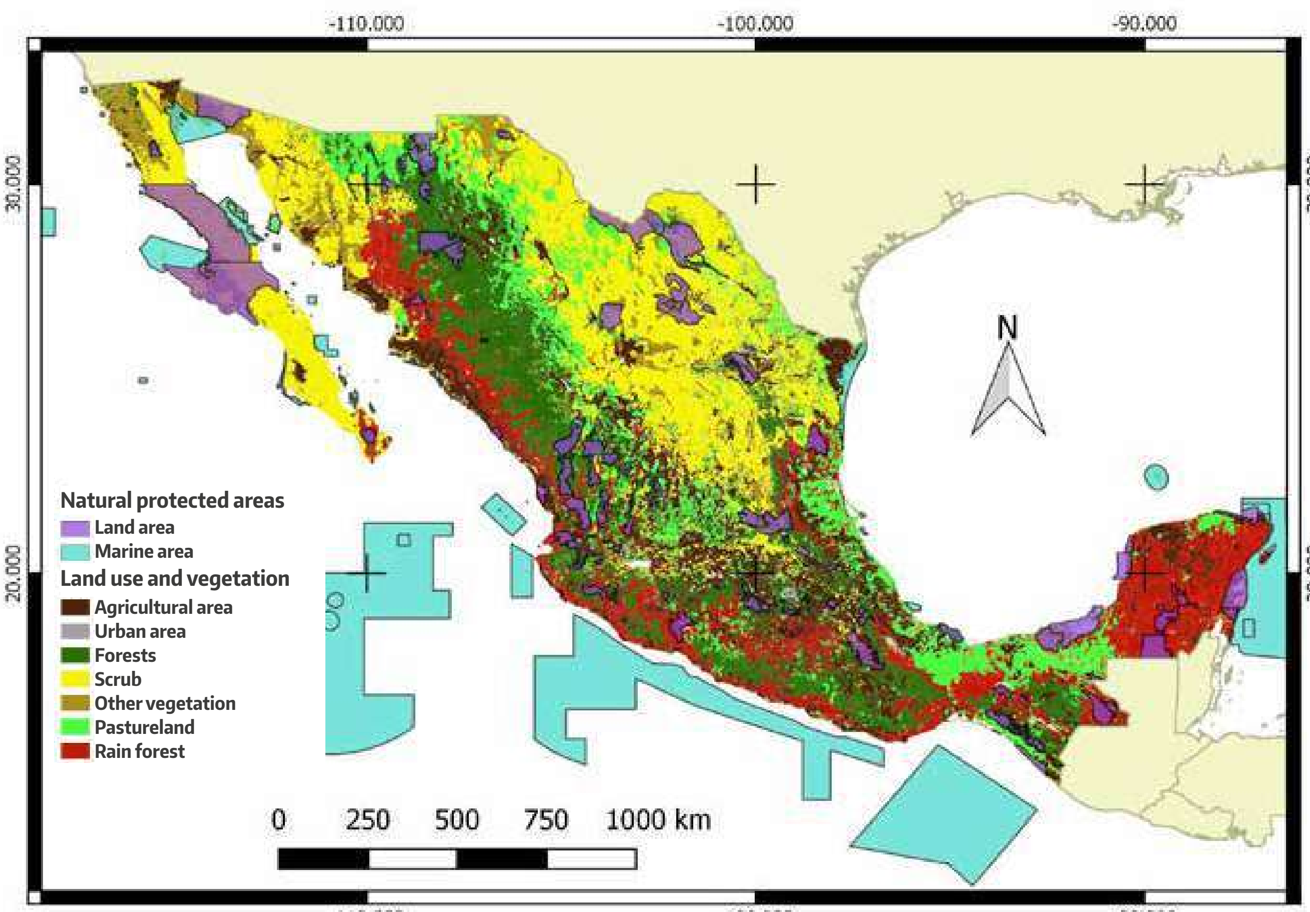
Sixty-four percent of the country's soils have been degraded, mainly due to water and wind erosion, although they also suffer from the loss of nutrients, organic matter and microscopic organisms, as well as compaction, acidification and other adverse processes, since they are used continuously (Hernández-Rodríguez et al., 2009).

c. Energy challenges

One of the most significant initiatives of the past 25 years, because of its historical, political and cultural importance, in addition to its profound economic and social consequences, is Mexico's Energy Reform. This reform seeks to consolidate public policies and strategies to strengthen the national energy sector which is undergoing a stage of great challenges, changes and transformations (Sánchez-Cano, 2014). In recent years, the infrastructure of Petróleos Mexicanos (PEMEX) and the Federal Electricity Commission (CFE) has deteriorated to such an extent that Mexico imports gas despite having it in its subsoil. It has oil, but imports its derivatives: gasoline, diesel, turbosine, Liquefied Petroleum gas (LP) and petrochemicals (SENER, 2014).

PEMEX's annual report shows that oil extraction continues to decline (it currently stands at 2.5 million barrels per day) and that PEMEX has experienced enormous difficulty in stabilizing it (Sánchez-Cano, 2014). Electricity also faces enormous challenges, since populations with over 100,000 inhabitants have electrification rates of over 99%, whereas in smaller, marginalized localities (with fewer than 2,500 inhabitants), this figure is 93.5% (Sánchez-Cano, 2014). Moreover, it has been estimated that by 2050, the energy demand will be 112% higher (OECD, 2012).

Figure 4. Map of the Mexico with information on the main types of land use and plant cover (built from INEGI, 2013). Terrestrial and Maritime Protected Natural Areas (CONANP, 2017) overlap



d. Conflicts and challenges of biodiversity

Mexico has an enormous range of ecosystems due to its location, relief, climates and evolutionary history, making it one of the world's five most biodiverse countries. This mega-diversity offers many opportunities for development and, in turn, entails enormous responsibility for its conservation and sustainable use. As in the rest of the world, the main in situ mechanism for preserving biodiversity is Protected Natural Areas (**Figure 4**). The country has a National System of Protected Areas with an area of over 17 million ha, containing 45 biosphere reserves, 66 national parks, 40 protected areas of flora and fauna, 18 sanctuaries, eight areas for protecting natural resources and five national monuments (CONANP, 2017).

i. Conflicts associated with the overexploitation of natural resources

Habitat destruction and overexploitation of flora and fauna (illicit extraction and mismanagement) are the main causes of biodiversity loss. For example, although Mexico has approximately 500 commercially important fish species (CONABIO, 2014), extraction has concentrated in a few species. Only eight commercial fisheries account for over 40% of the production volume and value of the country's total capture (INAPESCA, 2014). Moreover, it is estimated that 22.5% of the country's total fisheries are overexploited, 63.3% have reached their catch limits, and only 14.2% still have production potential (CONABIO, 2006). Overfishing is leading to the extinction of numerous marine species. An example of this problem is the case of the Vaquita porpoise (*Phocoena sinus*), in danger of extinction due to the overexploitation of totoaba (*Totoaba macdonaldi*), in demand on the international market.

Another example of overexploitation in Mexico is the case of cacti. Their multiple uses mean that they are in high demand, which has been met by the extraction of individuals and seeds from their natural habitat, affecting populations and placing many species at risk (Becerra, 2000). Mexico has 913 cactus taxa (species and varieties), of which 57% are endemic and 30% are in some category of risk (Jiménez-Sierra, 2011).

ii. Loss of genetic diversity

Plant genetic resources constitute the biological basis of food security and are key elements for the improvement of agricultural crops through conventional genetic improvement and modern biotechnology techniques. All countries rely heavily on plant genetic resources from other countries for food and sustainable agricultural development (Debouck et al., 2008). A total of 15.4% of the species consumed as food in the world originate in Mexico (CONABIO, 2006), a center of origin and diversification of maize, chili, beans, squash, tomato, avocado, cactus nopal, cacao, henequen, vanilla, tobacco and cotton (Ramírez et al., 2000). However, the country's agricultural and livestock production policies have not directly encouraged the conservation of this wealth, mainly due to the absence of incentives that promote the diversification of agricultural crops, and the difficulty of generating markets for landrace products.

e. Forest Trends

Mexico has 65.6 million ha of temperate forests and rainforests covering 30 to 35 percent of the country (CONABIO, 2014). The forest area is composed of 51.1% of forest and 49.9% of rainforest. CONAFOR estimates that approximately 21.6 million ha of rainforests have the potential for sustainable commercial production. The annual removal of wood is 56 million cubic meters, 64.3% of which corresponds to firewood, 23.2% to the production of unauthorized industrial wood and 12.5% to the production of authorized industrial wood (CONAFOR-FAO, 2009,;FAO, 2010). The main challenges for the forest sector in Mexico are: reducing deforestation – Mexico has one of the world's highest deforestation rates - and increasing the reforested area; eliminating illegal logging, exploiting the potential of timber production in native forest through sustainable management; and increasing sustained wood production through the promotion of commercial forestry plantations, such as agroforestry and silvopastoral systems (CONAFOR-FAO, 2009).

f. Potential impacts of climate change

Several signs of climate change have been observed in Mexico, such as: (i) increased desertification in the northern regions of the country; ii) extreme temperature increase; for example, in Mexico City, it has increased by approximately 4°C; (iii) intense storms, as well as long periods of heat, and (iv) forest loss and the disappearance of national glaciers located in the Pico de Orizaba, Popocatépetl and Iztaccíhuatl volcanoes.

g. Resilience to extreme events

Mexico is subject to a broad range of natural phenomena that can cause disasters. As part of the Pacific Ring of Fire, it is affected by strong seismic and volcanic activity. Two thirds of its territory have significant seismic risk and there are 14 volcanoes considered active (CENAPRED, 2001). Moreover, the country's location in an intertropical region makes it vulnerable to hurricanes, formed in both the Pacific Ocean and the Atlantic. Storms that occur during the rainy season can be intense and cause flooding and landslides. Conversely, the scarcity of rainfall affects several regions, which in turn can lead to droughts that negatively impact agriculture, livestock and the economy in general. Associated with the scarcity of rain are forest fires, which cause plant-cover loss and miscellaneous damage (CENAPRED, 2001). Although drought is the most frequent phenomenon, flooding is more likely to affect the agricultural sector when it occurs in highly productive areas (SIAP, 2016).

Vulnerability to natural disasters can depend on many variables. For example, an area with a slope greater than 25%, exposed to winds or rains (slope orientation), with little soil cover, poor infrastructure and low infiltration, is considered to be more vulnerable and less able to recover from an extreme natural event (Altieri et al., 2011). According to a recent analysis, the 20 municipalities with the least resilience in the country are located in four states: Oaxaca, Chiapas, Veracruz and Guerrero (CENAPRED, 2015).

h. Outlook for the future

The conservation and proper management of edaphic and biological biodiversity are crucial to the proper management and increase of soil fertility, and to enabling food production in a sustainable way without compromising natural resources. It is essential to implement research programs to establish in-vitro propagation systems to meet the demand for species at risk, as well as to strengthen inspection and surveillance actions in ANP. The 2025 Forest Strategic Program developed by CONAFOR must also be linked to other efforts, such as the 2030 Water Agenda, designed to consolidate the implementation of a sustainability water policy (CONAGUA, 2011).

Energy Reform encourages investment in alternative forms of energy such as wind and solar, which together with the implementation of the regulatory framework to mitigate climate change that includes the General Law of Climate Change (INECC, 2016), will support solutions to alleviate the region's high vulnerability.

There are various strategies to reduce the impact of natural disasters and create resilience. Regulating urban settlements and improving infrastructure can reduce the losses caused by disasters. Other actions include reforestation, since forests intercept winds and can have a protective effect. In addition, mature forests, which have deeper roots and anchorage, retain soil, which is important for preventing landslides. The presence of secondary vegetation also reduces the level of soil erosion, while barriers and terraces protect soil from erosion by runoff. The construction of infiltration trenches or drainage channels is key to diverting excess water, preventing floods and reducing erosion and landslides (Altieri et al., 2011). The conservation of mangroves and coral reefs helps prevent coastal disasters, while intelligent agricultural practices involving sustainable intensification reduce the pressure to expand the agricultural frontier.

IV. Technology and Innovation

a. The Role of Biotechnology

Modern biotechnology encompasses virtually all sectors of industry, particularly the food, chemical and pharmaceutical industries. Biotechnology could play a leading role in the development of agricultural and livestock activities in Mexico.

The public should realize that it offers a wide range of technological platforms with different applications and that it is not restricted to the production of transgenic or GM organisms.

i. Vegetable farming

In the case of agriculture, tissue culture for the propagation of crops such as potato, agave and flower-producing species has not achieved its full potential in Mexico. Although some successful companies propagate blue agave for the tequila industry, for example, there is still an open market for many important crops. Molecular markers and genomic strategies should be used to make crop breeding programs swifter and more effective in reducing the time and cost of producing new varieties. Molecular markers are used, albeit incipiently, in the breeding programs of public institutions, while a number of companies that produce commercial maize seeds and other crops are beginning to use these markers and double haploids in their programs. Several laboratories have DNA sequencers with the capacity to decipher and annotate plant genomes. LANGEBIO's research programs have spearheaded genome sequencing programs for beans, chilies and avocados. However, the use of genomic information for breeding programs has just begun in Mexico and has only been established by CIMMYT for the improvement of maize and wheat.

There have been efforts to research and develop bacteria that promote the growth of plants and those that improve fertilizer use, known as biofertilizers. Although this area has been used for several decades, in recent years, it has become more important due to the urgent need to reduce fertilizer and pesticide use. The study of plant microbiomes to understand which microorganism consortia have the greatest influence on productivity and resistance to biotic and abiotic factors, has an enormous future for developing more effective, crop-specific inoculants that impact productivity and reduce agrochemical use. A number of laboratories at various public institutions in Mexico are already launching research programs for the study of the microbiomes of strategic plants for Mexican agriculture such as maize and beans.

Plant engineering in Mexico has experienced a relative boom for over two decades, since the number of research groups for genetically modifying various plant species has expanded during this period. Although most groups work with model plants, there are several with the capacity to make genetic modifications in maize, tomato, potato and bean, among other crops. Two of the constraints on the development of agriculture in Mexico are: the shortcomings of the genetic improvement programs using the most modern biotechnological tools and the regulatory difficulty of approving the use of transgenics.

ii. Livestock agriculture

The greatest current impact on the livestock sector is the use of biotechnology related to animal health. Recent decades have seen the development of a broad range of therapeutic products of biotechnological origin for the treatment of diseases in the veterinary environment, as well as for use in their prevention. Included in the former are proteins, antibodies, enzymes and even various gene therapy procedures, while the latter include diagnostic kits for identifying genes or marker proteins for potential diseases or infections, as well as vaccines. In general, the animal health market in Mexico is controlled by 10 transnational companies fighting over a $1.49 billion USD market (FiercePharma, 2016). This market corresponds mainly to vaccines for the three most important livestock species in the country: poultry, cattle and swine, although there is also a major pet product market. Companies in Mexico have been established by forming partnerships with transnational companies, although several regulatory agencies have been created at the state level, such as CANIFARMA.

After the development of insulin, growth hormone was the second modern biotechnology product. In its variant for various animals (bovine somatotropin), this protein has been produced in several GM organisms and used in the livestock and aquaculture sectors. In fact, in Mexico, the use of recombinant protein was approved in the early 1990s to increase milk production in cows (Bolívar, 2004).

Probiotics and immune system stimulants have been used as an alternative to the enormous concern and rejection society has shown toward the use of antibiotics in the feeding of practically all species. Tools are available to make genetic breeding programs more efficient, such as obtaining the genome and more specifically methods for mapping resistance factors or genes with disease susceptibility or specific animal defects or characteristics.

In this later aspect, since the previous century, it has been possible to genetically modify animals to improve their characteristics. However, opposition to their introduction into the food market, and complex regulation remain a major constraint. Over the past 30 years, a dozen GM animals including pigs, cows and salmon have been developed. Given the situation at the international level, this sector has not been developed in Mexico, or at least there is no product that has been submitted to regulatory agencies. It is noteworthy that an enzyme called phytase is produced by certain companies in Mexico to be added to feed for monogastric animals, among other uses.

It is important to note the potential of modern genomic editing techniques such as TALEN and CRISPR-CAS, which impact all areas affected by biotechnology. In this case, it would be a type of genetic editing that could dispense with introducing a foreign gene into the host (McNutt, 2015; Hall, 2016).

As in other sectors, modern biotechnology in the livestock sector has given a significant boost to the existing industry. At the beginning of the 21st century, it was estimated that in the early decades, the market for biotechnology products in the sector, worth several billion dollars due to the 2,500 products available for the treatment of nearly 200 specific animal diseases, would double. However, the sector's most important potential continues to be limited by the position of a group of society that rejects the consumption of GM animals.

iii. Pests and diseases

In both Mexico and most of the countries where genetically modified plants have been authorized, *Bacillus thurigiensis* proteins have permitted the control of the most important insect pests that attack commercial crops. In environmental terms, all the reports cite the environmental advantages of specific biological insecticides, such as Cry proteins, over the broad-spectrum pesticides mentioned in *Silent Spring*, published a half century ago by Rachel Carson, outlining the toxic role of organophosphorus pesticides in health and the environment, particularly DDT. Since then, over 450 types of arthropods resistant to one or more pesticides have been detected. Fortunately for farmers and the environment, a new pest control paradigm is emerging with the use of modern biotechnology and the development of GM plants containing the genes for Cry proteins (Heckel, 2012).

After two decades of use of insecticide proteins in GM plants in Mexico (mainly cotton) and the rest of the world (cotton, maize, soy and canola), it has been possible to quantify the benefit of the thousands of liters of pesticides no longer applied as a result of the use of GM insect-resistant plants.

The elimination of the most devastating pests (Heliothis/Helicoverpa) has been observed in almost all cotton crops worldwide, including Mexico, demonstrating that Cry proteins in GM plants provide biocontrol services for agriculture, and even allow them to return to the original seeds (Lu et al., 2012; SENASICA, 2016). The economic benefits are evident, particularly in developing countries. For example, in 2015 nearly half the profits from planting GM plants were obtained by peasants in these countries (Brookes and Barfoot, 2017). In the specific case of Mexico, after 20 years of planting GM cotton, producers' earnings are estimated at $500 million USD, not counting the benefits to health and the environment by avoiding the use of toxic agrochemicals. The fact that insecticide has not been used has prevented the application of between 0.21 and 0.85 kg/ha of active pesticide ingredients. Another indirect advantage associated with pest reduction is the presence of mycotoxins in infected plants. In the case of Mexico, this advantage does not yet apply, since no other insect-resistant GM crops have been planted.

In Mexico, several key crops are economically and socially affected by extremely damaging pests, crops such as limes, attacked by a bacteria responsible for HuangLongBing (HLB) and coffee, the target of the borer beetle, *Hypothenemus hampei*. It is essential to incorporate modern biotechnology tools such as interfering RNA (RNAi) into biological control, which will provide a short cut in the fight against pests and diseases that impact agriculture.

For the Colorado beetle, a pest that affects potatoes worldwide, there is already a strategy based on this molecular tool. There have also been developments in Latin America, such as bean varieties produced by a state-owned company in Brazil that are resistant to the golden virus, transmitted by the white mosquito. In Mexico, the main challenge remains the reduction of the amount of pesticides used in agriculture, particularly in corn for controlling worm-eaters (*Spodoptera frugiperda*) for which 3,000 t of active ingredient are applied annually. This is followed by lepidoptera, such as the black cutworm (*Agrotis ipsilon*) and the corn earworm (*Helicoverpa zea*), controlled by one-to-three insecticide applications every season (Blanco et al., 2014).

b. Prospects for novel agricultural products

Technologies developed in Mexico using plants' genetic modification include the production of drought-tolerant plants by a group from CINVESTAV in Mexico City, as well as those requiring fewer fertilizers and herbicides for their optimal productivity, developed by CINVESTAV researchers in Irapuato.

The strategy for producing plants with higher drought tolerance is based on increasing the content of trehalose, a disaccharide that has been associated with water-loss tolerance in many biological systems. Increasing the concentration in plants was unsuccessful due to the overexpression of the genes that encode the enzymes responsible for its synthesis. Accordingly, Beatriz Xoconostle's group at CINVESTAV in Mexico City used a strategy to reduce the expression of genes that destroy trehalose, which raised the level of trehalose in maize plants, thereby increasing their drought tolerance.

In order to create crops requiring less fertilizer, a novel strategy was used based on solving the main problem of the use of phosphates as a fertilizer to boost crop growth. The main problem is that phosphates react quickly with the cations present in soil particles and are strongly fixed by adsorption and unavailable for plant roots to absorb them. Phosphates are the only chemical form of phosphorus plants are able to use. To solve the phosphate problem, the research group run by Dr. Luis Herrera at CINVESTAV, Irapuato, used phosphites rather than phosphates, since the former do not react with the cations in soil particles and are therefore far more readily absorbed by roots and potentially a much more suitable fertilizer. The problem is that plants are unable to metabolize phosphite, thus they cannot feed on that source of phosphorus. In order to be able to use it as fertilizer, plants were genetically modified so that the phosphite absorbed by the root was converted to phosphate, in other words, a non-metabolizable molecule was converted into a nutrient. When implemented, this system can selectively fertilize the GM crop, which can save up to over 50% of fertilizer as well as decreasing the use of weed killer- Since weeds are unable to use phosphites as a source of phosphorus, they will not be able to grow rapidly and therefore will not affect crop productivity. These two examples are proof of the potential of research in molecular biology and plant biotechnology in Mexico.

c. Opportunities and obstacles to new management technologies

For reasons of cost and in order to reduce the environmental and ecological damage caused by agriculture, it is essential to reduce water and agrochemical consumption. Improved irrigation systems coupled with the use of improved varieties, including genetically modified ones, provide a major opportunity to increase agricultural productivity by reducing the ecological impact. However, achieving this requires establishing long-term public policies through funds to promote the use of efficient irrigation systems and the use of improved seed for all crops. For example, for a variety of reasons, the use of genetically modified crops has been on hold for over 20 years, despite the fact that a biosafety law on genetically modified organisms was passed over 10 years ago.

d. Development of aquaculture/ marine resources

Among the countries that engage in fishing activity, Mexico moved up from 30th place in contribution to total catch during the 1950-1980 period to 17th in the past 20 years, and currently produces about 1.5% of the world's total volume. Conversely, in relation to aquaculture, there were about 151 thousand t of products grown in marine, freshwater and brackish waters, meaning that Mexico ranked 25th worldwide (CONAPESCA, 2010). However, it is important to note that there are regional productivity differences. The Pacific coast states contribute the largest volume of fishery and aquaculture products, with an average percentage of 80%, followed by the Gulf and Caribbean shore with 18% and 2.0% of Inland Waters, respectively (DOF, 2014).

In 2012, fishing and aquaculture accounted for approximately 0.18% of Mexico's GDP. These activities are crucial to the production of foods with high protein value for human consumption and their contribution to microeconomics. In 2012, national fishery and aquaculture production stood at 1.68 million t, 85% of which corresponded to fishing and 15% to aquaculture. Nationwide, six species account for 69% of the total value of fish production: shrimp, tilapia, tuna, octopus, sardine and trout (DOF, 2014).

Three species account for 79.7% of the total volume of aquaculture: bream, shrimp and oyster. A total of 9,230 units of aquaculture production with an area of 115.910 ha have been recorded, with 75% being cultivated with shrimp alone (CDRSSA, 2015b). Moreover, in the past ten years, aquaculture in Mexico has experienced an average growth rate of 3.4% and is identified as a viable alternative for reducing the pressure on wild fish resources. Nonetheless, aquaculture faces enormous challenges regarding genetic improvement, health, quality and safety, and the elaboration and production of balanced diets that must be met if it is to be developed in a sustained manner, so as not to depend on the importation of inputs (DOF, 2014) or the overexploitation of this activity.

V. Enhancing the efficiency of food systems

a. Outlook for increased technology-based agricultural production

In 2008, the European Union Joint Research Center (JRC) undertook a study on worldwide biotechnological development, in both the public and private sectors. It predicted that by 2015, there would be 91 new characters conferred on plants already on the market. These characters would provide protection from pests and diseases, resistance to climate factors and additional nutritional properties, such as the elimination of toxic characters, worldwide. By 2014, there were only 16 new characters on the market, mainly agronomic and developed by the private sector.

What has become of all the expectations related to improvements in nutritional quality, food safety and crop safety?

A study in 2012 of technology developers in this sector concludes that, on average, it takes US $136 million and approximately 13 years bring a product to the field, despite technological improvements and the efficiency of manufacturing processes. Nonetheless, the cost and time involved in the regulatory process has increased by 50% over the past decade, making marketing difficult, although many of the developments were achieved in the public sector and therefore do not involve royalty payments to the producer.

The modification of agricultural characteristics is expected to have an indirect impact on factors such as water availability and temperature. Whereas precision agriculture favors the extremely controlled use of water and nutrients in crops, it is likely that changes in the physiological properties of seeds will have the greatest impact on productivity in the short and medium term. Thus, reports have been written on the design of more efficient plants by modulating the expression of certain genes. In the case of maize, for example, regulation of the expression of the *Plastochron1* gene coding for a cytochrome c increases biomass and seed yield, lengthening the duration of cell division (Sun et al., 2017). The same can happen through modifications that achieve more efficient photosynthesis, or greater carbon use.

b. Infrastructure needs

Mexico currently has over 3,000 agricultural warehouses, 1,133 animal slaughterhouses, 89 wholesale food outlets, 65 fishing ports, 26,727 km of railway, 389,345 km of road network and 3,093 dams for agricultural irrigation (SIAP, 2016). Nevertheless, it is essential to invest in infrastructure to connect trunk distribution hubs and streamline port operations and capacity. Also, at the local level, there is a need to consolidate product collection networks, in order to reduce the intermediaries and the producers who receive a direct income from the marketing process.

Greater investment is also required to reactivate the railroad as the most economic means of transporting agricultural products. Last, it is necessary to invest in infrastructure to make efficient use of water in the agricultural sector and to have drip, rainwater and mist-collection irrigation systems.

c. Food use and waste minimization strategies

The food industry comprises 22% of the total manufacturing industry nationwide (COMECYT-FUMEC, 2009). The states with the largest number of economic units of processed foods are: the State of Mexico, Puebla, Oaxaca, Mexico City and Veracruz (Terán-Durazo, 2015). Most food companies concentrate on the production of bakery and tortilla products (31% and 22%), respectively followed by industries specializing in the slaughtering, packaging and processing of livestock and poultry (22%) and then dairy farms (12.6%).

It is estimated that 37.26% of food in Mexico is wasted, equivalent to 10.4 million t per year, creating a loss of over 100 billion pesos. Some of the causes of waste can be found in the value chain, lack of certification, lack of quality standards, inefficient management, bad practices, inadequate packaging systems, transportation, distribution and storage, and lack of training. Consumers are also responsible for waste, due to excessive purchases or improper handling of merchandise (FAO, 2015). To address this problem, the National Crusade against Hunger Council 2016 presented several strategies to reduce food losses: the creation of the Technical Group on Food Losses, the implementation of the "Creation of Productive Chains in the Coasts of Mexico" project, support for research on practical, technical solutions for food waste, and the distribution of recovered food in the poorest areas of the country, with the support of the Mexican Association of Food Banks, comprising 60 banks in 29 states (SEDESOL, 2016). The implementation of these strategies and their effectiveness should be carefully evaluated.

d. Conflicts between food production and energy production

The need to achieve food self-sufficiency by increasing food production and the search for alternative sources of renewable energy from agricultural raw materials is a global conflict (Ajanovic, 2011; Graham-Rowe, 2011). However, the conflict is particularly critical in a country such as Mexico, where maize constitutes the basis of the diet, yet at the same time, together with sugar cane, is the best choice for the production of first-generation biofuels. This is compounded by the fact that the country's economic growth - sustained by oil exports for decades - has been heavily affected by the reduction of production capacity, due to the exhaustion of the most important wells, and the fall in international oil barrel prices.

Despite the need to gradually replace fossil energy with renewable energy, in an attempt to strike a balance between the use of soil for food supply and the production of energy inputs, in February 2008, Congress issued a Law on the Promotion and Development of Bioenergetics, which sought to protect food sovereignty and security and prevent the risk of loss from a government perspective. However, it is a controversial instrument, since it paradoxically inhibits the promotion of bioenergetics and has limited the adoption of sustainable energy-supply models in Mexico. This situation is not only compounded by low oil prices in the international market, but also by the development of recovery techniques through fracking that have given the U.S. energy independence, although from the point of view of sustainability, this technology constitutes a setback.

In principle, the law was intended to promote market development, the promotion of participation schemes and free competition in this sector. The Intersecretarial Commission for the Development of Bioenergy was created, formed by the Secretariat of Energy (SE), SAGARPA and SEMARNAT. The first two were tasked with the issuance of Official Mexican Standards (NOM) and permits, and the third with dealing with the environmental liabilities caused by the production, transportation and commercialization of bioenergetics. Last, the law includes procedures, infractions and sanctions related to the sector (Ampudia, 2008; Quadri, 2012).

All this has spawned a complicated system of requirements, with high transaction costs for the producers of inputs for energy purposes (maize, cane, stubble, oilseed, etc.), discouraging development and technological innovation. It is important to recall the current ban on high-yielding GM corn, without which productivity is at best maintained by native varieties. SAGARPA only issues a permit to produce biofuels from corn when there are surplus inventories of domestic grain production to satisfy national consumption. For agricultural crops other than maize, notice of planting must be submitted to SAGARPA. Producers must also state that they will be cultivated exclusively on farmland and that forests will not be converted to agricultural land. Moreover, in Mexico there is limited availability of land for cultivation (approximately 33%).

It has been pointed out that this law gave rise to an unconstitutional rule, since it affects the right of ownership and the freedom of industry of producers of agricultural inputs for bioenergetics, as well as of those who market and consume them. In short, the high transaction costs generated by the NOM regime and previous permits, coupled with the legal impossibility of using GM organisms to increase productivity - even if only for industrial use - have prevented both the food and energy sectors from being properly developed in the country. Indirectly, projects to produce biofuels made only from jatropha, oil palm and sorghum as raw materials have been encouraged. A clear policy and programs to promote alternative strategies are urgently needed to produce biofuels with microalgae or other photosynthetic organisms that would not compete for arable land, such as maize or sugar cane.

VI. Public Health Considerations

a. Foodborne diseases

There is a broad spectrum of public health diseases, gastroenteritis and diarrhea being the most frequent symptoms associated with their condition and attributable to various microbial pathogens including bacteria, viruses and various parasites. Unofficial figures suggest that there are 5 million cases annually. The susceptibility, severity and lethality of these diseases depends on several factors, such as the person's immune status, nutritional condition, age and certain other factors specific to each ailment. As one might expect, the most susceptible populations are children under the age of five, expectant mothers, the elderly, and last those who for some reason are immunocompromised. Additional complications can arise when a person suffers from other diseases, particularly those associated with metabolic syndrome and diabetes.

According to the Center for Epidemiological Surveillance and Disease Control, which belongs to the Secretariat of Health, in 2011, there were 5'345,571 cases of intestinal infectious diseases, whereas by week 51 of 2016, the number had decreased to 4'822,218 (Boletín Epidemiológico 2016). Between 2011 and 2015, the weekly average of new cases of intestinal disorders was 62,311. Statistics include diseases such as cholera, typhoid, paratyphoid, salmonellosis, shigellosis, ill-defined infections, intestinal amebiasis, amebic liver abscesses, those caused by protozoa, giardiasis and helminthiasis. Diarrhea is the most common condition associated with food poisoning (*salmonellosis*, *Escherichia coli*, *staphylococci*, etc.), although there are more dangerous conditions such as listeriosis, botulism, toxoplasmosis and hepatitis A, for which age is the most important component of morbidity and mortality, since it increases in a directly proportional manner to this factor.

The states with the highest incidence of gastrointestinal diseases, in order of importance, are: Mexico City, Jalisco, followed by Veracruz, Nuevo León and Chiapas. Conversely, the states least affected by these digestive disorders are: Campeche, Tlaxcala and Quintana Roo, although these are total data that do not take population size into account.

b. Overweight and obesity

Like most of the world's countries, Mexico is experiencing a severe crisis of overweight and obesity, so much so that in 2016 the Secretariat of Health issued an epidemiological emergency due to diabetes and obesity given the magnitude and importance of the problem. The figures are as alarming as in the rest of the world. According to data from the National Health and Nutrition Survey (ENSANUT, 2012), 71.2% of the adult population in our country (about 55,372,611 people) were overweight or obese, while 9.2% (7'154,888 people) had diabetes. Specifically, 10 million Mexicans have been diagnosed with diabetes, meaning that Mexico ranks 9th worldwide. However, the figure may be higher, since six of 10 diabetics had never had their blood sugar measured until they saw a doctor as the result of a related symptom. It is one of the leading causes of death in the country, with a logarithmic increase in the mortality rate, from 2.0 to 70.9 deaths per 100,000 inhabitants between 1930 and 2008. It has been estimated by the Secretariat of Health that 98,000 Mexicans a year currently die because of diabetes, due to its association with other diseases such as hypertension, neuropathy, nephropathy and atherosclerosis, with diabetes being the main current cause of blindness, since two of every five persons with diabetes end up suffering from it. The costs to the Health System is extremely high since 14% of diabetics require dialysis, 30% of those who develop diabetic foot end up with an amputation and 10% develop neuropathies.

It is a well-known fact that 90% of diabetes cases are associated with poor eating habits and physical inactivity. In Mexico, the situation is compounded by Mexicans' propensity to consume refined sugar, mainly through soft drinks (Hert et al., 2014). Mexico ranks first in annual soft-drink consumption, with 163 liters (1) per capita, 40% above the U.S., where per-capita consumption is 118 liters. Consumption tripled between 1999 and 2006. It is estimated that seven of 10 children in rural communities accompany the first meal of the day with a soft drink (Ávila-Nava et al., 2017).

Given that a quarter of Mexican's caloric intake is derived from soft drinks, strategies and campaigns aimed at changing consumer habits have focused primarily on sugary drinks, particularly among children. This constitutes a serious social and economic conflict, since this public health problem is associated with a crop that supports more than two million Mexicans who earn their livelihood from sugar-cane harvesting and processing. Indeed, Mexico is self-sufficient in cane sugar, with an average production of 52 ml t/year (2004-2014), yet has encountered serious trade problems with the U.S. in exporting its surplus. This year (2017), even before the review of the North American Free Trade Agreement (NAFTA), the refined sugar export quota to the U.S. has been substantially reduced, meaning that Mexico can only export unrefined sugar. At the same time, soft drink bottling is one of the most powerful industries within the country's food and economic sector (Clark et al., 2012).

c. Expected changes in the current consumption pattern (and implications for food imports)

Toward understanding and encouraging changes of attitude toward consumption. Emergency of personalized nutrition

As of January 1, 2014 in Mexico it was decided to levy a $1/l (Mexican peso per liter) tax on sweetened beverages. In an article published in the British Medical Journal, a year after this measure had been applied, researchers from the National Institute of Public Health, in collaboration with researchers from the University of North Carolina, concluded that bottled soft-drink purchases had fallen by 6% over the same period in 2014 (Colchero et al., 2016), particularly among low-income families. This groundbreaking study in quantifying the effect of this type of policy concludes that, although the change is moderate, it is essential to continue implementing and assessing the program, particularly to detect how consumers have adjusted to the measure. The policy should be accompanied by an intense campaign to prevent access to sugary drinks in schools and introduce drinking fountains. However, there are as yet no data on the compliance with and impact of these measures.

The "Hispanic Paradox," a term coined by Kyriakos Markides to describe a 30-year-old epidemiological phenomenon among Hispanics in the U.S., refers to the fact that Hispanics have greater longevity, despite their unfavorable socioeconomic status and difficulties in accessing the health system (Anonymous, 2015). The editorial refers to a report by the U.S. Centers for Disease Control (CDC), which confirms the differences between Hispanics and the White population. Hispanics showed a 24% lower risk of suffering any of the 15 leading causes of death among U.S.-born Whites, primarily cancer and heart disease. This does not spare the population from diabetes, which, together with liver diseases and death from homicide, are substantially higher among Latinos than Whites, as is the problem of obesity. The article concludes by pointing to the fact that health authorities cannot ignore the health of Hispanics, particularly considering the current trend toward personalized medicine and the risk factors associated with each population. In this regard, specific studies by the National Institute of Genomic Medicine in Mexico have unveiled genetic risk factors for diabetes associated with Mexicans. They refer to specific mutations not seen in European or Asian population, or even in the northern regions of the country, but among Cora and Maya Indians, and to a lesser extent, among the Zapotec and Otomí.

An analysis of the correlation between the weight differential between Mexican and U.S. populations and their evolution since NAFTA raises the question of whether, in public health terms, this is a good agreement for Mexico in terms of health. The percentage of obese women in 1988 was 10% in Mexico, compared to 25% in the U.S. By 2006, these figures had risen to 32 and 35% (Young & Hopkins, 2014), in other words, the health advantage that the Mexicans' diet had conferred before NAFTA had been lost. Despite constituting 11% of the population in the U.S., the Hispanic population accounts for 33% of the consumption of beans which, together with corn, constitutes the base of the Mexican diet. In per-capita consumption, Hispanics consume 4 to 5 times more beans than the White population. Studies are still required to determine the causes that contribute to this correlation.

In the case of corn, tortilla consumption in Mexico decreased by 30 kg per capita annually in the last decade, triggered by the elimination of the government subsidy on corn prices, according to information from industrialists in this field. In 1997, when it was decided to eliminate the tortilla subsidy, average annual tortilla consumption was 120 kg per capita. A decade later, every Mexican eats an average of 90 kg of tortilla a year, in other words, 25% less. One of the main instruments used by Mexican health authorities to deal with the problem of diabetes and obesity is the recovery of the traditional diet, and the cereals, vegetables, fruits and dishes it comprises. The fact that Mexican cuisine has recently been recognized by UNESCO as intangible world heritage, coupled with widespread evidence of the health benefits of its ingredients, lends credibility and support to any health campaign for Mexicans.

VII. Political considerations

a. Public programs and subsidies in the Mexican agricultural sector (Distortions created by subsidies and other outmoded agricultural policies)

In 1940, the State adopted a key role in regulating economic, political and social relations for the countryside, with particular emphasis on welfare processes. Agricultural policy in the 1970s and 1980s was based on increasing direct government interventions through price guarantees and subsidies for the acquisition of credits, inputs and food consumption focusing mainly on grain and oilseed producers. Support was provided for storage, distribution and processing, as well as corn tortilla price subsidies. Commercial protection through the application of import licenses resulted in poor performance by the agricultural sector, which in turn led to rentierism, unemployment and inefficient production (Yúñez, 2010). These policies created distortions and discretionary support, limiting access to certain sectors of the population.

Following the constitutional reform of 1992, Article 27 was amended and a new Agrarian Law enacted with a two-fold aim: i) delimit the expansion of the agricultural frontier due to land distribution and the growth of smallholdings, and ii) promote the market of lands belonging to the ejido due to the stagnation of production (Taylor et al., 2007). To this end, new regulatory schemes were established with the aim of reducing the public and administrative expenditure of the State, which reoriented federal policies in this area. Due to the prevalence of smallholdings, the heterogeneity of conditions in productive agricultural units and differences in the development of the states, the sector suffered from a lack of market access, technological backwardness, low productivity, low incomes and migration from the countryside to the city (FAO-SAGARPA, 2012). Consequently, agrarian development policies have diversified over the years to meet the needs of productive units by channeling various supports and subsidies into them (SAGARPA, 2017, FIRA, 2015).

In the 1990s, programs were promoted to combat rural poverty and the sustainable use of natural resources and public policies were designed to facilitate the transition of the sector to the free market context, in line with the passage of NAFTA. The Support and Services for Agricultural Marketing Agency (ASERCA) and its various programs have operated since 1991 through subsidies to producers and buyers, mainly for grains and oilseeds. The Direct Support for the Countryside Program (PROCAMPO) was established in 1994 as a system to lend certainty to low-income producers and eliminate the distortions caused by guaranteed support. Its main objective was the reorganization of activities and crop conversion to shift to more competitive varieties and reduce dependence on basic crops. Its inclusive aim made the instrument less accurate. Due to the lack of clarity regarding its objectives, the program was used with interpretations in the transfer of resources to support the current income of rural producers, or to strengthen productive aspects of agricultural units. Public subsidies encouraged transfers that offset the effects of international competition on domestic producers, most of which benefited ejido owners of rain-fed farmland. Unfortunately, the atomization of funds in smallholdings and the low performance of the agricultural productive units that received support continued.

Lack of precision, targeting problems, irrelevant support and absence of coordination with other public policies in the sector strongly limited results (FAO-SAGARPA, 2015a). A similar thing happened with other programs due to their modular application. Their implementation created inequalities among beneficiary producers and negative effects on non-beneficiaries, further polarizing the countryside (Taylor et al., 2007). The State's commitment to streamlining the use of resources through increases in investment and bank loans has not been fully achieved. Evaluations of guarantee programs indicate that credit subjects have mainly been producers from higher income strata, since they have less difficulty providing the guarantee requirements requested by the financing institutions (FAO-SAGARPA, 2015b). Productive stratification persists with very poor sectors that prefer to migrate from the countryside and continue the process of reorientating the national agricultural supply toward the production of more competitive crops to leverage global market trends. Family farmers who used the programs concurrently achieved better performance (FAO-SAGARPA, PROCAMPO Component and Guarantees Component).

Since 2001, a new legal framework has encouraged the concurrence of programs to improve their effectiveness and interrelation. The main policy instrument in force is the Concurrent Special Program for Sustainable Rural Development (PEC, 2012), which brings together public policies on rural development. Structured in nine aspects, under a scheme of intersecretarial co-responsibility, it promotes 10 regional multisectoral strategic projects aligned with the National Development Program and leverages the National System of Support to Programs Inherent to the Promotion of Sustainable Rural Development Policy, with productive, competitive and social approaches.

b. Promotion of nutrition-sensitive agriculture to provide healthy, sustainable diets, linked to resource use and food prices

Mexico is classified as having a moderate level of food insecurity, with regard to access to food. Nationwide, 23.3% of the population has deficits in access to food, rising to 32% in rural areas. The National Crusade against Hunger (2014) recognizes that food deprivation is the result of a complex, multidimensional socioeconomic environment that requires a holistic approach and multiple public policy instruments for food, health, education, housing, services and income.

The Integral Rural Development Program (PIDER) was created in 2014 to address the problems of food insecurity experienced by a high percentage of the country's rural population, based on the regrouping of previous programs (CONEVAL, 2015). Its purpose is "to contribute to eradicating food shortages in rural areas by producing food with a sustainable approach for the population in extreme poverty in marginalized and peri-urban rural areas, so that this population can produce food with a sustainable approach". In this context, SAGARPA and the Secretariat of Social Development (SEDESOL) provide support to encourage family farming, productive projects and welfare services. Efforts have also been made to promote the component of the Special Program for Food Security (PESA), an FAO-SAGARPA collaboration aimed at achieving the food and nutrition security of families from rural areas with high and very high marginalization. In 2016, 26,036 productive projects benefited 207,762 families from 8,594 rural localities in 923 municipalities, with the support of 332 Rural Development Agencies (SARD) and 12 Multidisciplinary Technical Teams (PESA-85, SAGARPA, 2016a). The results obtained will have to be evaluated to determine the effectiveness of these programs and decide whether they should be continued and extended in future administrations.

c. Policies that encourage technological innovation

Expenditure on agricultural research and development accounts for a mere 0.016% of total GDP. Federal spending on agriculture corresponds to just 10.2% of the total budget allocated to the Special Concurrent Program (PEC) for research, development and technology transfer (CEDRSSA, 2017). The most recent CONEVAL evaluation indicates a low effect of research and technological development activities on productivity and their low use in productive processes. The limited application of innovations and knowledge is compounded by the fact that there is no effective link with producers' demands and needs. Public policies in this area are usually fragmented and the objectives of existing programs are too broad and inaccurate, hampering the effectiveness of public investment for research and technological development in the sector (CONEVAL, 2015). Nevertheless, PIDER components include the Integral Development of Value Chains to promote productive aspects and technical assistance and training, and Outreach and Productive Innovation for outreach activities in states, linkage with national and foreign institutions, training and agricultural education outreach.

CONACYT allocates resources for basic and applied research through institutional funds and the CONACYT-SAGARPA Sectoral Fund to maintain the Research, Innovation and Agricultural Technological Development component, aimed at solving problems in the production, industrialization or commercialization of products, integrating biodiversity and modernizing the production of agricultural crops with machinery and equipment (SAGARPA, 2016a). There are other programs designed to enhance the competitiveness and coordination of agricultural production chains through the improvement of technical and research capacities, as well as the maximal use of binding entities, such as the National Research and Technological Transfer System for Rural Development (SNITT), the National System of Training and Integral Rural Technical Assistance (SNCATRI), the CONACYT Thematic Networks and the PRODUCE foundations, which foster links between research institutions and user producers. However, the lack of clarity of these programs, the indefinition of strategic priorities and the opacity of the mechanisms for granting support limit their effectiveness.

On the basis of sectoral diagnoses (CONEVAL, 2017), it has been observed that stagnation depends on the poor genetic quality of seeds and low investment in innovation to improve value chains. The Sustainable Modernization of Traditional Agriculture (MasAgro) Program is a rural research and development project sponsored by SAGARPA and CIMMYT and designed to promote the sustainable intensification of maize and wheat production in Mexico. MasAgro develops research and capacities designed to increase the profitability and stability of maize and wheat yields. The Program also seeks to increase farmers' incomes and the sustainability of their production systems through collaborative research schemes, the development and dissemination of adapted seed varieties, and sustainable agronomic technologies and practices.

Technological options include the development of productive strategies and innovations using modern biotechnology. These latter applications are subject to regulation through the LBOGM, which establishes that resources will be allocated through the CIBIOGEM FUND to promote research, development and innovation projects in biotechnology, designed to solve the country's specific productive needs and directly benefit national producers (LBOGM, 2005).

d. Policies that strengthen human resources

In the 1990s, private technical assistance was promoted, with costs being absorbed by the government and producers. This third-party model requires the development of professional services with trained personnel and the ability to encourage producers' participation. In 2016, a list was compiled of 3,836 outreach workers, who benefited 150,000 producers from 31 states in the E1, E2 and E3 strata (SAGARPA, 2016a). Through Objective 2, the PEC "...encourages the training of high level human capital, associated with the development needs of the rural sector," for which there is an Education and Research Program for capacity building in education and training professionals in agricultural work. Efforts have also been made to consolidate women's strategic participation in the agricultural sector through social inclusion and gender equity programs. Between 2011 and 2015, women's participation in productive work was 19.7% while their access to land ownership has gradually increased. Programs such as PROMETE (Fund for Supporting the Productivity of Entrepreneurial Women) are designed to promote women's participation in productive projects (SAGARPA, 2016b). Other programs such as PROSPERA education, PROSPERA social inclusion, agricultural workers and capacity building in education are also oriented toward human resource training.

e. Policies that redesign agricultural ecology (land use, bioeconomics, etc.)

The PESA component lends continuity to programs for the promotion of agricultural ecology projects. Beneficiaries receive support packages for family gardens and farms, and training and technical services are provided directly, in an attempt to achieve an agroecological approach. Resources focus on the development of family orchards and backyard agricultural projects, which benefit women and the elderly living under marginalized conditions. The Family, Peri-urban and Backyard Agriculture component is used to encourage food production in 57 urban and peri-urban areas in 20 states, and horticultural, poultry and fruit packs have been delivered for food production, mainly for self-consumption.

The Integral Value Chain Development component supports projects for products such as honey, coffee, lime, prickly pear, walnut, mango, papaya, bananas, maize, beans, vegetables, sheep, cattle (beef and milk), tilapia and shrimp, among others, benefiting people in extremely poor rural areas with high or very high marginalization.

Three components are available for sustainable regional development and wildlife protection. These programs provide economic support to people residing in localities located in protected natural areas, priority regions and areas of influence, to undertake projects, technical studies and training courses designed to conserve ecosystems and their biodiversity, or produce wildlife management units. The approach is designed to benefit 20 authorized species and conserve the habitats of other endangered species (CEDRSSA, 2017).

f. Policies to promote the consumption of healthy foods

Mexico has a long history of implementing programs and policies aimed at improving the nutrition of vulnerable groups (Baquera et al., 2001). In this regard, the Secretariat of Health has launched major campaigns on nutrition and healthy eating habits. The main national policies are oriented toward food production and consumption, with subsidy programs for food products in the basic basket, tortillas and milk. Direct interventions are promoted for complementary micronutrient supplementation and nutrition education for vulnerable groups. Human development and food support programs, social milk supply (LICONSA) and school breakfasts are implemented through the System for Integral Family Development (DIF).

The National Crusade against Hunger, involving the coordination of 70 federal programs in 19 units for the allocation of resources with national coverage, has the following objectives: reduce the hunger of people in extreme multidimensional poverty, through adequate food and nutrition; eliminate acute malnutrition and improve child weight and height indicators; increase the food production and income of peasants and small farmers; minimize postharvest and food losses during storage, transportation, distribution and marketing; and promote community participation to eradicate hunger. Moreover, special attention is paid to the safety of the food consumed by the actions of the Federal Commission for Protection from Health Risks (COFEPRIS, SSA) and the National Food Safety and Quality Service (SENASICA, SAGARPA).

g. The country's comparative advantages in agriculture

Mexico's geographical position, diversity of climates and large territory provide a great variety of crops and agricultural, fishing and livestock species. As a result of its infrastructure and human resources, the country ranks 12th in world food production, 13th in agricultural crops and 11th in livestock production (SAGARPA, 2016b). Although there are constraints on agricultural production units, the productive sector as a whole is highly competitive with a diversified portfolio of high-quality fresh food and produce.

h. International trade issues

Mexico currently has a positive agri-food trade surplus and a growing annual agri-food trade. It is a leader in international agricultural and agroindustrial markets with good potential for growth, mainly in beer, avocado, tomato, tequila, beef, vegetables and fruit. The agri-food exports sector is dynamic, with 11 free trade agreements with 45 countries, constituting a potential market of approximately 1.462 million people, and constantly seeks new market niches to improve sales of agricultural, livestock and fishery products. According to international standards, the state promotes health policies with the purpose of increasing the supply and competitiveness of Mexican agricultural products and reducing access barriers to national and international markets.

i. Market challenges

Population growth will be the main driver of global demand for agricultural commodities over the next few years. With a population projection of 8.1 billion by 2025, food demand must be met by improving efficiency, expanding production options that create only small increases in the production base (OECD-FAO) and streamlining the use of the sowing surface of crops and cattle herds. This will test the technological alternatives available to the agricultural sector to achieve sustainability and market supply goals.

According to FAO indicators, agricultural commodity price projections are declining, with a tendency to stabilize in the medium term. It would be useful to have agricultural technologies that add value to products. In this respect, challenges continue to focus on increasing the productivity of the sector, maintaining the competitiveness and quality of the food exported, while at the same time, combining social and productive objectives for the sustainable use of natural resources and the conservation of biological diversity.

VIII. Abstract

a. Potential national agricultural scenarios for agricultural production in the next fifty years

Mexico faces enormous challenges to its food and nutrition security, which will only be able to be resolved through the coordinated action of various sectors that have an impact on the production problem. On the one hand, there is a need to implement strategies for adaptation to and mitigation of climate change, and to include programs for the conservation and sustainable use of biodiversity and genetic resources for agriculture and food. There is also an urgent need to boost effective investment for the development of the countryside through partnerships between the public and private sectors and academia, in order to generate innovations that solve all the productive problems of the various strata involved in food production. It is also necessary to promote educational programs and technical and scientific training to attract young people to the countryside, and for the activities associated with it to be a genuine source of decent work. All this is associated with trans-administration agricultural policies that allow continuity and follow-up for effective programs and adapt those that require improvements. This takes place in a regulatory context that encourages innovation and provides security for investment and the strengthening of agricultural practices that ensure food independence in a sustainable manner, while supplying a competitive market at fair prices for producers that are affordable for the entire population.

b. Priority actions to achieve and preserve agricultural sustainability

Mexico has vast natural resources, diversified agricultural capacity, operational institutional infrastructure and competition in technological development. There are state policies focused on addressing the main problems of agriculture, nutrition and the environment, usually implemented in a modular way in an incipient transversal scheme. It would be useful to publicize national strategies for the concurrence of public policies and coordinate their implementation to provide greater clarity and regulatory certainty, promote synergies and joint institutional actions and leverage the nation's advantages in order to achieve the food security and sustainability objectives demanded by Mexican society.

References

ALIANZA (2016). Catálogo de Buenas Prácticas para la Reducción de Riesgos de Desastre. Alianza para la Reducción de Riesgos y Recuperación ante Desastres, conformada por Ayuda en Acción México, Fomento Social Banamex, Oxfam Mexico, el Programa de Apoyo a la Reducción de Riesgos de Desastres en México (PMR) del Programa de Naciones Unidas para el Desarrollo (PNUD) and World Vision Mexico.

Alba F., Banegas I., Giorguli S. and de Oliveira O. (2007). El bono demográfico en los programas de las políticas públicas de México (2000-2006): un análisis introductorio, en Consejo Nacional de Población, La Situación Demográfica de México, 2006. Distrito Federal, Consejo Nacional de Población.

Ajanovic A. (2011). Biofuels versus food production: Does biofuels production increase food prices? Energy, 2011, vol. 36, issue 4, pp. 2070-2076.

Altieri M. A., Funes F., Henao A., Nicholls C., León T., Vázquez, L., and Zuluaga G. (2011). Hacia una metodología para la identificación, diagnóstico y sistematización de sistemas agrícolas resilientes a eventos climáticos extremos. Documento de trabajo de la Red Iberoamericana de Agroecología Para el Desarrollo de Sistemas Agrícolas Resilientes al Cambio Climático.

Ampudia, M. S. (2008). La Ley de Promoción y Desarrollo de los Bioenergéticos. Un análisis económico de una falla de gobierno. Revista Derecho Ambiental y Ecología. Centro de Estudios Jurídicos y Ambientales. Retrieved from http://www.ceja.org.mx/revista.php?id_rubrique=215

Anonymous (2015). The Hispanic Paradox. Lancet. Vol. 385, May 16: p. 1918.

Arrazola-Ovando E., and López-Arévalo J. (2012). Crisis en el sector rural y migración mexicana. Comunicación V Premio José Luis Sampedro. XVI Reunión de Economía Mundial. Spain.

Ávila-Nava A., et al. (2017). Food combination based on a pre-Hispanic Mexican diet decreases metabolic and cognitive abnormalities and gut microbiota dysbiosis caused by a sucrose-enriched high fat diet in rats. Molecular Nutrition & Food Research, 61, 1.

Banco Mundial, 2016. Retrieved from: http://datos.bancomundial.org/indicador/AG.LND.ARBL.ZS?locations=MX&view=chart

Baquera, et al. (2001). Políticas y programas de alimentación y nutrición en México, Salud Pública de México, vol. 43, no. 5, pp. 464-477.

Becerra R. (2000). Las cactáceas, plantas amenazadas por su belleza. CONABIO. Biodiversitas, 32:1-5.

Blanco C. et al. (2014). Maize pests in Mexico and challenges for the adoption of integrated pest management programs. Journal of Integrated Pest Management, Open Access 5(4). Retrieved from: DOI: http://dx.doi.org/10.1603/IPM14006

Boletín Epidemiológico (2016). Sistema Nacional de Vigilancia Epidemiológica. Sistema Único de Información. Secretaría de Salud. No 52, Vol. 33, Semana 52. 25-December 31, 2016.

Bolívar F. G. (2004). Fundamentos y casos exitosos de la Biotecnología Moderna. El Colegio Nacional.

Brookes G and Barfoot P. (2017). GM Crops. Global and socioeconomical impacts 1996-2015. PG Economics Ltd., Dorchester UK.

Caballero, J. y Cortés, L. (2012). Base de Datos Etnobotánicos de Plantas de México (BADEPLAM). Jardín Botánico Instituto de Biología, Universidad Nacional Autónoma de México, Mexico City, Mexico.

Casas A., Otero-Arnáiz A., Pérez-Negrón, E. and Valiente-Banuet, A. (2007). In situ management and domestication of plants in Mesoamerica. Annals of Botany 100:1101-1115.

CENAPRED (2001). Diagnóstico de Peligros e Identificación de Riesgos de Desastres en México: Atlas Nacional de Riesgos de la República Mexicana. Secretaría de Gobernación, Sistema Nacional de Protección Civil, Centro Nacional de Prevención de Desastres. Mexico City, Mexico.

CENAPRED (2015). Índice de Resiliencia a Nivel Municipal. Dirección de Análisis y Gestión de Riesgos, Subdirección de Estudios Económicos y Sociales, Centro Nacional de Prevención de Desastres (preliminary document). Mexico City, Mexico.

CEDRSSA (2015a). Recurso Suelo: Elementos para la definición de una política pública en México. Centro de Estudios para el Desarrollo Rural Sostenible y la Soberanía Alimentaria. Reporte No. 24. Retrieved from: http://www.cedrssa.gob.mx/?doc=3046 (07/07/2017)

CDRSSA (2015b). La acuacultura. Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria. Cámara de Diputados, LXII Legislatura.

CEDRSSA (2017). El Programa Especial Concurrente para el Desarrollo Rural Sustentable en la cuenta Pública 2016: Análisis y comentarios. Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria, Cámara de Diputados, June 2017.

Clark S. E., Hawkes C., Murphy S. M., Hansen Kuhn K. A. & Wallinga D. (2012). Exporting obesity: US farm and trade policy and the transformation of the Mexican consumer food environment. International Journal of Occupational and Environmental Health. Jan-Mar 18(1) pp. 53-65.

COFECE (2015). Comisión Federal de Competencia Económica. Reporte sobre las condiciones de competencia del sector agroalimentario. Retrieved from: https://www.cofece.mx/cofece/index.php/prensa/historico-de-noticias/reporte-sobre-las-condiciones-de-competencia-en-el-sector-agroalimentario

Colchero M. A., Popkin B. M., Rivera J. A. & Ng S. W. (2016). Beverage purchases from stores in Mexico under the excise tax on sugar sweetened beverages: observational study. British Medical Journal, 352:h6704. Retrieved from: http://dx.doi.org/10.1136/bmj.h6704

COMECYT-FUMEC (2009). Estudio de Tendencias y Oportunidades para el Sector de Alimentos Procesados del Estado de México. Consejo Mexiquense de Ciencia y Tecnología, Fundación México-Estados Unidos para la Ciencia.

CONABIO (1998). Hidrografía Catálogo de metadatos geográficos. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Catálogo de metadatos geográficos. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.

CONABIO (2001). Mapa de suelos dominantes de la República Mexicana. Catálogo de metadatos geográficos. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.

CONABIO (2006). Capital natural y bienestar social. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México.

CONAFOR-FAO (2009). Competitividad del Sector Forestal de México Tendencias y Perspectivas. DOI: 10.13140/RG.2.2.11871.87201

CONAGUA (2011). Agenda del Agua 2030. Subdirección General de Programación, Coordinación General de Atención Institucional, Comunicación y Cultura del Agua de la Comisión Nacional del Agua. Mexico City, Mexico.

CONAGUA (2014). Estadísticas del agua en México. Mexico City, Mexico.

CONAGUA (2015). Atlas del Agua en México 2015. Subdirección General de Programación, Comunicación y Cultura del Agua de la Comisión Nacional del Agua. Mexico City, Mexico.

CONANP (2017). Áreas Naturales Protegidas. Información Espacial. Comisión Nacional de Áreas Naturales Protegidas.

CONAPESCA (2010). Políticas de Ordenamiento para la Pesca y Acuacultura Sustentables, en el marco de Programa Rector de Pesca y Acuacultura. Comisión Nacional de Acuacultura y Pesca, Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Mexico, 56 pp.

CONAPO-SEDESOL (2012). Catálogo: Sistema Urbano Nacional 2012.

CONAPO (2016). Proyecciones de Población. Retrieved from: http://www3.inegi.org.mx/sistemas/temas/default.aspx?s=est&c=17484

CONEVAL (2015). S-258 Evaluación de Diseño: Programa Integrar de Desarrollo Rural SAGARPA. Retrieved from: http://www.sagarpa.gob.mx/programas2/evaluacionesExternas/Documents/Evaluaci%C3%B3n%20de%20Dise%C3%B1o/S-258%20Programa%20Integral%20de%20Desarrollo%20Rural.pdf

CONEVAL (2017). Evaluación del Programa Sectorial de Desarrollo Agropecuario, Pesquero y Alimentario 2013-2018; Consejo Nacional de Evaluación de la Política de Desarrollo Social. Retrieved from: http://www.coneval.org.mx/Evaluacion/IEPSM/Paginas/Evaluaciones_Programas_Sectoriales.aspx

Cruzada Nacional contra el hambre (2014). Retrieved from: http://sinhambre.gob.mx/

DOF (2014). PROGRAMA Institucional del INAPESCA 2013-2018. Retrieved from: http://www.dof.gob.mx/nota_detalle.php?codigo=5356331&fecha=14/08/2014

Encuesta Nacional Agropecuaria (2014). SAGARPA INEGI. Boletín Especial. Retrieved from: http://www.inegi.org.mx/saladeprensa/boletines/2015/especiales/especiales2015_08_8.pdf

ESANUT (2012). Encuesta Nacional de Salud y Nutrición 2012. Retrieved from: http://ensanut.insp.mx/ http://ensanut.insp.mx/informes/ENSANUT2012ResultadosNacionales.pdf

Espinosa, D., Ocegueda, S., Aguilar, C., Flores, O., Llorente-Bousquets, J., y Vázquez, B. (2008). El conocimiento biogeográfico de las especies y su regionalización natural. En: Capital natural de México, vol. I: Conocimiento actual de la biodiversidad. CONABIO, Mexico, pp. 33-65.

FAO (2010). Evaluación de los recursos forestales mundiales. Informe Nacional, Mexico.

FAO-SAGARPA (2012). Diagnóstico del Sector Rural y Pesquero: Identificación de la Problemática del Sector Agropecuario y Pesquero de México, 2012.

FAO (2015). Pérdidas y desperdicios de alimentos en América Latina y el Caribe. Boletín #2. Retrieved from: http://www.fao.org/3/a-i4655s.pdf

FAO-SAGARPA (2015a). Componente PROCAMPO. Evaluación Nacional de Resultados 2013, November 2015. Retrieved from: http://www.fao-evaluacion.org.mx/evaluacion/library/files/Informe%20PROCAMPO.pdf

FAO-SAGARPA (2015b). Componente Garantías. Evaluación Nacional de Resultados 2013, November 2015. Retrieved from: http://www.fao-evaluacion.org.mx/evaluacion/library/files/Informe%20Garant%C3%ADas.pdf

Fernández S. R., Morales C. L. A., y Gálvez M. A. (2013). Importancia de los maíces nativos de México en la dieta nacional: Una revisión indispensable. Revista fitotecnia mexicana, 36, 275-283.

FiercePharma (2016). Retrieved from: http://www.fiercepharma.com/special-report/boehringer-ingelheim-vetmedica-top-10-animal-health-companies

FIRA (Fideicomisos Instituidos en Relación con la Agricultura) (s/f). Retrieved from: https://www.fira.gob.mx

FIRA (2015). Panorama Agroalimentario: Maíz 2015.

Fondo de las Naciones Unidas para la Población (2012). Population Issues. Retrieved from: http://www.unfpa.org/issues/

Gil-Méndez, J. (2007). La migración como factor de cambio en el espacio agrícola de localidades rurales ubicadas en el Valle de Ixtlán, Michoacán, in Revista de Investigaciones México-Estados Unidos CIMEXUS, Vol. II, No. 2, July-December 2007, ININEE, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, México.

Giourguli S. (2017). Perdió México su bono demográfico, la esperanza es el bono de género. Entrevista de la Agencia Informativa CONACYT. Julio 2016. Retrieved from: http://conacytprensa.mx/index.php/ciencia/humanidades/8938-perdio-mexico-su-bono-demografico-la-esperanza-es-el-bono-de-genero

Graham-Rowe D. (2011). Beyond food versus fuel. Nature, 474, S6-S8.

Hall S. (2016). New gene editing techniques could transform food crops –or die on the vine. Scientific American. March 2016.

Heckel D. (2012). Insecticide resistance after Silent Spring. Science, Vol. 337, 6102, pp. 1612-1614337.OJO September.

Hernández Rodríguez, A., Ojeda Barrios, D., Vences Contreras, C., y Chávez González, C. (2009). Situación actual del recurso suelo y la incorporación de abonos orgánicos como estrategia de conservación. Synthesis:OJO Aventuras del pensamiento, 49, 1-6.

Hert K. A., et al. TRES AUTORES (2014). Decreased consumption of sugar-sweetened beverages improved selected biomarkers of chronic disease risk among US adults: 1999 to 2010. Nutrition Research, 34, pp. 58-65.

IICA (2012). 70 años de Historia. Instituto Interamericano de Cooperación para la Agricultura. ISBN: 978-92-9248-401-9. Mexico.

INAPESCA (2006). Sustentabilidad y Pesca Responsable en México: Evaluación y Manejo. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Instituto Nacional de la Pesca, Mexico City, Mexico.

INAPESCA (2014). Sustentabilidad y Pesca Responsable en México: Evaluación y Manejo. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Instituto Nacional de la Pesca, Mexico City, Mexico.

Índice de Sostenibilidad Alimentaria 2016. Retrieved from: http://foodsustainability.eiu.com/country-ranking/

INECC (2016). Informe de la Situación del Medio Ambiente en México. Compendio de Estadísticas Ambientales. Indicadores Clave, de Desempeño Ambiental y de Crecimiento Verde. Sección Cambio Climático. Mexico City, Mexico.

INEGI (2013). Conjunto de datos vectoriales de uso de suelo y vegetación, escala: 1:250000. Edición: 2a. Instituto Nacional de Estadística y Geografía.

INEGI (2015). Balanza comercial de mercancías de México, Información revisada enero-junio, 2015.

Islas-Rivera, V. M., Moctezuma-Navarro, E., Hernández-García, S., Lelis-Zaragoza, M. y Ruvalcaba-Martínez, J. I. (2011). Urbanización y motorización en México. Instituto Mexicano del Transporte, Secretaría de Comunicaciones y Transportes, Publicación Técnica No. 362.

IUSS (2007). Base Referencial Mundial del Recurso Suelo. Primera actualización. Informes sobre Recursos Mundiales de Suelos No. 103. Grupo de Trabajo WRB, FAO. Roma, Italia.

Jiménez-Sierra, C. L. (2011). Las cactáceas mexicanas y los riesgos que enfrentan. Revista Digital Universitaria, Volume 12, No. 1.

Ley de Bioseguridad de Organismos Genéticamente Modificados (2005). Artículo 28. Diario Oficial de la Federación.

Lu Y, et al. (2012). Widespread adoption of Bt cotton and insecticide decrease promotes biocontrol services. Nature. DOI:10.1038/nature 11153.

Luna-Vega, I. (2008). Aplicaciones de la biogeografía histórica a la distribución de las plantas mexicanas. Revista Mexicana de Biodiversidad, 1(1), 217-242.

Magaña-Rueda, V. O. (2006). Informe sobre escenarios futuros del sector agua en México bajo cambio climático para las climatologías del 2020, 2050 y 2080. 3ª Comunicación Nacional sobre Cambio Climático. Instituto Nacional de Ecología (INE), Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). Mexico City, Mexico.

Martínez-Campos, S. A. y Alcalá-Sánchez, I. G. (2012). La migración campo-ciudad, un grave problema social y educativo. Primer Congreso Internacional de Educación, Chihuahua, Chihuahua, Mexico.

McNutt M. (2015). Breakthrough to genome editing. Science, Vol. 350, 6267, 1445.

Miranda-Colín, S. (2000). Mejoramiento genético del maíz en la época prehispánica. Agricultura Técnica en México, 26:3-15.

Navarro-Chávez J. C. L., and Ayvar-Campos F. J. (2013). Competitividad, Migración y Desarrollo Rural: Una caracterización del caso mexicano. CIMEXUS, 4(1), 11-28.

OECD (2012). OECD Environmental Outlook to 2050: The Consequences of Inaction, OECD Publishing. Retrieved from: http://dx.doi.org/10.1787/9789264122246-en (10/07/2017).

OECD (2013). Water Security for Better Lives. OECD Studies on Water, OECD

Publishing. Retrieved from: http://www.keepeek.com/Digital-Asset-Management/oecd/environment/water-security_9789264202405-en#page1 (07/07/2017)

OCDE-FAO. Panorama General, Perspectivas Agrícolas 2016-2025.

Oliver-Morales I. M. (2016). Financiamiento Pecuario: Llave del Éxito. LXXX Asamblea General Ordinaria, Confederación Nacional de Organizaciones Ganaderas. Baja California, México.

Ortega, F., Sedlock, R. L. and Speed, R. C. (2000). Evolución tectónica de México durante el Fanerozoico. In: Llorente, J., González., E. and Papavero, N. (Eds.), Biodiversidad, taxonomía y biogeografía de artrópodos de México, vol. II. UNAM, CONABIO, Mexico, pp. 3-59.

Programa Especial Concurrente, DOF, May 2, 2014.

Quadri de la Torre G. (2011). Biocombustibles, ¿pero qué necesidad? El Economista, August 5, 2011.

Rojas-Rangel T. (2009). La crisis del sector rural y el coste migratorio en México. Iberoforum: Revista de Ciencias Sociales de la Universidad Iberoamericana, 4(8).

SAGARPA (2016a). 4° Informe de Labores, 2015-2016.

SAGARPA (2016b). Atlas Agroalimentario 2016. Servicio de Información Agroalimentaria y Pesquera (SIAP).

SAGARPA (2017). Programas de Apoyo y Fomento. Retrieved from:http://www.sagarpa.gob.mx/ProgramasSAGARPA/Paginas/default.aspx

Sánchez-Cano J. E. (2014). Los Retos del Sector Energético Mexicano Frente al Siglo XXI. Perfiles de las Ciencias Sociales, 1(1).

Sánchez J. J., Goodman, M .M. & Stuber, C. W. (2000). Isozymatic and morphological diversity in the races of maize of México. Economic Botany. 54(1): 43-59.

SEDESOL (2016). Desperdicio de Alimentos en México: Infografía. Cruzada Nacional Sin Hambre, Secretaría de Desarrollo Social. Retrieved from: http://www.sedesol.gob.mx/boletinesSinHambre/Informativo_02/infografia.html

SEMARNAT (2012). Informe de la Situación del Medio Ambiente en México: Compendio de Estadísticas Ambientales, Indicadores Clave y de Desempeño Ambiental. Sistema Nacional de Información Ambiental y de Recursos Naturales (SNIARN). Mexico City, Mexico. Retrieved from: http://apps1.semarnat.gob.mx/dgeia/informe_12/pdf/Informe_2012.pdf (07/07/2017)

SENASICA (2016). Acuerdos de declaratoria de zonas libres de plagas reglamentadas del algodonero. Retrieved from: http://publico.senasica.gob.mx/?doc=30372

SENER (2014). Estrategia Nacional de Energía 2014-2028. Secretaría de Energía. Mexico City, Mexico.

Serna-Saldívar, S. O. and Amaya-Guerra, C. A. (2008). El papel de la tortilla nixtamalizada en la nutrición y la alimentación. In: Nixtamalización del Maíz a la Tortilla: Aspectos Nutrimentales y Toxicológicos. Rodríguez-García, M. E., Serna-Saldívar, S. O., and Sánchez-Sinencio, F. (Eds.). Universidad Autónoma de Querétaro, Querétaro, Mexico. pp. 105-151.

SIAP (2016a). Anuario Estadístico de la Producción Agrícola. Cierre de la Producción agrícola 2016. Retrieved from: http://nube.siap.gob.mx/cierre_agricola/

SIAP (2016b). Atlas Agroalimentario 2016. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, Servicio de Información Agroalimentaria y Pesquera, Mexico City, Mexico.

SINAPROC (2017). Plan de Contingencias para temporada de incendios forestales. Sistema Nacional de Protección Civil. Mexico City, Mexico.

Sobrino J. (2011). La urbanización en el México contemporáneo. Reunión de Expertos Sobre: "Población, Territorio y Desarrollo Sostenible": Comisión Económica para América Latina y el Caribe, Naciones Unidas.

Sun X, et al. TRES AUTORES (2017). Nature Communications. March 16. DOI: 10.1028/ncoms14752

Taylor J., Yúñez A., and González A. (2007). Informe consolidado: Estudios sobre Políticas Públicas para el Sector Rural en México. Proyecto del Banco Interamericano de Desarrollo para la Secretaría de Hacienda y

Crédito Público. Retrieved from: http://www.cedrssa.gob.mx/includes/asp/download.asp?iddocumento=1886&idurl=2653

Terán-Durazo, G. (2015). El Sector de los Alimentos Procesados en México. Análisis Actinver, Estudios Sectoriales y Regionales, Departamentos de Análisis Económico, Cuantitativo y Deuda.

Toledo, V. M. (Editor). (2010). La biodiversidad de México: inventarios, manejos, usos, informática, conservación e importancia cultural. Fondo de Cultura Económica: Consejo Nacional para la Cultura y las Artes, ISBN: 9786074555318 e ISBN: 6074555311.

UNTAC (2013). United Nations Conference on Trade and Development. Mexico's agriculture development: perspectives and outlook. 184 pp.

Vidal-Zepeda, R. (2005). Las regiones climáticas de México. Instituto de Geografía, UNAM, Mexico City, Mexico.

Young R. & Hopkins A. (2014). Review of the Hispanic paradox: time to spill the beans. R.J. Eur. Respir. Review. 23: 439-449.

Yúnez, A. (2010). Las políticas públicas dirigidas al sector rural: el carácter de las reformas para el cambio estructural. In: Los grandes problemas de México, Economía Rural XI, 1st. ed. El Colegio de México, pp. 23-62.

Zúñiga-Herrera, E. & Arroyo-Alejandre, J. (2006). Los procesos contemporáneos de la migración. Migración México-Estados Unidos: Implicaciones y retos para ambos países. México, CONAPOUG-COLMEX-CIESAS-Casa Juan Pablos.

Acknowledgments

The authors would like to thank **Gerardo Sotomayor Serrano** for his help with the editing and copy-editing.

Box 4

Improving Production Efficiencies at Small-to-Medium Scales: Using Microbial Symbiosis

Michael F. Allen, Distinguished Professor, University of California, Riverside.

Agricultural advances in the 20th century have been largely associated with large-scale monoculture based agricultural production, but novel technologies that build on microbial symbioses are applicable in both small and medium production and offer a broad range of novel opportunities for the 21st century. For example, the application of mycorrhizae (plant-fungal mutualisms) in forestry to inoculate tree seedlings and in crop systems to inoculate legumes has been a common practice for over a generation. Today, an engineering revolution in miniaturization, advances in understanding natural gene migration, especially "horizontal gene transfer", and microbe-gene-environment interactions, all combine to drive an entire suite of new technologies. Moreover, these novel approaches can mitigate the increasing costs, both economic and environmental, of the use of fossil fuels. These novel approaches are changing the efficiency of spatial and temporal land use and resource allocation (e.g. irrigation, fertilization), both within and between fields and regions. These advances also open a range of opportunities for introducing traits that improve production, while increasing the sustainability of systems ranging from garden plots to swidden rotational fields.

Symbiotic mutualistic microbes have been regulating nutrient acquisition and carbon dynamics throughout Earth's history through direct elemental exchanges such as, phosphate, nitrogen, and water acquisition, or through indirect activities including disease resistance, influencing root:shoot ratios, and on a large-scale, by regulating long-term processes such as carbon sequestration in soils. As we learn more about the functioning of microbes in ecosystems, and about the structure of genes within microbes, we are beginning to understand and harness the multiple interactions that subsume the complexity of life.

An example: Multicropping and swidden agriculture. In the lowland Maya regions of Mexico and Central America, small (1ha) patches of land are cleared by cutting and burning the tropical seasonal forest. The new patch opened by this slash and burn approach, plus patches cleared one or two years earlier, are planted to milpa, a combination of maize, beans, and squash, interspersed with other crops ranging from chilies to hennequin. The milpa combination is especially interesting in that beans climb the stalks of maize, while squash provides a ground cover reducing weed invasions. Importantly, all of these crops form arbuscular mycorrhizal mutualisms with fungi in the Glomales order, an ancient fungal group dating to the Silurian geologic period. Because the association is not species specific, glomalean fungi connect most of the plants in the milpa, and extend to nearby patches of plants. A practical case study following the eruption of the volcano, Mount St. Helens revealed legumes as initial colonizers, associated with bright red nodules, indicative of active N_2 fixation. (The red nodules are indicative of leghaemoglobin that scavenges O_2 thereby preventing the inhibition of N_2 fixation.) When inoculated with glomalean fungi (artificially or naturally), other plants also established forming more complex patches and all plants in the new complex increased production. In the milpa, when beans are part of these patches, the associated rhizobium nodules fix atmospheric N_2, providing nitrate for protein synthesis by the host plants. When connected to a mycorrhizal network, not only is the host provided with nitrogen, but also the other plants, including maize, that are interconnected through an extensive hyphal network benefit. These fungi develop with the successional forest, but are lost rapidly following milpa production. Hence, the integration of a successional forest with the rotational swidden milpa system takes advantage of a structural system that has provided a stable production system for millennia (**Figure 1**).

Figure 1. An arbuscular mycorrhizal (AM) patch of plants and a milpa ecosystem. Shown are the AM fungal spores from a tropical seasonal forest in Mexico (upper left). These fungi connect legumes that fix atmospheric nitrogen (N_2) into usable forms, which not only enhances the growth of that individual (upper right), but also neighbors (lower left). This exchange is occurring in milpa fields throughout the Americas, although it is rarely recognized (lower right).

The formation of the mycorrhiza can dramatically increase root production and branching, and these mycorrhizal hyphal networks produce compounds that degrade slowly, especially a class of glycoproteins called glomalin, which initiate and contribute to aggregate formation (**Figure 2**). These hyphae and the aggregates that they form are distinctive, and can be recognized using even simple sub-port microscopy.

To further exploit this system, workshops were developed, first for graduate students and postdocs in Argentina, and subsequently for undergraduates in Mexico, who later taught their own workshops in a local technical high school. These workshops used simple and affordable materials and procedures appropriate to the family soils of the students. The workshops were aimed at providing simple approaches to the improved management of soil mycorrhiza, thereby exploiting their beneficial properties to increase crop productivity.

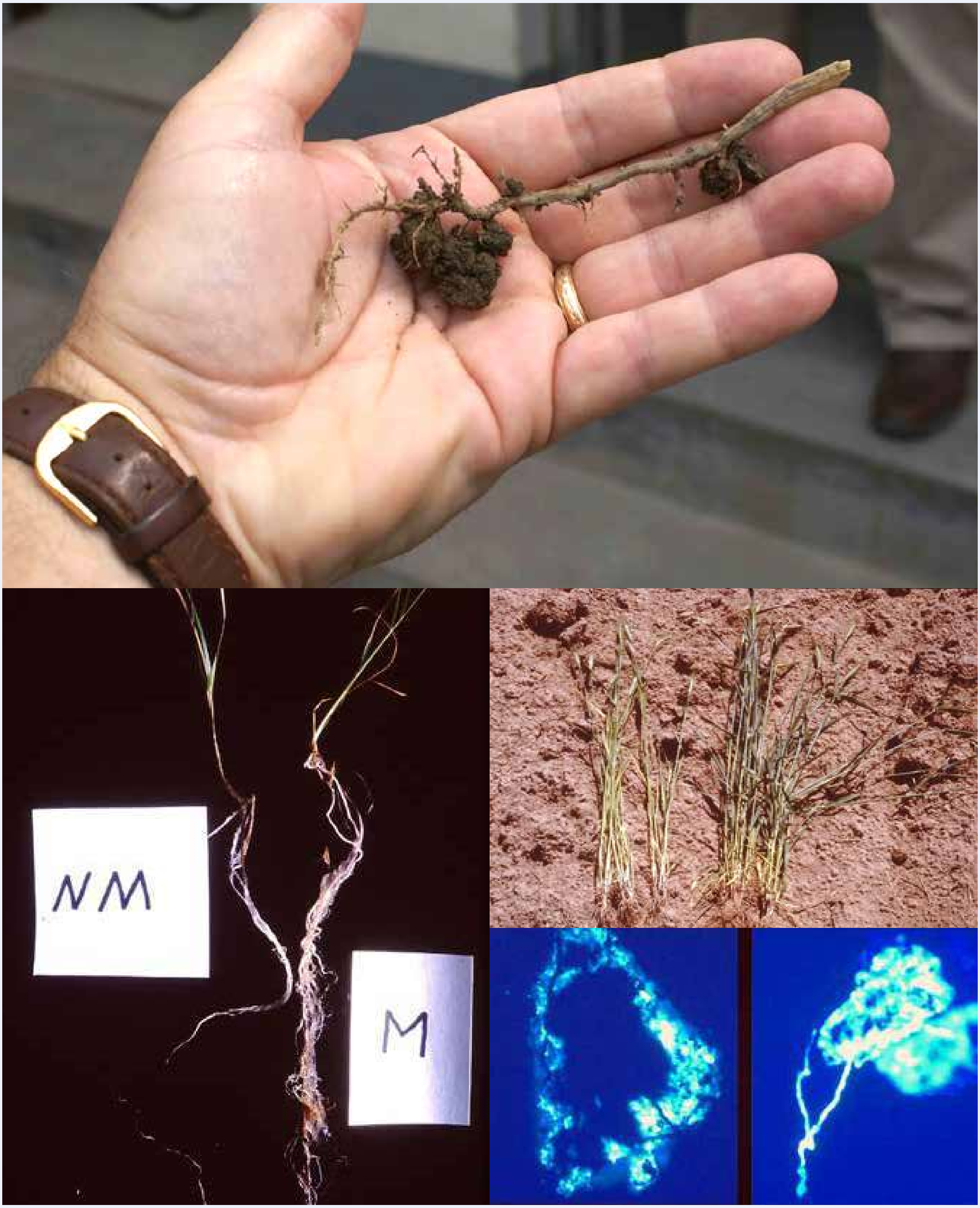


Figure 2. Root growth in response to arbuscular mycorrhizae of a native grass (lower left) and wheat (right middle). These fungi not only transfer nutrients to the host, but stimulate the formation of aggregates through the production of glomalin (lower right), a class of glycoproteins that can form up to 25% of soil stable organic matter and trigger the formation of aggregates, important for assessing a healthy soil (top panel).

Other mycorrhizal fungi have the natural capacity to tolerate heavy metals and other pollutants. For example, an isolate of *Pisolithus* sp. was found to support the growth of pines on spoils contaminated with heavy metals. These pines were harvestable for wood products and were protected from the metals by the mutualistic fungi (**Figure 3**).

Figure 3. A *Pisolithus* sp. forming an ectomycorrhiza with a host Aleppo pine in heavy-metal laden toxic waste in Spain. This association could enhance plantation forest reestablishment and has been used on many continents.

We are only just beginning to understand the ecology of microbial symbionts. One emerging finding is that many crucial genes are carried in plasmids, including genes for host specificity among rhizobia infecting legumes. Plasmids are extranuclear genetic elements that can move among colonies horizontally (in addition to their vertical tranmission from one generation to the next).

There is an enormous reservoir of important genetic traits in wildlands globally, and especially in the America's. These traits have potential economic value through their effects on nutrient transformations, disease resistance, drought tolerance, carbon sequestration, and production stability. Many of these technologies have minimal equipment requirements and virtually every country, and indeed, most agricultural high schools, can undertake and expand the application of these technologies locally. We have only begun to tap this tremendous resource.

Food and Nutrition Security for the Sustainable Development of Nicaragua

Daily life in popular market Roberto Huembes from Managua, Nicaragua © Shutterstock

Nicaragua

[1] Jorge A. Huete-Pérez
[2] Manuel Ortega Hegg
[3] Mario R. López
[4] Mauricio Córdoba
[5] Salvador Montenegro
[6] Katherine Vammen
[7] María J. Cortez
[8] Ivania A. Cornejo

By enabling the participation of public universities in the development of appropriate transgenic crops, **Nicaragua could leverage the benefits of agricultural biotechnology** through a sustainable development approach.

Summary

Nicaragua's economy relies on agriculture, representing the main income source of thousands of families in rural areas where poverty is concentrated. Despite continued efforts to increase agricultural productivity, Nicaragua has the lowest yields of most of the important crops in Central America. Many factors contribute to low productivity in Nicaragua, including emerging pests and diseases, low soil fertility, low quality of seeds and climate change. Climate change is expected to disproportionately affect smallholder farmers in Nicaragua, who already face numerous risks to agricultural production.

Smallholder agriculture and family farming is considered an engine for poverty reduction and sustainable development in Nicaragua. Food security in Nicaragua will demand improving water productivity and keeping good balances with food supply, although crop yield could increase through intensified irrigation. Furthermore, these practices along with temperature and rainfall changes may impact the soil -water balance affecting water productivity in the future.

Vital technical, financial and institutional support is required to advance agricultural production and food security in Nicaragua, particularly to be more resilient to pest and disease outbreaks and extreme weather events. Agricultural biotechnology could be a key technological platform to foster sustainable economy and to enhance food security in Nicaragua. Some new varieties of relevance to Central America could be developed to overcome droughts, floods, new pest and diseases and other problems derived from climate change.

Since most research and innovation in Nicaragua is conducted at public universities, encouraging their research capacities will enable them to play a more important role in technological innovations for agriculture, including Genetic Modification (GM) research relevant to the needs of food security. By facilitating the participation of public universities in the Genetically Modified (GM) crop- development process, Nicaragua could reap the benefits of agricultural biotechnology through a sustainable development approach.

Open dialog among policy makers, researchers and communities should be encouraged so that technologies and planning processes respond not only to producers' needs but most importantly to the needs of food and nutrition security.

Introduction

Nicaragua has made progress over the past two decades in addressing food security and nutrition issues. However, there are many challenges facing this small Central- American nation that is still recovering from the wars and political polarization of the 20th century. Moreover, Nicaragua is constantly affected by major rainfall fluctuations as well as periodic droughts that affect agriculture, clearly reflecting the impact of climate change.

This text draws on the experience of several national institutions and organizations as well as the work of several national and foreign authors who have contributed critical, purposeful analysis of the current situation in matters related to food and nutrition security. This chapter begins with a general presentation of the country from the point of view of population, geography, socioeconomics and ecosystems. The most important agricultural activities are described in order to outline the institutional framework available for knowledge management and the state of scientific research regarding the issues addressed, which are crucial for addressing the problem in a coherent, systematic way. This is followed by an overview of the use of science and technology, with particular emphasis on agriculture, livestock and aquaculture. The authors document the efficiency of the national food system and address the link between food security and public health, specifically nutrition, obesity and foodborne diseases. A critical reflection is presented on the core problems of food security in its relationship with public policies, focusing on the role of the academic sector, universities and the Academy of Sciences.

Last, a number of guidelines on how to address the central challenges are offered, based on the fact that food and nutritional security must be a fundamental priority for Nicaraguan society.

General and Sociodemographic Characteristics

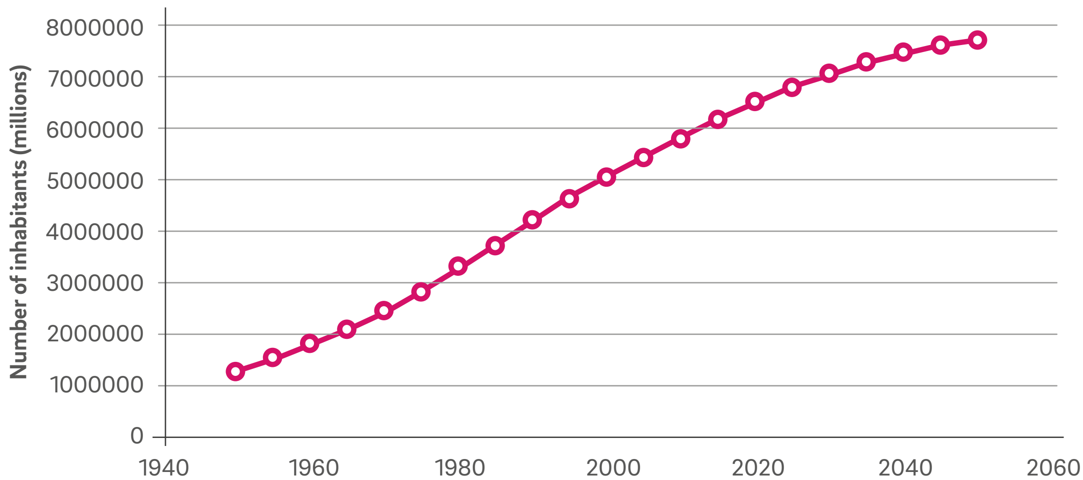
Nicaragua is the largest country in Central America with an area of 129,494 km². It can be divided into three major regions: the Pacific; the central or mountainous zone and the Caribbean. The Pacific region is characterized by flat agricultural lands stretching from the coast of that ocean approximately 75 km inland, until it meets the volcanic mountain range of Los Maribios belonging to the Pacific Ring of Fire, which extends as far as Chile. Sesame, peanut and sugar cane are grown in this region. Other major crops are maize and soybean. The Pacific region also includes the two largest freshwater lakes in Central America: the Xolotlán or Managua Lake (1,344 km²) and the Cocibolca or Nicaragua Lake (9,000 km²). The central or mountainous region is characterized by mountain peaks rising 2,000 meters above sea level (masl), where coffee plantations are developed. This region has numerous valleys producing vegetables, beans, maize and rice.

The largest region is the Caribbean or Atlantic region, encompassing 45% of Nicaraguan territory, subdivided into the autonomous regions of the North and South Atlantic. This vast area is characterized by lowlands crossed by numerous rivers such as the Rio Grande de Matagalpa, Prinzapolca and the Coco River that flow into the Caribbean.

The climate of Nicaragua is usually warm tropical with slight temperature variations depending on the height above sea level. The

[1] **Jorge A. Huete-Pérez,** Chapter Coordinator. Molecular Biologist, Central American University and Academy of Sciences of Nicaragua, jorgehuete@uca-cbm.org [2] **Manuel Ortega Hegg,** Sociologist, University of Central America (UCA) and Academy of Sciences of Nicaragua, mortega@uca.edu.ni [3] **Mario R. López, Economist,** National Autonomous University of Nicaragua and Academy of Sciences of Nicaragua, mariolopez2005@gmail.com [4] **Mauricio Córdoba,** Engineer, specializing in Territorial Development, University of Central America (UCA), cgat.fctya@uca.edu.ni [5] **Salvador Montenegro,** Biologist, Specialist in Water Resources, Academy of Sciences of Nicaragua, smontenegroguillen@gmail.com [6] **Katherine Vammen,** Microbiologist, Biochemist, Specialist in Water Resources, University of Central America (UCA) and Academy of Sciences of Nicaragua, katherine.vammen@uca.edu.ni [7] **María J. Cortez,** Chemical Engineer, Food Technology Specialist, University of Central America (UCA), cortez@uca.edu.ni [8] **Ivania A. Cornejo,** Engineer in Environmental Quality, Specialist in Environmental and Forestry Management, University of Central America (UCA), iandreacornejo@gmail.com

Figure 1. Projection of size of Nicaraguan population (1950-2050)



Source: Drawn up by the author based on data from UNDP (2015).

hot areas are the lowlands ranging from sea level to 750 masl. In these areas, daytime temperatures range from 30-33°C, while nighttime temperatures fluctuate between 21 and 24°C. Cooler temperatures occur in the central region of Nicaragua at elevations ranging from 750 to 1,600 masl , fluctuating between 24 and 27°C during the day and between 15 and 21°C at night, especially in the months of December and January. Temperatures in certain areas above 1,600 masl can go below 15°C.

Rainfall varies greatly in Nicaragua. The Caribbean region can receive an annual average of 2,500 to 6,500 millimeters. However, in the zone known as the "Dry Corridor," rainfall is erratic and less than 600 millimeters per year (INETER). This zone is extremely vulnerable due to the long, recurrent periods of drought accompanied by high temperatures, which make farming more difficult.

Most of the population is concentrated in the Pacific due to the greater service and commerce infrastructure, and to a lower extent in the Caribbean region. From 1950 to 2000, Nicaragua increased its population five-fold to more than 5 million people -56% urban and 44% rural (UNSD, 1999). An annual growth rate of 2.8% for the period from 1995-2000 and growth rates of 4.8% for urban areas (due to immigration) and 1.3% for rural areas, as well as the reduction of mortality, have favored the urbanization of the population, expected to be a major trend in the coming years (**Figure 1**).

Nicaragua's urbanization has accelerated since the 1990s. From 1970 to 1990, the urban population expanded at an annual rate of 4% and the rural population at just 2.3%. Population growth and relatively rapid urbanization require investments in infrastructure in terms of potable water, basic services, improved sanitation facilities, employment and wages, and health and education.

According to the United Nations Development Program (UNDP, 2015), Nicaragua has a population of 6.2 million, 58.5% of which is urban. In 2014, the Human Development Index (HDI) for Nicaragua was 0.631, meaning that it ranks 125 of 187 countries. Nicaragua's HDI is slightly above that of Guatemala and El Salvador, but below the average of 0.748 for the remainder of the countries in Latin America and the Caribbean. Life expectancy in Nicaragua is 74.9 years.

Nicaraguan migration has increased as a result of climate change, especially among the most vulnerable and rural populations where the highest levels of poverty are concentrated. Although the agricultural sector generates jobs, farm workers lack land and other means of production, therefore their incomes, which is one of the causes of the historical trend in migrations. One way to curb this migration would be to increase labor productivity in rural areas through the reinforcement of family farming. Poverty incidence is higher in rural areas: 68.5% and 30.5% for poverty and extreme poverty, respectively (UNDP, 2000). The lowest incidence of poverty is in the Pacific. The most severely affected groups are children under 14, equivalent to 80% of the total in rural areas.

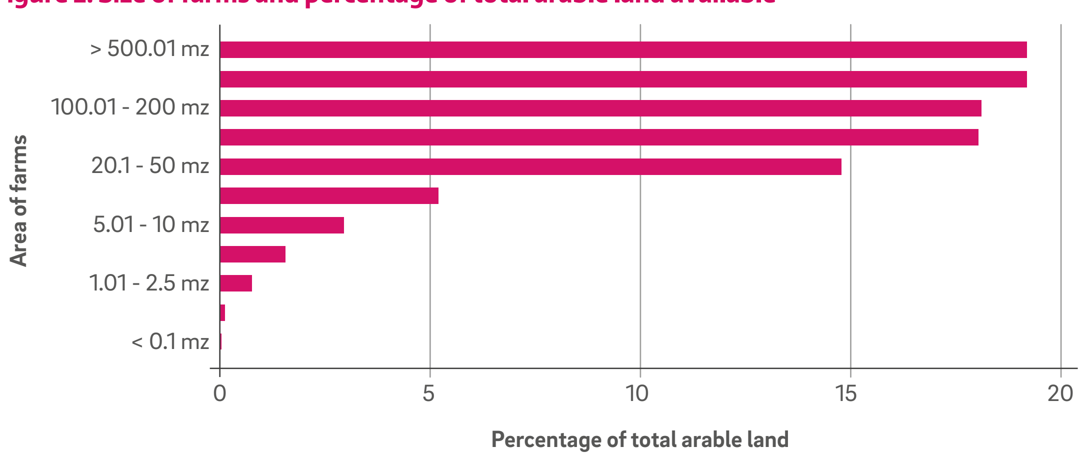
Key agricultural activities

Historically, agriculture has been Nicaragua's main economic activity. This condition has its roots in the Colonial era. In the 1500s, with the arrival of the Spaniards, indigenous productive systems practically disappeared, since the native population was forced to work in the gold mines. In the 1600s, livestock production was introduced from Europe accompanied by traditional crops such as corn, indigo and tobacco. However, Nicaragua's incursion into the international market began in earnest during the coffee boom between 1840 and 1940, which marked the country's economy. After World War II, Nicaraguan agriculture diversified with new livestock breeds and other crops such as sugar cane and cotton were introduced, mainly in the Pacific region. During the 1960s, the economy continued to grow under the incentive of the Central American common market, which later weakened. However, in the 1970s, the economy continued to grow, reaching a record high of Gross Domestic Product (GDP) in 1974. However, these figures were influenced by investment in the reconstruction of the capital, Managua, following the earthquake of 1972. The growth of the economy declined drastically as a result of the war that ended the Somoza dictatorship in 1979. During the 1980s, the Sandinista revolution, which had international aid, began a process of reconstructing the country in which education and health were prioritized.

According to the National Agricultural Census (CENAGRO, 2011), the total area for agriculture is 8.6 million (1 manzana = 0.72 acres) Seventy-five percent of the land is in the hands of farms with an area of over 50 manzanas, while farms with another 100 manzanas occupy 56% of the land. Farms ranging from 0.1 to 20 manzanas barely account for 11% of Nicaragua's arable land. This last segment contains the type of family agriculture that supplies important foodstuffs to the Nicaraguan population, contributing greatly to the nation's food security (**Figure 2**).

Agriculture plays a key role in food security, particularly because since cereals are the main source of protein and energy available to the Nicaraguan population. From the 1960s to 2010, cereal production showed an upward trend not only in relation to the planted area, but also regarding yield (**Figure 3**). In the 1980s, the area-under-cultivation decreased due to the war in

Figure 2. Size of farms and percentage of total arable land available

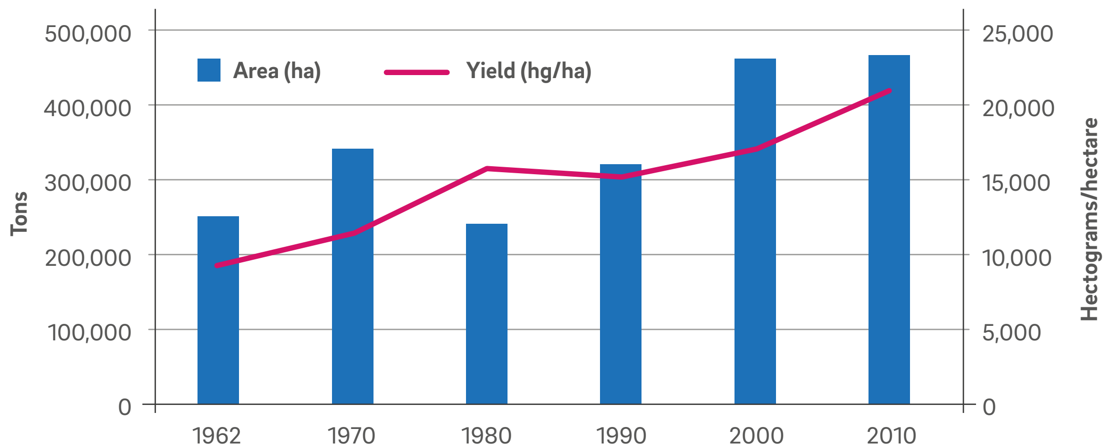


Source: Compiled by the authors with data from CENAGRO (2011).

northern Nicaragua, although yield was higher than in the 1970s.

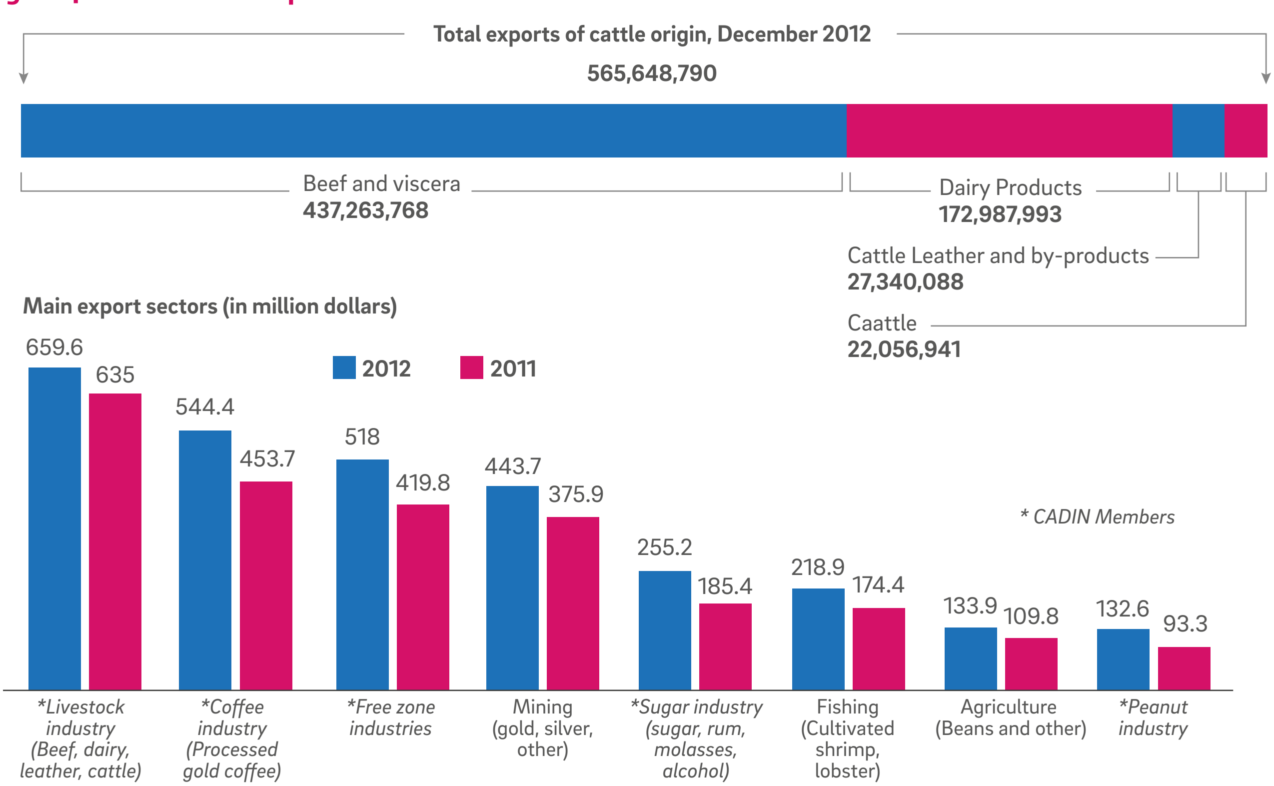
The livestock sector has accounted for a large share of the economy in recent years, proving to be the sector with the highest growth in exports for the 2011-2012 period, above the coffee sector, free zones and mining (CADIN, 2013). Of the total exports for 2012, the highest growth was in the meats and viscera sector, with 66%, followed by the dairy sector, with 26% (**Figure 4**). Nicaragua's

Figure 3. Total cereal production in Nicaragua (1962-2010)



Source: Compiled by the authors based on data from the UN Food and Agriculture Organization (FAO) (2012).

Figure 4. Livestock sector production 2011-2012



Source: CADIN (2013).

livestock sector has been characterized by extensive production with a low yield and high environmental impact. This poses the challenge of raising its technological level to increase its productivity while preserving the environment.

Livestock raising has created serious problems due to poor management and externalities of disastrous magnitude for the population. However, the problem is not agriculture or livestock, which are necessary, but the conventional farming model.

The country's agricultural exports remained above US $1 billion from 2010 to 2015, with 2012 the year of greatest exports (581.7 million) and 2015 the year with highest imports (273.7 million) (**Figure 5**).

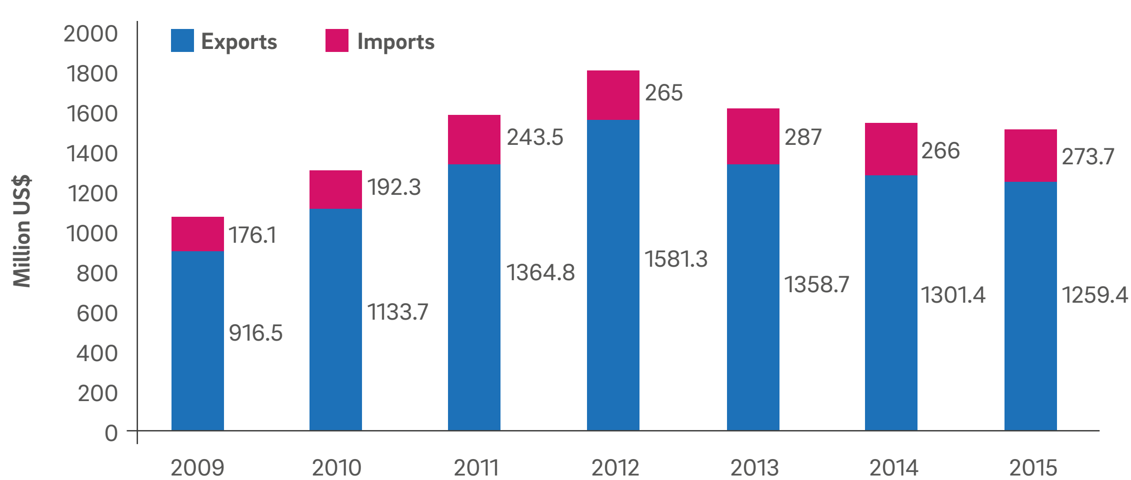
Challenges of family farming

Agriculture and livestock raising constitute the link between society and nature and are the axis of economic, social and cultural life for the country and its inhabitants (Morales, 2011). The main impact of climate change is in the area known as the "Dry Corridor". This geographical zone represents 34% of Nicaraguan territory with an area of 41,148.03 km², yet which concentrates 80% of the national population. This area includes the Departments of Nueva Segovia, Madriz, Estelí, Chinandega, León, Managua, Rivas, Masaya, Granada and Carazo, and part of the Departments of Matagalpa, Jinotega, Boaco and Chontales with a total of 116 municipalities (Baires et al., 2002).

According to Baires et al. (2002), 80% of productive families in Nicaragua earn their livelihood from family agriculture. Family agriculture is a model in Nicaraguan agriculture that contributes decisively to food sovereignty although not necessarily under the best production conditions. This type of agriculture has the highest number of farms in a smaller area of land, yet large production occupies most of the land in Nicaragua. The role of small family farming is doubly commendable, not only because it guarantees food sovereignty, but also because it has preserved soils, water and biodiversity to guarantee its survival. Even under marginal conditions, agricultural family farming contributes significantly to the national agriculture.

This produces items that are vital to the daily food supply of the Nicaraguan population, supplying over 60% of beans, 50% of maize, 40% of pork and 30% of domestic production of meat and milk, roots and tubers, vegetables and cacao (**Figure 6**). Family agriculture accounts for a smaller portion of the poultry sector, since it has mostly been acquired by transnational capital in the food industry.

Figure 5. Balance of exports and imports of agricultural products (2009-2015)



Source: Compiled by the authors based on data from ECLAC (2015), Perspectives on agriculture and rural development in the Americas.

The application of Law 765 on the Promotion of Agroecology and its regulations should encourage the family agriculture model -and its resilience.

Environmental characteristics and ecosystem status

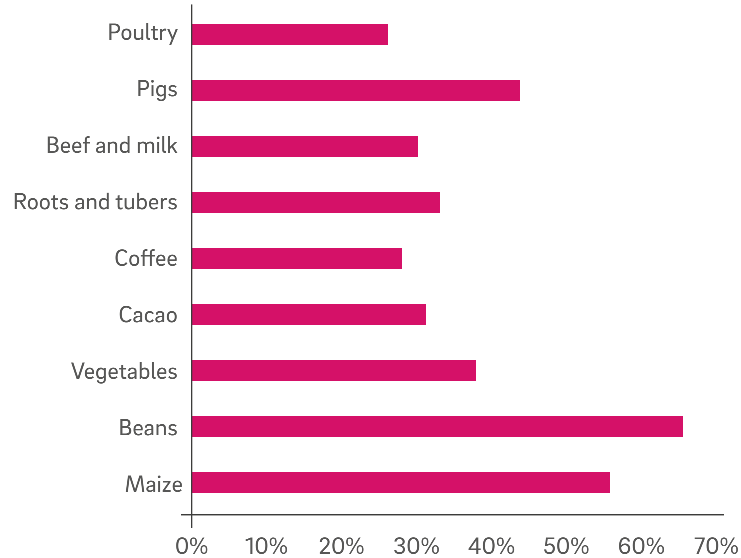
Water status

The water cycle annually deposits 311 km^3 of rain in Nicaragua, which would cover the 130 thousand km^2 of the country with a layer of nearly 2.5 m of water. Approximately 60 km^3 of water manage to infiltrate the soil while the rest evaporates, returning to the atmosphere, or draining in the form of rivers towards the slopes of the Pacific and the Caribbean, remaining temporarily in crater lakes and lagoons. FAO global statistics system Aquastat shows that by 2014, per-capita renewable water resources were 27,056 m^3/inhabitant/year, equivalent to 74,126 liters per person per day. Despite this nominal abundance of water, the population's access to potable water, especially of adequate quality, continues to limit national development. Worse still, Aquastat shows that in 1992 Nicaragua's total renewable water resources per capita totaled 37,886 (m^3/inhab/year), equivalent to 103.79 (liters/inhab/day). Thus, in just two decades (1992-2014), this indicator of the daily water supply per person was reduced by 29,671 liters per day per person (approximately 30% less). It is worrisome to note, moreover, a significant upward trend in this daily loss per person progressively.

The effects of this progressive reduction in access to water have been reported in documents such as "Socio-Environmental Crisis of Nicaragua Post Drought 2016" (Centro Humboldt, 2016).

Although Nicaragua has all the water of optimal quality it needs to irrigate the best agricultural soils and supply potable water to its entire population with the excellent waters of the Great Lake Cocibolca, it continues to depend on increasingly unpredictable and irregular rainfall regimes, which means betting our food security and national economic sustainability on a game of chance based on uncontrollable factors influenced by variability and global climate change.

Figure 6. Percentage of items produced by family agriculture in Nicaragua



Source: Compiled by the authors. Data: FAO, 2015.

Nicaragua has the capacity to implement measures to adapt to climate change at the local level, responsibly correcting the effects caused by the absence of territorial administration at the national level. It is well known that environmental stressors that are already commonplace such as deforestation, soil use changes, waterproofing in water recharge areas, overexploitation of aquifers, contamination of bodies of water by solid and liquid waste, and abuse of toxic agrochemicals, among others, cause erosion (water and wind), reduction of groundwater, loss of water quality, reduction of water flows and even the disappearance of water sources.

The need to build capacities to manage water behavior once it reaches the surface of the land is the goal of Integrated Water Resource Management (IWRM), defined by the Technical Committee of the Global Water Partnership as "a process that promotes the coordinated management and development of water, land and related resources, in order to maximize the resulting social and economic well-being without compromising the sustainability of ecosystems".

IWRM could serve as a tool for watershed use and protection. This provision is contained in Laws 620 (General Law on National Waters) and 699 (Law created by the Commission for Sustainable Development of the Apanás, Xolotlán and Cocibolca Lakes and San Juan River Basins, whose core is the Comprehensive Management Plan for the Great Lakes Basin of Nicaragua). The objective is to correct inadequate land uses that make Nicaragua particularly vulnerable to the effects of climate variability and change. The aim is not just to "reforest", but to jointly plan and implement (with the participation of the state, civil society, academia and all stakeholders) integral development plans appropriate to each water basin, correcting each of the environmental problems, in order to achieve social, economic and environmentally sustainable goals: water for all uses and users. For this reason, the civil society proposal formulated by the Nicaraguan Alliance for Climate Change (ANACC), the "2020 Environmental Agenda for Sustainable Development, Nicaragua" (Centro Humboldt, 2016), emphasizes the need to implement the following actions:

- Fulfill the commitments of the General Law of National Waters (Law 620), recorded as Guiding Principles for Water Resources and Management Instruments;-
- Constitute the National Information System for Water Resources, consisting mainly of geographic, meteorological, hydrological and hydrogeological information and including databank management, network operation and maintenance and the dissemination of the information obtained.
- Implement Water Planning. The formulation and integration of water planning will also take the necessary criteria into account to ensure the sustainable, beneficial and integral use of the water resources of watersheds and aquifers as management units. Water planning involves the formulation of a National Water Resource Plan by the national water authority, which will serve as the basis for the development of plans and programs by basin, under the responsibility of the Basin Organizations.

Implications of forest trends

Scattered forests and trees provide fruit, edible seeds and other wild foods, sustaining much of the food chain. The strong link between forests and food and nutrition security has sometimes been overlooked, although it has gained greater recognition in recent years, together with the importance of the protection and sustainable management of forests to ensure the food needs of a growing population.

The national deforestation rate has been estimated at 70 thousand hectares (ha) per year, according to the latest National Forest Inventory (INAFOR, 2008). At this rate, the 3.25 million ha of existing forests could disappear in under 50 years. As in other developing countries, the primary causes of deforestation in Nicaragua are related to the change in land use caused by extensive agriculture and livestock raising.

The loss and degradation of forests leads to the subsequent degradation of water resources, soil health and biodiversity. This degradation of ecosystems can cause a decrease in populations of species which are important because of their food and nutrition value, such as the case of the reduction of fish stocks in deforested watersheds. Food and water are also becoming scarce in the Pacific Dry Corridor due to longer drought periods caused by climate change, while deforested landscapes reduce the region's resilience to these events.

Firewood for cooking is another important piece in the link between forests and food security. This is the most common use of forest products (23.5%), even more so than wood (18.5%) and demand for it has also contributed to forest degradation and deforestation (INAFOR, 2008). According to the Economic Commission for Latin America and the Caribbean (2015), approximately 60% of the population uses firewood for domestic use. The 2011-2025 National Firewood and Coal Strategy, promoted by the Ministry of Energy and Mines and the National Forest Institute, seeks to promote the sustainability of this resource and to establish a fuel-wood production chain, ensuring its quality and traceability. The forest-loss trend would progressively reduce the availability of firewood, affecting thousands of families in rural and urban areas.

Map 1. Nicaraguan Regions

Map 2. Nicaraguan Agricultural Map

The Caribbean region, where over 60% of forests are located, is also the second region with the highest incidence of poverty and extreme poverty (INIDE, 2016). The impact on forest ecosystems, due largely to inadequate agricultural practices, threatens food security, especially for rural and indigenous communities that rely more directly on forest resources for their basic needs, or are unable to afford other available food resources in urban centers at higher prices.

Regarding forest management, actions have been taken in terms of legislation, policy development, forest fire prevention and control systems, the forest traceability system and reforestation plans with special attention to riparian zones because of their importance for water resources (Bornemann et al., 2012). However, technical, financial and human resources in the forest-management framework have been insufficient, and the implementation of regulations is as yet incipient, particularly in the protected areas of the Caribbean and its buffer zones, where natural resource governance is precarious.

Continuous damage to forests and their ecosystems will increase negative impacts in terms of the availability, access and stability of food resources. Adequate policies and practices in the agricultural and forestry sectors must be integrated as part of a national food and nutrition security strategy. This need has been reflected in the Food and Nutrition Sovereignty and Security Law (Law 693, 2009) as well as in the Inclusive Rural Development Sector Plan, which includes the National Food Plan, the National Forestry Program and the National Rural Agroindustry Program (MAGFOR, 2009, Córdoba, Ponce & Dietsch, 2014).

It is hoped that these efforts will continue and result in adequate financing and the promotion of research, small business and innovation, and effective forestry incentives. This would support the management and reforestation of forest ecosystems with emphasis on: improving forest management practices to maintain or increase food supplies, transforming wild food products into value-added products, and promoting more efficient production systems including agroforestry systems. Forest governance, under a collaborative and inclusive model, is key to the implementation of forest policies aimed at food and nutrition security.

A particular case related to the current context of national forests is the Bosawas Biosphere Reserve, the largest forest reserve in Central America (measuring 19,926 km², 15% of the total area of Nicaragua) and the third largest worldwide. Declared a Biosphere Reserve by UNESCO in 1997, it is one of the finest examples of tropical rainforest and cloud forests in the region, with enormous global relevance due to its wealth of biodiversity and water resources. However, in recent decades, it has been severely affected by extractive deforestation. Since 2000, the Bosawas Biosphere Reserve has been invaded by settlers who clear-felled the forest to engage in agriculture and livestock raising. The threat is increasing and to date more than 2,500 km² have been deforested. There is a permanent situation of armed conflict that makes it impossible to implement a development process with a forest protection and management plan. There are fierce social conflicts between the indigenous population (Mayagnas and Miskitos) and the "settlers", which has exacerbated the poverty of the community and reduced biodiversity. The existing Management Plan has not been implemented and there is currently no capacity or will to manage and defend this reserve. Unsolved conflicts within Biosphere Reserves exacerbate the vulnerability of indigenous communities with important implications to indigenous rights and national food security

Institutional framework for the management of food security knowledge in Nicaragua

Over the past 50 years, scientific research in Nicaragua in matters of food security has adopted a linear approach to technological generation and transfer, based on the green revolution (which made intensive use of the artificial management of fertility, mechanization and simplification of biodiversity) with negative impacts on forest cover, with profound impacts on the environmental degradation and the quality of life of important Central-American populations that face the deterioration of their health. A supply-driven innovation model was designed.

In 2000, the institutional organizational model sought a turnaround for demand-driven innovation, creating the Foundation for the Technological Development of Agriculture and Forestry of Nicaragua (FUNICA), that brings together private and public universities, nongovernmental organizations and of the government. From 2007 to the present (2017), the institutional organizational model has returned to an approach centered on the preponderant role of the State.

The current institutional framework for the agricultural sector and food security was created between 2000 and 2005, driven by development cooperation. It is promoted by PRORURAL, a sectoral instrument for the country's rural and agri-food development, which was renamed Inclusive PRORURAL in 2007 and given the mission of supporting the development of family farming. Since its formation, the Rural Public Agricultural System (RPAS) has interacted with the rural private rural system sporadically and its dynamics reflected the existence of aid and cooperation from donors.

Current instruments for Food and Nutrition Security (FNS) were grouped together and completed in the period from 2007-2009, serving as the basis for articles 30 and 31 of the Food and Nutrition Sovereignty and Security Act (FNSSA). The FNS approach is part of the National Human Development Plan (NHDP) 2008-2012, and the instrument on which it is based, is the Zero Hunger Program (ZHP). During this period, however the food and nutrition security approach was expanded to include food sovereignty, introducing elements of development. As a result of ZHP (2007), the sectors involved have revised their instruments, and strengthened ZHP, through the Ministry of Health's Policy Toward the Eradication of Child Malnutrition (MINSA 2008) and the FNS Policy of the Ministry of Agriculture and Forestry, MAGFOR (2009).

During the period from 2012 to 2106, the NHDP grouped together the policy instruments related to Law 693 and developed new public-policy instruments that demand new lines of knowledge management and instruments such as the Agroecological Policy (2011).

The Universities of the National Council of Universities (CNU) begin a process of alliance with the National Institute of Agricultural Technology (INTA) and established the National System of Agricultural Research and Innovation (SNIA) in 2015. This was expressed in the NHDP model of alliances of the NHDP for the purpose of improving coordination and complementing research and innovation processes among producers, universities, public and private research centers and universities.

Law of Sovereignty and National Food Security (Law 693)

Law 693 establishes specific functions for universities in the field of knowledge management through the Sectoral Technical Councils of Food Security, responsible for submitting technical recommendations to the FNSS Executive Secretariat, policy proposals and coordinating with territorial agencies. With this is established a food system capable of sustainably providing safe, nutritious, culturally acceptable food, framed in our cultural and environmental heritage. These articles promote the transformation of the means of production in the food system, "In harmony with the environment, by prioritizing small and medium production, to increase productivity and diversification within the framework of an inclusive, fair market, oriented to achieving national food autonomy based on the national food culture".

The law encourages a nutritional system "That will meet energy, nutritional and cultural needs, and guarantee the health and well-being of our communities, eliminate malnutrition, prioritize care for expectant mothers and infants and eradicate chronic childhood malnutrition".

In education, the law establishes an educational system that trains entrepreneurial human resources and promotes knowledge in the student population and the school community which "Enables them to make more sustainable use of local resources, strengthens the culture of production and consumption based on national cultural diversity and promotes behavioral changes to improve the food and nutrition status of Nicaraguan families". It also promotes respect for the right to cultural food diversity.

In the environmental sphere, the law approves a "natural environmental system that ensures the quality of water, soil and biodiversity, within the framework of the conservation and sustainable management of natural resources, which guarantees food and nutrition, health, culture and the richness of our communities".

Law No. 881 makes Nicaragua the first country in the world to have a Nicaraguan Legal Digest in Food and Nutrition Sovereignty and Security (2014), establishing the comprehensive limits of the scope of Law 693.

This law also determines how the results presented in sectoral responsibilities should be achieved, indicating the coordination, articulation and harmonization of sectoral skills both internally and with other sectors. This multi-sectoral, multi-territorial and multi-stakeholder adaptation represents significant advances in integrated FNS approaches. However, the common understanding for linking sectoral and territorial policies and among territorial levels for a long-term vision is under construction. One of its weaknesses is that the territorial approach has been missing from the last two national development plans. In this context, knowledge management is a central axis that positions the academic sector as a key player in achieving an inclusive, integrated and sustainable territorial-development model as a response to the challenges of the processes and territorial dynamics for the next 50 years.

National Agricultural Research Systems

Nicaragua's traditional agricultural research system has been deficient regarding achevements in agricultural yields, labor productivity and the sustainable intensification of the economy per unit area, fundamental in a country with 70% of its territory located on slopes.

An analysis of productivity and technical efficiency shows that, in the areas of basic grains, the improvement over 55 years has been due more to the extension of the area-under-cultivation than to the increase in yields (Zúñiga-González, 2016), which has had a profound impact on the country's forest cover and biodiversity. Hurtado (2016) notes that there has been an increase in yield per area over the past 20 years, albeit below that of the U.S. and most Central-American countries, which increases vulnerabilities to free trade treaties linked to agri-food trade. According to Baumester (2009), one in five producers and one in ten rural inhabitants are linked to basic grain production.

The knowledge management development model has been divorced from biodiversity management and the dialogue of knowledge, as a result of which agricultural technology has focused on a few monocrops, within the framework of artificial fertility management, which made agri-food production extremely vulnerable to oil price increases (2007/2008, 2010/2014), as well as controlling the area by worker unit to optimize income (under the Central-American territorial conditions of restrictions on agricultural surface), rather than useful biomass per unit area to increase income.

The intra-annual stabilization of labor markets or the construction of a territorial vision of rural labor markets have never been on the agenda. All this lies at the root of the country's food and nutrition security weaknesses.

Research capacities that require further development

Research capacities for the agro-food system in Nicaragua have focused on artificial fertility management, biota simplification and mechanization.

However, the recent introduction of agroecological policy (2011) into the Ministry of Agriculture and the availability of this type of degree program at universities with agricultural sciences paves the way for substantial changes in the territorial economic management of agri-food production systems, such as biodiversity management and the optimization of useful biomass per unit area required for the recovery of the environmental economies of the hillsides, mainly in the dry tropics, and value chains structured on the basis of biodiversity management.

Knowledge management designed to improve market conditions (by guaranteeing a minimum income and the intra-annual stability of labor markets) continues to be absent from academic and political reflection.

Impact assessment remains a central problem in knowledge management. In part, this problem requires the creation of a solid analytical and database management capacity that are weak areas with respect to the human capital involved in the analysis of technology generation in the agricultural sector (Tschirley, Flores, & Mather, 2010). Data from scientific publications (INASP, 2008) show that universities emphasize areas related to agri-food production, which provides them with the conditions for solving pressing FNSS problems in this area, although very little effort is made in economic areas, which omits fundamental elements of the current SSH determinants.

Scientific collaboration networks

The system of internal scientific collaboration among universities in Nicaragua is still not robust, despite the fact that there are 59 universities in Nicaragua. Scientific collaboration and collective management are necessary at various territorial levels. Strengthening the knowledge management of CNU commissions as well as that of the National Environmental Information System (SINIA) at the national level could result in the formation of different types of networks, systematically strengthening social capital for research. In this respect, it is essential to work on internal networks and those among universities.

This knowledge management space has a research agenda that must be strengthened by being linked to the knowledge management priorities and needs of public instruments or the demands of vulnerable populations regarding their human right to food.

Research institutes at universities and public institutes have yet to establish dynamic, stable connections. Relational models are conditioned by low funding for interaction and the creation of a common, consensual agenda for interacting on key and priority issues such as productivity and the relationship with food security in the country. There are still no agreements for joint work in seeking funds or the use of scholarships and grants.

At the international level, the largest universities have implemented collaboration and internationalization programs as a new dimension of links, which must be strengthened. Data from scientific publications show that universities have international relations via research projects and that academics are in contact with their colleagues in the U.S., Europe and Costa Rica.

Access to and maintenance of databases for monitoring farming systems

According to the Michigan State University capacities study, Nicaragua has excellent databases for monitoring FNS domains, although there are weaknesses in the management of these bases.

Law 693 establishes a National Evaluation and Monitoring System for food and nutrition sovereignty and security, based on sectoral evaluation and monitoring systems. However, it has not been functional due to the absence of the secretariat itself. Due to the sectoral approach to FNS, public information has been centralized in several ministries (Health, Education, Agriculture, Development, Industry and Commerce), each with a different type of information management, meaning that data are presented in a diverse, disintegrated way. Although there is a law on access to public information, this situation makes it difficult to access current, official data. Some transborder municipalities have set up municipal FNS observatories.

At the university level, the Central American University and the National Autonomous University of Nicaragua (UNAN-León) participate, through their Law faculties, in the Observatory on the Right to Food of Latin America and the Caribbean (ODA). Efforts must be made to shift from a legalistic to a holistic approach from the determinants of FNS. It is an observatory which the Inter-University Council for Food and Nutrition Sovereignty and Security (CIUSSAN) has begun to manage with FAO, within the framework of South-South Cooperation. Likewise, CIUSSAN hopes to enter ODA as the first university consortium to submit this application. However, information from the monitoring and evaluation of government FNS programs is limited.

Scientific development and infrastructure

In Nicaragua, the universities produce the largest amount of research, although one problem is the lack of systematization of their knowledge products, services and technologies. According to CONICTY studies (2008, 2014), there are 91 Research and Development (R&D) units of the member universities of the National Council of Universities, together with 16 R&D units in the private university sector.

In Nicaragua, scientific development observed in the past 20 years, from the perspective of universities, shows the following trends:

- The first phase reflects the evolutionary path of a technical approach (acquisition of equipment and artifacts). This phase was largely provided by Swedish and Spanish cooperation funds.
- A second phase of development of intellectual capital between the 1980s and mid-2004, when many academics from the universities obtained doctorates from countries in the Socialist bloc; subsequently from Scandinavian countries and then from universities in Central America.
- A third phase (2005-2016) shows user pressure for the system to be relevant on the demand side, with the National Council of Universities (CNU) (CNU, 2011; 2012) activating the issue of social accountability.

The absence of a policy; law and a specific plan has limited the progress of scientific matters. The reports of social accountability that the CNU annually submits to Nicaraguan society must be more substantial regarding the analysis of data.

Inter- and transdisciplinary research capacities, modeling

Inter- and transdisciplinary research is infrequent at universities belonging to the National Council of Universities (CNU) and virtually absent at private universities. The shift from Mode 2 Interaction and a Humboldt-type university in Nicaragua has yet to take place. Disciplinary models still prevail in the universities' conceptual frameworks and degree program structures.

There are a number of research projects, albeit sporadic, at universities experimenting with inter- and transdisciplinarity, focusing on the issue of rural development and improving the Master degree programs taught at UNAN Managua (Hofmann-Souke et al., 2016) and methods of interaction with communities as actors (DEPARTIR, 2011) at the Agrarian University, UNA.

The field of modeling the university's interactions with social actors is a deficient area of study at universities. The creation and protection of the value of knowledge at universities and their interactions with communities, national and regional actors, and the indigenous population is weak and ephemeral (Alänge & Scheinberg, 2006). Development of a skilled labor force in Nicaragua is hampered by the country's productive specialization pattern characterized by low productivity, low wages and a deficient social security system.

Education systems operate in a dislocated, disarticulated manner. The Achilles' heel of skilled labor development in the country's rural and agricultural sectors is closely linked to the education level and retention and dropout rates in the early stages of the education system (usually after fourth grade), which fails to offer useful, attractive, education appropriate for rural development that would result in a sustainable food system. This has contributed to rural migration and the aging of rural labor. This dynamic affects the leveraging of the demographic bonus the country is currently experiencing (Delgadillo, 2010).

Nicaragua's private universities have a low frequency of research. Very few are involved in providing data to update science and technology indicators (CONICYT, 2014). Within the framework of the relationship with FAO under the South-South Cooperation model, CIUSSAN establishes criteria to define the contribution of research to FNS. These indicators will be delivered to the Nicaraguan National Council of Universities (NUC) once they have been discussed with the Research Commission of that organization. This effort will make it possible to define parameters to quantify and qualify the contribution of research to FNS.

Perspectives for university work

The role of universities in the national innovation system is vital, as is the creation of technological products and services to cope with the expected increase in food demand due to population growth, within the framework of a sustainable food system. There are spaces to co-produce knowledge among the universities themselves, with the private sector and the indigenous communities in the Nicaraguan Caribbean regions (Alänge & Scheinberg, 2006).

Productivity in Nicaraguan agriculture is key to food security. It requires an integrated effort by the education system to influence its current state through the generation and accumulation of knowledge. Work must be done regarding the high rates of youth and poverty and low productivity (USAID/BFS/ARP-Funded-Project, 2014).

In order to meet these enormous challenges, knowledge management system must be thoroughly overhauled by:

- Strengthening university and inter-university collaboration.
- Establishing a funding system to encourage synergies that will increase transdisciplinary involvement and interaction with social actors regarding knowledge, protect intellectual property and validate the co-production of knowledge.
- Integration of all education subsystems for the development of human talent.
- Tackling the problem of food security and rural poverty will require the adoption of a comprehensive intervention approach that will permit a major effort to incorporate new technologies and promote innovation.

Technology and Innovation

Nicaragua's economy relies on agriculture, representing the main income source of thousands of families in rural areas where poverty is concentrated. In 2015, agricultural activities grew 3.3%, which means a contribution of 0.3 points to GNP growth. This was driven mainly by the input of coffee and basic grain crops (BCN, 2015). However, despite many investments aiming to increase productivity, when compared with other countries in Central America, Nicaragua holds the lowest yields in most major crops (**Table 1**). Crop yields such as maize and the common bean, key components of Nicaraguans' diet, still are the least productive ones. Conversely, groundnut and sorghum are among the highest, probably caused by the high investments in inputs and technology by the private sector.

There are many factors that reduce productivity; droughts, floods, occurrence of new pest and diseases, low soil fertility, low quality of seeds, among others. Indeed, Nicaraguan agriculture faces many challenges to cope with food production under climate-change conditions following traditional approaches. According to BCN (2015) and MAG (2015, 2016) "El Niño" phenomenon triggered two consecutive droughts in 2014 and 2015 that reduced the food production of many important crops, focused mainly on first cropping seasons. In contrast, in 2016 rains were under normal levels after June, but its extension during November and December threatened the harvesting of sugar cane, common beans, maize, cacao and coffee. Probably, this fluctuating occurrence of rains will continue on in the next years. Climate simulations built using 16 different models suggest that by 2050, temperatures will increase an average of 1.8oC with a variation between -21 and 6% affecting mainly the months of March, May, June and July.

Table 1. Performance of economically important harvests (ton.ha-1) in 2014

Country	Crops							
	Maize	Bean	Rice	Sorghum	Soya	Sugarcane	Coffee	Peanut
Nicaragua	1.5	0.7	4.3	2.2	2.3	89.3	0.7	5.5
Costa Rica	1.7	0.7	3.9	NA	NA	68.7	0.9	1.1
El Salvador	2.6	1.0	5.9	1.7	1.9	85	0.3	NA
Honduras	1.7	0.8	6.4	1.2	2.1	82.4	0.9	0.5
Guatemala	2.1	0.9	2.9	1.7	2.5	103.6	0.9	1.2

Source: FAO (2014); NA = not available.

Within the climate-change context, agricultural biotechnology plays a crucial role for droughts, floods, new pests and diseases and other problems derived from climate change. In Nicaragua, biotechnology tools and techniques most applied are tissue culture and molecular markers. In 2008, there were 35 investigators at 10 national institutions with capacities to apply biotechnology tools and techniques, five of these universities, four government institutions and one private company (IICA 2008).

In the last decade, there have been some efforts to apply agricultural biotechnology tools and techniques in plant breeding and plant pathology areas. All those research works provided tools applied to enforce the conservation of plant genetic resources, seed production and breeding programs in important species, for instance maize, common bean, cacao, coffee, red pine and cocoyam, through the identification of novel genetic variation and the use of molecular markers to assist phenotypic selection (Loáisiga 2007; Jiménez 2009; Loáisiga 2010; Rivera 2010; Loáisiga 2011; Ruiz et al., 2011; Aragón et al., 2012; Aragón et al., 2012b; Aragón et al., 2012c; Jiménez and Korpelainen 2012; Jiménez et al., 2012; Tijerino 2012; INTA 2013; Jiménez 2014; Tijerino and Korpelainen 2014). Also, some research has been focused of improving methodologies for the detection of local strains of pathogens in tomato, potato, cocoyam, common bean and cacao using molecular markers, providing insights of evolution and dynamic along cropping systems and agroecosystems (Reyes et al., 2009; Herrera et al., 2011; Marcenaro and Valkonen 2016). Additionally, some efforts have been to provide new protocols to micropropagate cacao using somatic embryogenesis (Juárez 2012).

Plant agriculture

Plant production in Nicaragua, considering the current context, could be grouped as crops with good profitability, such as sugar cane, groundnut, banana, coffee, tobacco, cacao (fine or aroma), oil palm, vegetables (on high lands and into greenhouse), maize (hybrids) sorghum (red-seeded hybrids) and rice (irrigated systems). Coffee represents around 54% of agricultural exports (BCN 2015). The production of those crops is carried out using as a start point high-quality seeds or plantlets applying a "conventional package" of inputs such as irrigation, fertilizers and pesticides. Also, most of the fieldwork is conducted using machinery and automatized technology.

On the other hand, In the second group we have those crops that are for subsistence, but of course, they could have high potential, such as common beans, maize (synthetic varieties), sorghum, rice (rainfall systems), vegetables (not produced into greenhouse), plantain and fruits that remain with a wide technological deficit and then low productivity.

Agricultural biotechnology has the potential to contribute to both groups with special emphasis on the second one. First, it is important to consider the low use of high-quality seeds and plantlets which is less than 15%. Second, in case of vegetative propagated species, many seedborne diseases are spread through propagules producing infections that increase cost management by increasing the applications of pesticides and threatening food safety. The use of tissue-culture techniques corresponding to somatic embryogenesis and shoot-tip culture has the advantage of providing healthy plants and in some cases inducing tolerance to biotic and abiotic stresses. There techniques are suitable to provide plantlets of coffee, banana, sugar cane, pineapple, potato, roots and tubers.

According to the national production map (INETER 2016), sugar cane, banana, plantain, coffee and fruits are around 241,000 hectares, thus the potential demand of plants is still high. Nonetheless, considering the high costs of vitro-plantlets, compared with conventional ways, it is important to continue investigating by means of new micropropagation protocols and conducting innovations to allow produce vitro-plantlets at lower costs. In this respect, the utilization of local resources should occupy research agendas of private and governmental laboratories.

On the other hand, the use of benefic microorganisms to be used to fertilize crops and to control pests and diseases has increased during the last decade in comparison with the use of chemical compounds. The main reasons are the necessity of identifying new alternatives to restore the fertility of soils and to controlnew pests and diseases. There are many opportunities in this science field and more private companies have increased the number of biological products offered to farmers. This field looks very promising to the rise of innovative companies that aim to provide new solutions to crop management.

In 2016, the international conferences lead by Nicaraguan Institute of Agricultural Technology (INTA) in cacao, coffee, fruits, roots and tubers, vegetables and agroecology have as a common program the organization of a fair, showing biological compounds produced using fungi from the genera Glomus, Beauveria, Metarrizium, and Trichoderma. These events promoted plant production under an agroecological approach with the participation of small farmers who produce their own bio-compounds with government support. Nonetheless, more efforts must be triggered in order to identify novel strains of biological agents that efficiently control pests and diseases at lower costs, promoting their practical use in different crops. To achieve this, the research must be oriented toward producing concentrated compounds easily used in large areas instead of toward the artisanal manner.

The use of molecular markers to enhance the conservation of plant genetic resources and breeding should be applied to more domesticated species in order to estimate levels of genetic diversity and enhancing the breeding. Although molecular markers could provide useful information, genomic selection may bring the significant advance in breeding projects. In this regard, SNP (Single Nucleotide Polymorphism) detection has become a marker system with high potential, because of the high abundance of source polymorphisms and the ease with which allele calls are automated and analyzed in important crops, for instance maize, rice and common beans (Ariani et al., 2016; Spindel et al., 2015; Gorjanc et al., 2016; Marulanda et al., 2016).

Most of the varieties used in Nicaragua are obtained from efforts of regional breeding programs through the cooperation of INTA with International Research Centers, members of CGIAR (Consultative Group on International Agricultural Research). Many of these breeding programs are supported with SNP technology to some degree . However, climate change in the last decade has changed the national agendas concerning plant breeding, focusing on participatory plant breeding aiming to obtain varieties well-adapted to local conditions; for example, the project "Support to the Seed Production of Basic Grains for Food Security in Nicaragua" (http://intapapssan.info/papssan/) drove participatory breeding using local germplasm of maize, common bean, sorghum and rice, implementing more than 160 breeding process along the three years between 2011 and 2014. This means that genomic advances should be connected to national initiatives in order to speed up the genetic gains in those projects. In this sense, quality traits such as high nutritional content and industrial characteristics could be added to national projects.

Genetic Modified Organisms (GMO) is a common topic of discussion in conferences and debates in Nicaragua. However, despite the importance of many events to solve problems in agriculture and their commercial availability, there are an immense technology gaps that has not been exhausted to produce enough food in a sustainable way.

The success of agricultural biotechnology in Central America will rest on sufficient institutional support to promote private-sector investments. It will also require further stimulation of public efforts, mainly at universities, to assess and adapt the technology to the specific regional needs. Since 2000, the University of Central America (UCA) at Managua has been organizing and hosting international biotechnology conferences with world-renowned scientists and networking opportunities for the scientific, nonscientific and student communities. Some of these conferences have focused on food security, biosafety and agricultural development (Huete-Pérez & Roberts, 2016).

There is no commercial production of GM crops in Nicaragua. In 2010, the Nicaraguan Parliament approved Law 705 on "The Prevention of Risks from Living Modified Organisms Through Molecular Biotechnology". Its application, however, has been restricted due to a lack of procedural norms necessary for its implementation (Huete-Pérez & Roberts, 2016).

Current national legislation and the performance of international markets could support the idea that Genetically Modified Organisms (GMO) could be in use soon in some crops with high profitability. Directing agricultural biotechnological development toward sustainable growth and food security in Nicaragua must take into consideration the wider environment available to facilitate the technology, as well as the possible impacts of specific GM crops on rural livelihoods (Huete-Pérez & Roberts, 2016). However, it should be noted that some academics do not share the view that, in the case of Nicaragua, GMO could contribute to food security.

Animal agriculture

Animal production is mainly concentrated in cattle, pig and chicken production in Nicaragua. According to BCN (2015) the value added to livestock increased by 3.9%, contributing 0.2 points to GNP growth. This was an effect of increased swine and chicken slaughter, and the production of eggs and milk. Contrariwise, there were decrease sin cattle slaughter and the exports of standing cattle. Thus, the growth of chicken and egg production is explained by more investments from the sector. On the other hand, swine slaughter was stimulated by higher demand in the country. Finally, milk production increased the yields during that period of time.

In Nicaragua, animal breeding is incipient and it could be considered impractical in economical ways, because of the high investments related to formal animal-breeding projects in the developed world. Also, the prices of specialized sires are significantly high. Then, it makes more sense to improve the productive characteristics of herds by using artificial insemination. There have been many programs with the purpose to making available the semen of many breeds, providing training opportunities.

Other techniques such as embryo transplant could also improve the genetic quality of herds significantly faster than using artificial insemination. Pig and chicken breeds are specialized only in conventional production and depend on the importation of pups and chicks. Even though there is high on-farm genetic diversity in pigs and chicken, its potential remains unveiled and underutilized. In the same way as plants, genomic selection in alliance with international research centers could provide novel breeds that fit new challenges of climate change, increasing poultry, egg and pork on-yard production and improving food and nutritional security. On the other hand, the generation of animal vaccines and medicines, as well as novel products for nutrition, is still emerging compared with other countries in the region, and then it is important to promote research projects and investments in this typed of enterprise.

Pests and diseases

Climate change has multiple effects on agriculture, but perhaps one of the most prominent is the occurrence of new virulent strains of pests and diseases that reduce the quality and productivity of crops and animals. During 2016, for instance, the fall armyworm [Spodoptera frugiperda (Hübner)] produced huge damages in maize during the first cropping season, despite its being considered a second-order pest. The same situation can be observed in other pests such as the broad mite [Poliphagotarsonemus latus (Banks)] in sweet pepper, leaf miners (Liriomyza spp.) in vegetables and the recent occurrence of yellow aphid in sorghum in 2016. Diseases also have changed their dynamics, affecting crops in monoculture arrangements. Some examples are brown spot in groundnut, root rot disease in cocoyam, rust in coffee and black spot in maize.

Pests and diseases affect food security in vulnerable production systems by means of yield reduction nd the increasing cost associated with their management by small-scaled farmers, in most cases with farmers trying to control pests and diseases, exceeding the economic threshold causing dramatic loses. Most of these infections are associated with unbalanced agroecosystems, poor seed quality and soil contaminations. Therefore, agricultural biotechnology may reduce risks by providing good-quality seeds and propagules. Similarly, diagnoses using molecular and biochemical techniques must aid in the timely focus on infections, preventing their spread.

Currently, there are mechanisms that monitor pests and diseases and use agricultural biotechnological tools all in agreement with national legislation and norms. It is important that research results and protocols obtained in the last decade are incorporated into the toolbox utilized by governmental authorities to improve those mechanisms constantly (Reyes et al., 2009). Finally, use of beneficial microorganisms would help decrease the impact of pests and diseases by means of breaking down any resistance to chemical control.

Prospects for novel agricultural products

In general, Nicaragua has been a producer of raw materials over the last decades with poor added value to agricultural products. The field production of vegetables, cacao, coffee and fruits has a high potential for transformation and value adding. For instance, according to the national production map 2016 (INETER 2016) fruit species are established as plantations on 8,500 hectares in the Departments of Río San Juan, Carazo, Masaya, Managua and Rivas, but in many species there is overproduction in short time periods, producing huge losses by fruit over-ripening without any transformation. Similarly, the processing of flour and chips from plantain, cassava, cocoyam and other roots and tubers are still limited.

Thus, there are many opportunities to develop innovative products taking advantage of the overproduction of fruits, cereals, roots and tubers, and plantain. To enforce this, it is necessary to develop agroindustry with some investments in machinery and good manufacturing practices.

There is global concern to promote good nutrition in the population. In this respect, biofortified varieties of common bean, sweet potato, maize, cassava and rice with a high content of iron, zinc and β-carotene are attractive to be transformed into new manufactured products with high market acceptance, contributing to healthy nutrition. The bean cookie manufactured by the University of Central America (UCA) using the common bean variety INTA Ferroso is a good example of this approach. Additionally, new crops recently promoted in the Dry Corridor such as amaranth (cv. INTA Futuro) seem to be promising in complementing other products to add nutritional value to products based on maize. Stevia also remains poorly valued, even though there are good climate conditions for its production.

The development of organic and agroecological production will permit us to export to other markets with more opportunities based on quality more than on quantity. This also applies to special varieties such as common beans known as "sedas", special coffee and fine cacao or aroma, for which international prices are often high and recognized.

Technology opportunities and obstacles

There are many opportunities to develop agriculture using modern technologies for crop and animal management in Nicaragua. Many of the practices are conducted using human labor and techniques with low efficiency. Of course, in most cases, the modernization of agriculture requires changing paradigms and making strong investments in technology.

Crops such as sugar cane, groundnut, oil palm and banana, which represent around 30% of arable land, are highly mechanized, using irrigation systems and a package of inputs. However, basic grains that represent around 47% remains an old technology. For instance, most grain-based farmers do not plan crop nutrition by conducting soil examinations, under- or over-applying fertilizers; the same situation can be reported for pest and disease management.

Protected agriculture that incorporates modern irrigation and nutrition systems are not extensively used in Nicaragua. Tomato, potato, sweet pepper, onion, flower and cucurbit production are conducted on open fields, exposing plants to virus vectors and pathogens and producing considerable losses in production and quality.

Cattle, pig and chicken production is not intensive; for instance, in cattle there are 1.5 cows per hectare of land, using poor grass as feed, producing fewer than four liters of milk per cow. This demonstrates that there is a high potential to increase cattle productivity by means of intensification and employing modern technologies. Likewise, research could be promoted on new grass and forage systems that reduce CH_4 emission intensity.

Aquaculture and marine resources

The production of marine shrimp is conducted in ponds with capacities between 10 to 50 hectares, under intensive, semi-intensive and artisanal using larvae from the wild. The expansion of the area of shrimp farming in the 2005 to 2014 period increased the area by 4,233 hectares over a period of nine years. The production of cultivated shrimp reported by INPESCA in 2014 was 30,527,900 kg, with a growth of 61.81%.

On the other hand, pisciculture units are limited to the small-scale production of fish with between 0.10 and 0.2 hectares with the cultivation of introduced species (tilapia and carp) as part of economic diversification and food security, on lands that have access to water. The innovation of techniques for fish cultivation on farms can contribute positively to develop this activity, but fish nutrition, water oxygenation and management are key factors to include in research agendas in upcoming years. There are no available reports of wolf cichlid and gar fish on farms, but this activity could provide good incomes to farmers who develop innovative projects, because these fish are preferred species in many restaurants. There are some experiences in rizipisciculture by rice farmers who produce irrigated rice in conjunction with carps and tilapia. However, famers must change the management of rice, avoiding the use of chemical compounds. Once again, the use of biological agents looks promising for developing this economic activity.

Efficiency of the Nicaraguan food system

The Nicaraguan food system underwent profound changes following the introduction of the current agroexport model based on green revolution technology (improved seed, agrochemicals, artificial fertility management, mechanization/ motorization). This change, begun in the 1950s, drove national food production from the plains and fertile valleys of the Pacific and center of the country to the slopes and agricultural frontiers. The change made the quality of life of family farming (both peasant and indigenous) more precarious. Since then, it has faced problems of land access, inadequate infrastructure of all kinds and poor labor markets (regarding work stability and minimum wages) coupled with a lack of social security. This economic model has favored the importation of cheap food, with high rates of subsidies in their countries-of-origin, to the detriment of local agro-food production. This has entailed major consequences for the country's present vulnerabilities, such as high sensitivity to international prices, loss of local food biota and significant erosion of the food culture.

Hurtado (2016) notes that according to FAOSTAT, Central America has 59 varieties of agri-food products. Nicaragua has 18, equivalent to approximately 31% of agri-food products, making it the least diversified country in the region.

Since 1960, the per-capita supply of cereals has increased from 0.13 to 0.17 t (30%). According to these data, oilseeds for agroexport have increased their yield more than six-fold, whereas roots and tubers as well as cereals have barely doubled theirs. Accordingly, average yields-per-unit-area of Nicaragua are a mere 20% of those in the U.S. While legumes have barely maintained 1961 yield levels, citrus, fruit and vegetables have yielded less than in 1961.

The per-capita supply of domestically produced animal protein expanded throughout this period, from 0.15 ton/pc/year in 1961 to 0.17 ton/pc/year in 2012 (13% for the whole period). At the beginning of the cycle, cattle accounted for 95% of the total supply, with dairy products comprising 85% of this production. By 2012, cattle production was equivalent to 85% of total national animal protein production (with dairy products accounting for 74%). Poultry production experienced a sustained expansion of the per-capita supply of animal protein, increasing its relative share of the total domestic production supply, from less than 5% to over 15%. Poultry and beef production increased from 98.36% of the total national supply of animal protein in 1961 to 99.94% in 2013. Aquaculture production expanded during the first period, although, following the collapse of freshwater fishing, this type of availability per capita contracted in the mid-1970s, without reaching the production levels of the time.

The collapse of the last FTA safeguards has an enormous potential to severely affect the basic grain sector, linked to 90% of the rural economy and chicken and beef production, leading to greater vulnerability of the Nicaraguan food system if international prices are adopted, as happened in previous crises (2004-2011).

Since the Nicaraguan food system has not had a long-term strategy, it has been undertaken on the worst land, with inadequate production models and poor knowledge management, resulting in a lack of food diversity, high postharvest losses and a deterioration of the water cycle due to pollution and deforestation. Technical and financial service systems are deficient and market intelligence systems for the sector non-existent.

Whereas in the past the development of the food system has been exclusive and uncoordinated, as well as unsustainable in all the territorial spaces it has occupied, this model is totally counterproductive in the face of climate change. This model (monoculture or a succession of a few crops, deforestation and artificial fertility management) has made a difference in society's vulnerability to extreme events such as the El Niño and La Niña. These phenomena have ranged from restrictions and excess water, which reduce agri-food production, to real tragedies with human losses, mobilization of communities for their protection and total agri-food losses.

The average age of basic grain producers in Central America is currently 49. Producers of basic grains, especially maize and beans, farm on an average area of 2.8 ha in Nicaragua (Van der Zee et al., 2012). This requires developing an inclusive, integrated and sustainable new territorial economy, involving the development of value chains in an environmental economy oriented toward the management of the overall fertility and the diversity of its biota, its forest cover and water, in a culture of social and solidarity-based economy, together with a food culture combined with sustainable environmental management that empowers women and is attractive to young people.

Health Considerations

Nicaragua is one of the countries in the region with the lowest Human Development Index, which translates into high levels of malnutrition, reaching values of up to 16.9% of chronic malnutrition according to FAO. Although Nicaragua has a legal framework that establishes food and nutritional security as a human right (Law 693), the strategies used by the government as legal instruments of the law have mainly been designed as flagship programs. They regard the population as beneficiaries, and operate as welfare programs, whereas in fact they are a legally stipulated right. (Gauster, 2014).

The Comprehensive School Nutrition Program (PINE) is one of the flagship programs developed to reduce child malnutrition. According to the government, 1.2 million pre-school and primary-school students have benefited from a school meal as a result of the program. However, the incidence of the program in reducing child malnutrition has not been clearly evaluated since the last height and weight census, taken in 2004 (Gobierno de Nicaragua, 2005). Moreover, the most recent official data on child malnutrition registered by the Pan-American Health Organization (PHO) obtained in 2007 reflected a 23% prevalence of chronic child malnutrition (FAO/OMS/OPS, 2017).

The lack of reliable official information is a major obstacle in assessing government strategies for implementing programs such as PINE. Some international organizations, such as the World Food Programme, report a lack of access to information and limitations on undertaking studies requiring direct information gathering (WFP, 2015).

In fact, there are no official reports on specific nutrition studies for Nicaragua in the past five years. The last official report, which cites a 5% overall malnutrition rate and an even higher percentage of malnutrition indicators in the rural population, was the Nicaraguan Demography and Health Survey, conducted in 2011-2012 (INIDE y MINSA, 2013). In Nicaragua, malnutrition is characterized by a lack of access to protein and micronutrients.

Climate change is a major factor because of the negative impact it has on the livelihoods and food availability of the most vulnerable sectors of the population. Adaptation strategies must incorporate the adoption of crops which, in addition to being resistant to climate variability, must also provide high concentrations of micronutrients useful for combating malnutrition due to the lack of these micronutrients or hidden hunger.

Moreover, the World Health Organization (WHO) reports a prevalence of 40.7% of overweight men in Nicaragua. The prevalence of overweight reported in women is considerably higher: 51.3%. Likewise, a greater prevalence of obesity is reported in women, with 21.1%, whereas obesity rates of 9.7% have been reported for men (WHO, 2016). The overweight index rose by 58% over a period of 18 years. The obesity index increased, but to a lower extent, totaling 28% according to a study undertaken in 1998 (FAO, 2010).

The lack of official information prevents the clear identification of the strengths and limitations of the implementation of policies, laws and strategies in the fight against food insecurity. This lack of information is clearly seen in the implementation of the Regulations and Manual of Procedures for the Surveillance of Foodborne Diseases, published in 2015. This legislation states that the Nicaraguan Ministry of Health (MINSA) is responsible for the Surveillance of FoodBorne Diseases (FBD) through the Directorate of Health Regulation and the Public Health Surveillance Department in coordination with the Local Integral Health Care Systems (SILAIS). Since SILAIS and health service establishments are responsible for dealing with cases and outbreaks, these are the main sources of information for the follow-up of FBD.

These factors reveal that very little coordination exists between policies at the micro and macro levels. Unlike flagship programs, macroeconomic decisions focus on competitiveness and the free market and do not specifically seek to ensure food and nutrition security. According to experts, the complexity of implementing the law creates virtually insurmountable obstacles in the absence of coordination among various macroeconomic sectors. Within the same context, other experts consider that many of the decisions taken at the macroeconomic level do not correspond to the established legal framework. An example of this type of decision is that despite the existence of a breastfeeding program, powdered milk is imported. Food patterns are not determined by the Food and Nutrition Security Act but by the free market.

Nicaragua has a broad legal framework that is often contradictory. In order to implement the food security law, the government should mainstream the principal goals of food and nutrition security, so that the population's right to food is taken into account in all socioeconomic policies.

Given the lack of access to the up-to-date, official information essential to steering efforts in the right direction, international agencies lack reliable information to help guide support for Nicaragua in these fundamental issues and permission has not been forthcoming to conduct their own studies.

Food-security problems related to public policies in the academic sector

The weakness of the agri-food sector is its very poor production. A great deal can be done in the academic sector through research that helps raise agricultural and forestry production.

The universities can reorient research from the research system, research centers and institutes, and technological skills toward appropriate production systems in rural territories and all productive environments.

Universities should also focus their teaching and work on the family farming-productive system-territory triad. This orientation is based on aligning teaching, research and outreach functions to locate proposals that involve conducting an analysis of the adaptive capacity and resilience of family agriculture. This dimension demands from academia a systemic analytical application and a holistic intervention approach. The implication is that studies should be conducted on territorial innovation systems and ways to innovate in the face of climate change.

Universities must identify and leverage the diversity of approaches, interdisciplinary and transdisciplinary work in order to suggest lines of work to achieve food and nutrition security with the various stakeholders. This dimension requires better communication and interaction between the country's scientific work and economic and productive policies. Progress will only be made in this respect if a co-production of a knowledge approach is established between academic and non-academic actors. The recognition of this process of coproduction makes it possible, among other things, to create appropriate products and services for addressing the phenomenon the country faces. This will also make it possible for the strategy of care and response with solutions to the phenomenon to be appropriate, thus reducing restrictions and obstacles to its assimilation, appropriation and adaptation by rural families and family farming as a whole.

This reconceptualization places the proposals to deal with agricultural systems within an agroecology approach that will gain momentum, and permeate and reduce the culture of conventional agriculture systems. This change will make it possible to appreciate the spatial dimension (zoning) and take the cultural dimension into account. Universities should offer the sociology of climate-change culture in families, territories and their response (resilience and adaptability to variability and climate change) as an area-of-study.

Work in the territories should be focused in such a way as to reduce, reuse, recycle and harness the output of productive systems. This dimension implies the use of biotic and abiotic resources in their different use options. The integral approach of the dimension adds value to the rural agribusiness process and work for the bioeconomy to reveal the country's biologically based economy.

The initiative of research, interaction and coproduction of knowledge in the face of rural change to address climate change in agriculture and food and nutrition security in the territories involves adopting a user perspective that will contribute to the improvement of products by means of the co-production of knowledge in order to avoid linear technological models and thereby develop response technologies from local knowledge, so that the intervention is not merely a patchwork of solutions. For example, in response to drought or floods as a result of climate change affecting the country's dry belt or areas with productive potential, the university must coordinate skills and approach agricultural sectors and family agriculture through the following: inclusive communication and outreach methodologies, respecting indigenous knowledge; an adequate, adaptive provision of inputs and resources for production systems in the territories, such as genetic material and work on the efficient use of water resources and water-harvesting alternatives; Creole varieties, crops and species, and encouraging universities to work in a coordinated way with agencies that produce meteorological data, in order to obtain a new record of pertinent, appropriate and real data in view of the incidence and recurrence of the phenomena of temperature increase and climatic variability.

Universities together with the public system of technology provision must coordinate to improve studies of the determinants of the country's food and nutrition security. Universities should change their focus and research the following issues: a) human consumption of water resources; b) current sources of water supply in the territories; c) research on water uses in non-agricultural parts in the territories; d) in academia, begin working on the dimension of the water economy and the assessment of water resources, and e) investigate the interconnections of the forest resource for the preservation of the country's water cycle.

The Nicaraguan Academy of Sciences (ACN), an important scientific organization that has become a key intermediary for scientific development, could encourage national scientific work to be linked to actual food and nutrition security problems. The ACN could facilitate the establishment of agendas agreed on by universities to identify what is scientifically possible, which is technologically feasible with the current science and technology system, in order to achieve an incremental, radical improvement of the nature of universities as knowledge providers. The ACN, together with universities belonging to the National Council of Universities (CNU), and the Nicaraguan Council of Science and Technology (CONICYT), and the business productive sector and the expressions in rural territory of the family economy must demand science-and-technology training policies that make achieving food and nutrition security a strategic priority of the National Human Development Plan.

However, we must be aware that in Nicaragua, the institutionalization of science is a very recent process and, although it is growing, its flowering will require sustained financial investment and its consolidation will take time.

In short, regarding food and nutrition security, universities must orient their research and outreach functions to enable the country to address the following problems:

- Nicaragua's traditional agricultural research system has been deficient regarding agricultural yields, labor productivity and sustainable intensification of the economy per unit area.
- The knowledge management model has been divorced from biodiversity management and the dialogue of knowledge. Consequently, agricultural technology has focused on a handful of products and monocropping.
- Research capacities for the agro-food system have focused on artificial fertility management, biota simplification and mechanization.
- Impact assessment remains a central problem in knowledge management. Little emphasis is placed on economic areas, leaving out fundamental elements of SSH determinants.
- The knowledge management system must be thoroughly overhauled by: improving and strengthening inter- and intra-university collaboration and financing system to encourage synergies and integrate education subsystems for the development of the country's human capital and talents.
- An integrated effort is required from the education system to influence its current state through the generation and accumulation of knowledge.
- Knowledge management is a central axis that positions the academic sector as a key player in achieving an inclusive, integrated and sustainable territorial development model as a response to the challenges of territorial processes and dynamics over the next 50 years.

Conclusion

Nicaragua will face complex challenges in the coming decade to ensure its food security. Adjustments will have to be made considering the population dynamics of Nicaragua and Central America, projected to increase dramatically over the next five decades.

Population challenges

Fifty percent of the Central-American population has been urban since 2012. This reflects the growing importance of consumers, their capacity for choice and the fact that attention must be paid to a proper food culture. In view of the fact that migration among age groups under 25 is mainly male, coupled with women's restrictions on access to resources, services and information, attention must be paid to equity in women's rights by eliminating barriers. Productivity must be increased and the economic rights of the most vulnerable populations strengthened.

Since the average age of producers is approximately 50, it is necessary to develop an agri-food sector as an opportunity for youth. This condition requires accelerating development strategies and making them more efficient and effective.

Challenges in the territorial development model

Special attention must be paid to biodiversity management and its seasonality as an opportunity, taking advantage of the variety of biodiversity resources, especially those used for food. Considering the topographical difficulties (sloping land, Caribbean plains with predominantly calcareous soils), an environmental economy based on forest cover is required, which is a sine qua non for sustainability. It is essential to take into account the diversity of agroecological niches by height, soils, topographies and orientations to macroclimates (Pacific and Caribbean), which means that a strategy to increase productivity based on homogenized seeds is out of the question. This demands specific agrienvironmental conditions and soil, which delays competitiveness in the international market. This requires adequate management of the genetic stock in native seeds, which is strategic for increasing productivity in the range of agroecological niches. In Nicaragua, the food production system is positioned mainly on slopes and agricultural frontiers. It also lacks appropriate knowledge management and coordination of technologies and markets, which results in low productivity and high postharvest losses. A comprehensive, inclusive vision of territorial development for a sustainable food system is essential.

Clean, environmentally friendly development is required, in which agroecological and organic production are an essential part of the solution.

Mechanisms must be developed that will permit access to land that is owned. The lack of long-term secure access to land has resulted in the impossibility of conservation and environmental protection technologies and economies, leading to gradual, unsustainable environmental degradation.

It is essential to optimize the production of useful food biomass per unit area, since arable area for per-capita agriculture is precarious. It is also necessary to strengthen agri-food trade and ensure the sustainability of the waters in the region.

Challenges regarding Free Trade Agreements

There is a need for basic policies to strengthen family farming, given that in Nicaragua, 90% of the rural economy is linked to basic grains. An appropriate economic model should optimize available surface-area income by diversifying risks, protecting the production of basic and meat grains and taking into account extra-regional trade in these products.

Integrating Central-American agri-food trade as community trade could help solve the problems of neglected territories. In terms of animal production to provide access to animal protein, policies should be promoted to ensure adequate production on the slopes (sheep and goat production) or reintroduce local species of iguanas, alligators and boas into the diet and sustainable food and nutrition system.

Challenges of the Food System regarding global processes

Adaptation to climate change requires endless adjustments: an environmental economy built on biodiversity and forest cover; regulation and territorial and social adaptation of bioenergy markets; a food culture that manages biodiversity and its seasonality; management of germplasm biodiversity for climate adaptations, a necessary condition for sustainability (geo-referenced seed banks); value chains that promote biodiversity and values that are adaptive to climate change. Policies for agro-food production, agroecological and organic production (elimination of production costs) and agri-food system organized in rings, by territorial capacities and needs, should be considered.

The current structure of the production and consumption of countries in the Central-American Integration System (SICA) makes them highly vulnerable to negative impacts on international food prices. The increase of food autonomy of SICA countries is a strategic necessity. This should occur as a result of increased productivity and optimization as well as the development of a food culture that optimizes the management of the available food biota and its seasonality.

Central Messages

- Nicaragua's economy and its food and nutrition security rely heavily on the impetus given to the agricultural sector
- The main factors affecting agricultural productivity in Nicaragua are emerging pests and diseases, low soil fertility, poor seed quality and climate change.
- One of the biggest challenges to be addressed is the possible impact of climate change, especially in rural areas with the greatest poverty´, known as the "Dry Corridor".
- Response to the most pressing needs in agriculture involves adopting a new model of agriculture that seeks competitiveness, productivity and rural poverty.
- Family agriculture is perceived as a central instrument for reducing poverty and ensuring food and nutrition security, taking into account their diversity regarding size, types of technologies used and their integration into markets. Public policies should seek to increase productive capacities and agricultural yield, and take into account the socioeconomic and agroecological configurations for environmental sustainability.

- Efforts must be made to mobilize and maximize the allocation and utilization of financial and technological resources, including the use of appropriate agricultural biotechnology to resist droughts, floods, new pests and diseases, and other problems arising from climate change.
- Since public universities have certain research and innovation strengths, boosting their capacities by focusing on agricultural innovations could result in the transition from conventional production systems to the emerging system of sustainable agroecology.
- A frank inclusive dialogue must be promoted among decision-makers, scientists and society in general in order to achieve the medium and long-term public policies by the challenges of food and nutrition security.
- The role of the Nicaraguan Academy of Sciences, which enjoys enormous credibility and respect in the society, will be decisive in the formulation of policies to address economic and social problems, in order to strengthen the necessary human resources and in the allocation and optimal use of public investments for the sustainable agro-food systems of the next 50 years.

References

Alänge, S., & Scheinberg, S. (2006). Intellectual Properties: Alternative Strategies to Value Creation in Life Sciences, (2000), 1–17.

Aragón, E., Rivera C., Korpelainen, H., Rojas, A, Elomaa, P., Valkonen, J.P.T. (2012). Genetic diversity of the native cultivated cacao (*Theobroma cacao L.*) accessions in Nicaragua assessed using microsatellite markers. *Plant genetic resources*, 10(3), 254-257.

Ariani, A., Berny Mier y Terán, J.C. Geps, P. (2016). Genome-wide identification of SNPs and copy number variation in common bean (*Phaseolus vulgaris L.*) using genotyping-by-sequencing (GBS). *Molecular Breeding*, 36-87.

Baires, S., Dietsch, L., Picado, C. (2004). Incidencia del CAFTA sobre la agricultura familiar en las zonas secas de Nicaragua. Encuentro: *Revista Académica de la Universidad Centroamericana* (67). pp. 50-68. ISSN 04724-9674

Baumeister, Eduardo (2009). *Pequeños Productores de Granos Básicos en América Central.* Primer informe; FAO, RUTA.

Banco Central de Nicaragua. (2015). Informe Anual 2015. Recuperado de: https://goo.gl/pQdLh4

Blandón U., Widmark A.K., Andersson B., Högberg N., Yuen J. E. (2012). Phenotypic variation within a clonal lineage of *Phytophhora* infestans infecting both tomato and potato in Nicaragua. *Phytopathology*, 102(3), 323-330.

Bornemann, G., Neira, O., Nárvaez, C., & Solórzano, J. L. (2012). Desafíos desde la seguridad alimentaria y nutricional en Nicaragua. Retrieved March 20, 2017 from https://goo.gl/EPnZSa

Cámara De Industrias de Nicaragua (2013). Guía Industrial. Managua, Nicaragua: Cámara de Industria de Nicaragua. Retrieved from https://goo.gl/8aEojb

Censo Nacional Agropecuario (2011). IV Censo Nacional Agropecuario. Retrieved from: http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/IICA_2013/Presentations/Country_presentations/Day2_Nicaragua.pdf

Centro Humboldt (2016). Crisis socio-ambiental de Nicaragua Post-sequía 2016. Retrieved from March 20, 2017 from: https://www.humboldt.org.ni/node/1624

Consejo Nacional de Universidades (2011). *Informe Rendición Social de Cuentas año 2011.*

Consejo Nacional de Universidades (2012). *Informe de Rendición Social de Cuentas año 2012.* (Vol. 42).

Consejo Nicaragüense de Ciencia y Tecnología (2008). *Directorio nacional de investigación* *y desarrollo. Informe Final de Consultoría.* Resumen Ejecutivo y Análisis de Resultados.

Consejo Nicaragüense de Ciencia y Tecnología (2014). *Construcción del Sistema de Indicadores de Ciencia, Tecnología e Innovación en Nicaragua.*

Córdova, M., Ponce, R., & Dietsch, L. (2014). *Caracterización de acciones y políticas de adaptación al cambio climático en el sector agropecuario y forestal en Nicaragua.* UE; Agronomes et veterinaires sans frontieres, Managua.

Delgadillo, M. (2010). El bono demográfico y sus efectos sobre el desarrollo económico y social de Nicaragua. Retrieved from: http://nicaragua.unfpa.org/sites/lac.unfpa.org /files/pub-pdf/bonodemografico-03_0.pdf

Departir (2011). Changing Minds and Structures : the Nicaraguan Agricultural University's growing Involvement with Rural Communities | Cambiando mentes y estructuras : El creciente involucramiento de la UNA con las comunidades rurales | DEPARTIR. Retrieved from https://goo.gl/QcegWE

Food and Agriculture Organization of the United Nations (2010). Nutrition country profile. Retrieved from http://www.fao.org/ag/agn/nutrition/nic_en.stm

Food and Agriculture Organization of the United Nations (2012). *Estudio de Caractarización del corredor seco centroamericano.* Honduras. Retrieved March 20, 2017 from: http://reliefweb.int/sites/reliefweb.int/files/resources/tomo_i_corredor_seco.pdf

Food and Agriculture Organization of the United Nations /Organización Mundial de la Salud/ Organización Panamericana de la Salud (2017). Panorama de la Seguridad Alimentaria y Nutricional. Sistemas Alimentarios Sostenibles para poner fin al Hambre y la Malnutrición. Santiago. Retrieved from http://www.fao.org/americas/recursos/panorama/es/

Gauster, S. (2014). Human rights in the design and implementation of local actions of the special programmes for food security in Guatemala, Honduras and Nicaragua: A comparative approach. Rome. Retrieved from http://www.fao.org/3/a-i3670e.pdf

Gobierno de Nicaragua (2005). Informe Final. Segundo Censo Nacional de Talla de escolares de primer grado de educación primaria de Nicaragua. Retrieved from https://goo.gl/rE9PDo

Gorjanc, G., Jenko, J., Hearne, S.J., Hickey, J.M. (2016). Initiating maize pre-breeding programs using genomic selection to harness polygenic variation from landrace populations. *BMC Genomics,* 17-30.

Herrera, I., Bryngelsson, T., Monzón, A., Geleta, M. (2011). Identification of coffee root-knot nematodes based on perineal pattern, SCAR markers and nuclear ribosomal DNA sequences. *Nematología Mediterránea,* 39, 1-8.

Hofmann-Souke, S., Acevedo, A., Camacho, T., Bokelmann, W., Cruz, J., Lopez, M., & Yumbla, M. R. (2016). Establishing transdisciplinary research and learning environments for rural development – a network and process model. http://doi.org/10.13140/RG.2.1.1148.3361.

Huete-Pérez, J.A & Roberts, RJ. (2016) Genetic modification (GM) technology for sustainable agriculture in Central America. In Innovative Farming and Forestry Across the Emerging World: the role of genetically modified crops and trees. Gent, Belgium. De Buck, S., Ingelbrecht, I., Heijde, M., and Van Montagu M. *International Industrial Biotechnology Network* (IIBN).

Hurtado, A. (2015). *Estado de la Soberanía Alimentaria de Centroamérica. Repensando la gobernabilidad regional para un desarrollo rural incluyente, integrado y sostenible frente a los grandes retos de la globalización.* ADHCA / OIKOS / UE / UNDEF.

Instituto Interamericano de Cooperación para la Agricultura (2008). Agrobiotecnología en América Latina y el Caribe: Estado Actual de su Desarrollo y Adopción. Retrieved from: http://orton.catie.ac.cr/repdoc/A5277e/A5277e.pdf

Instituto Interamericano de Cooperación para la Agricultura (2009). *Estado de la Agricultura Orgánica en Nicaragua. Propuestas para su Desarrollo y Fomento.* Managua, Nicaragua. ISBN13: 978-92-9039-982-7

Instituto Nacional Forestal (2008). Programa Forestal Nacional. Retrieved April 10, 2014 from: http://www.magfor.gob.ni/prorural/programasnacionales/planforestal.pdf

Instituto Nicaragüense de Estudios Territoriales (2016). Atlas de Escenarios Climáticos de Nicaragua. Retrieved from: http://www.ineter.gob.ni/libro/index.html?page=2

Instituto Nicaragüense de Tecnología Agropecuaria (2013). Catálogo de semillas criollas, acriolladas y parientes silvestres del frijol común de Nicaragua. Retrieved from: http://intapapssan.info/wpcontent/uploads/2013/12/Cat%C3%A1logoSemillasCriollasFrijol2013.pdf

International Network for the Availavity of Scientific Publications (2008). *Bibliometric study of Latin American countries supported by INASP 1996 – 2008.* Página 41. Tabla No.32.

Instituto Nacional de Información de Desarrollo (2016). Encuesta de Medición Del Nivel de Vida 2014. Retrieved from http://www.inide.gob.ni/Emnv/Emnv14/EMNV%202014-2%20Febrero%202016.pdf

Instituto Nacional de Información de Desarrollo y Ministerio de Salud (2013). Encuesta Nicaragüense de Demografía y Salud. Retrieved from: www.inide.gob.ni/endesa/Endesa11_12/HTML/endesa11/.../Informepreliminar.pdf

Jiménez, O.R. (2009). *Genetic purity of the common bean* (Phaseolus vulgaris L. cv. 'INTA ROJO') *during seed production in Nicaragua.* Master's thesis. University of Helsinki, Finland.

Jiménez, O.R., Korpelainen, H. (2012). Microsatellite markers reveal promising genetic diversity and seed trait associations in common bean landraces (Phaseolus vulgaris L.) from Nicaragua. *Plant Genetic Resources: Characterization and Utilization*, 10(2), 108-118.

Jiménez, O.R. (2014). *Genetic improvement of the common bean* (Phaseolus vulgaris) *using local germplasm assisted by molecular markers.* PhD Thesis. University of Helsinki, Finland. Retrieved from: http://ethesis.helsinki.fi

Juárez, D. A. (2012). *Somatic embryogenesis and long-term conservation of cocoa* (Theobroma cacao L.) *germplasm*. Master's thesis. University of Helsinki, Finland.

Landero, B., Vivas, E., Salmerón, F., Obando, S., & Valverde, L. (2016) Agricultura Sostenible para Enfrentar los Efectos del Cambio Climático en Nicaragua. Carrión Editores. Fundación Friedrich Ebert. Retrieved from: http://library.fes.de/pdf-files/bueros/fesamcentral/12896.pdf

Ley N° 693 (2010). Soberanía, Seguridad Alimentaria y Nutricional.

Ley N°. 881 (2005). Digesto Jurídico Nicaragüense de la Materia Soberanía y Seguridad Alimentaria y Nutricional (SSAN).

Loáisiga C.H. (2007). Chromosome C-banding of the teosinte *Zea nicaraguensis* and comparison to other *Zea* species. *Hereditas*, 144, 96-101.

Loáisiga, C.H., Brantestam, A.K., Diaz, O., Salomon B., Merker A. (2011). Genetic diversity in seven populations of Nicaraguan teosinte (*Zea nicaraguensis Iltis et Benz*) as estimated by microsatellite variation. *Genetic Resources and Crop Evolution,* 58(7), 1021-1028.

Marulanda, J.J., Mi, X., Melchinger, A.E., Xu., J.L., Würschum T., Longin F.H. (2016). Optimum breeding strategies using genomic selection for hybrid breeding in wheat, maize, rye, barley, rice and triticale. *Theoretical and Applied Genetics,* 129(10), 1901-1913.

Ministerio Agropecuario y Forestal (2009). Plan Sectorial Prorural Incluyente 2010-2014. Retrieved March 25, 2017 from http://www.magfor.gob.ni/prorural/VIIMISION/DocumentosBase/ PRORURAL%20INCLUYENTE%2030-07-2009.pdf

Ministerio Agropecuario y Forestal (2009). Política de Seguridad y Soberania Alimentaria y Nutricional desde el Sector Público, Agropecuario y Rural. Managua, Nicaragua. Retrieved March 25, 2017 from: http://www.magfor.gob.ni/descargas/SeguridadAlimentaria/ Politica%20SSAN%20UV%20140509.pdf

Ministerio de Salud (2007). *Marco Conceptual del Modelo de Salud Familiar y Comunitario (MOSAFC).*

Morales, H. (2011). *La Agroecología en la construcción de alternativas hacia la sostentabilidad.* México, DF: Siglo XXI Editores.

Programa de las Naciones Unidas para el Desarrollo (2000). Informe sobre Desarrollo Humano 2000. Retrieved from http://hdr.undp.org/sites/default/files/hdr_2000_es.pdf

Programa de las Naciones Unidas para el Desarrollo (2015). Informe anual del PNUD 2014-2015. Retrieved from http://www.ni.undp.org/content/nicaragua/es/home/library/poverty/Informemundial2014_2015.html

Reyes, G., Ransell, J.N., Nyman, M., Kvarnheden, A. (2009). Sequence characterization of Dasheen mosaic virus isolates from cocoyam in Nicaragua. *Archives of Virology* 154, 159–162.

Rivera C. (2010). *Using microsatellite markers to identify tentatively Nicaraguan cacao accessions resistant to* Phytophthora palmivora. Master's thesis. University of Helsinki.

Ruíz J.C, Roa O., Marín I. (2011). Molecular ecology of genetic diversity of cacao cultivated in the south-east region of Nicaragua. *International Research Journal of Agricultural Science and Soil Science,* 1(1), 6-13.

Tijerino A., Korpelainen H. (2014). Molecular characterization of Nicaraguan Pinus tecunumanii Schw. ex Eguiluz et Perry populations for in situ conservation. *Trees*, 28, 1249-1253.

Tschirley, D., Flores, L., & Mather, D. (2010). Análisis de Politicas Agrícolas y de Seguridad Alimentaria en Centroamerica: Evaluación de la Capacidad Institucional Local, la Disponibilidad de Datos y la Demanda Efectiva para Datos e Información. MSU Working Paper, (105).

Van der Zee, A. (2012). Estudio de caracterización del Corredor Seco Centroamericano. Retrieved from https://goo.gl/EykTQs

World Food Programme (2015). Informe de evaluación: Evaluación de Mitad de Período de la Operación del Programa país en Nicaragua - PP 200434 (2013 - 2018). Retrieved from http://documents.wfp.org/stellent/groups/public/documents/reports/wfp284202.pdf

World Health Organization (2016). Diabetes country profile. Retrieved from http://www.paho.org/hq/index.php?option=com_docman&task=doc_view&Itemid=270&gid=33858&lang=en

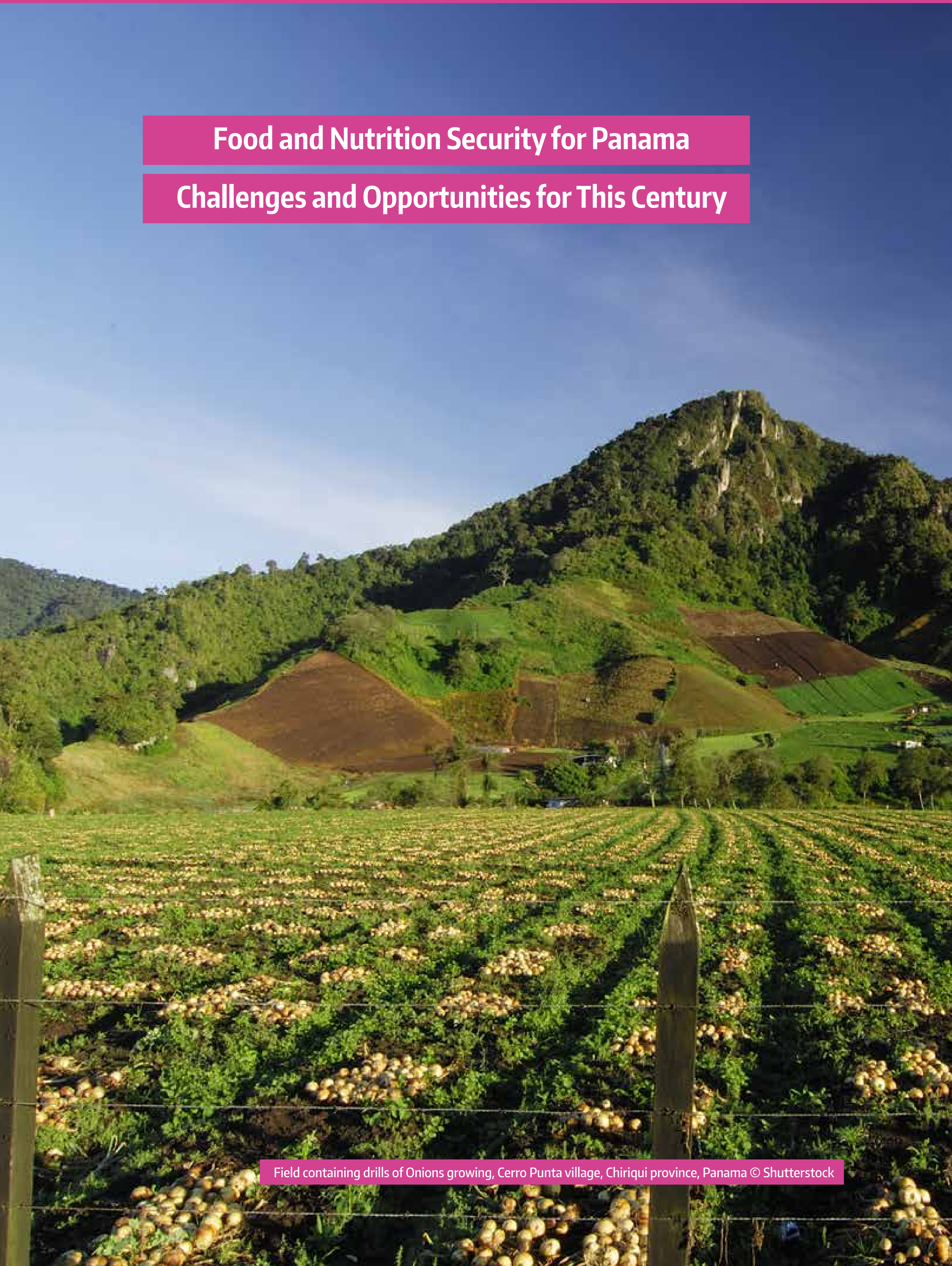
Zúniga-González, C. A. (2016). *Impact of productivity and technical efficiency of basic grains in Nicaragua, 1961-2013, (July).*

Acknowledgments

We are grateful for the great support of **Suyen Espinoza Miranda**, **Catalina Solano Urib**e, the **Center for Molecular Biology** and the **Academy of Sciences of Nicaragua**, and all of the authors who shared their publications and reflections with the editorial team. We would also like to thank **Adolfo Hurtado Díaz**, **Francisco Salmerón** and **Oswalt Jiménez** who provided some of the texts as well as valuable insights in the analysis of the issues discussed.

Food and Nutrition Security for Panama

Challenges and Opportunities for This Century



Field containing drills of Onions growing, Cerro Punta village, Chiriqui province, Panama © Shutterstock

Panama

[1] Bruno Zachrisson,
[2] Ismael Camargo,
[3] Carlos Him,
[4] Enrique Murillo,
[5] Rodrigo Cambra,
[6] Dimas Arcia

In Panama, the technological upturn is related to the development of value chains, one of the strategies required to optimize the use of national and international markets

Summary

Undertaking agricultural research, which leads to technological innovations resulting in food production, is an essential element in ensuring food and nutrition security for Panama. However, the country's social, economic and political scenarios must be analyzed within the context of the public policies for defining business strategies in order to facilitate access to national and international markets. Emerging scenarios should also be defined so that through knowledge generation, they will be able to strengthen the scientific and technological platform required to promote the necessary transformations. Therefore, investment in specialized human resource training, a variable that goes hand in hand with undertaking agricultural research, is a binomial that should be proposed in keeping with the challenges affecting food and nutrition security.

1. National characteristics

a. Physical characteristics and productive agricultural areas

Panama is located in the intertropical zone near Ecuador in the Northwest Hemisphere, between 7°12'08" (on Jicarita Island south of Coiba, in the province of Veraguas) and 9°38'46" north (in Tambor Island, off the coast of the province of Colón), 77°09'24" (at the 10-Alto Limón landmark, on the border between Panama and Colombia) and 83°03'07" west (at Auxiliary Milestone 60 on the border between Panama and Costa Rica). Panama is bordered on the North by the Caribbean Sea, on the South by the Pacific Ocean, on the East by Colombia and on the West by Costa Rica. The country has an area of 75,845.072 km2, equivalent to approximately 0.18% of the territory occupied by America. Located in the center of the American continent, it forms a link between North and South America. It consists of an isthmus with a width of 80 km at its narrowest point, which in turn links the Caribbean to the Pacific Ocean (ANAM, 2010). Agricultural land covers 30.4% of the country's total area (World Bank, 2016).

b. Demographic characteristics and future trends

In 2014, Panama's population was estimated at 3,913,275, comprising 1,965,087 males and 1,948,188 females (INEC, 2014), with an annual growth rate of 1.44%. A total of 66.6% of the population is concentrated in urban areas and only 33.4% in rural areas. A total of 5.9% of the economically active population is engaged in the primary sector, 19.9% in the secondary sector and 64.2% in the tertiary sector (UNDP, 2015). Although 9.5% of the population is undernourished, the country has achieved the target set in the Millennium Development Goals and is close to meeting the target established at the World Food Summit (FAO, 2015).

c. Population affected by lack of food and nutrition insecurity

Approximately 1,090,000 people live in poverty, and 481,000 in extreme poverty, accounting for 32.7% and 14.4% of the total population, respectively. A total of 19.1% of children under 5 showed delayed growth for their age (chronic malnutrition), 3.9% are underweight for their age (overall malnutrition) while approximately 1.2% are underweight for their height (acute malnutrition) (ENV 2008).

d. Agricultural production systems

Panama boasts a variety of agricultural, livestock, fishery and aquaculture production systems, the most important being rainfed and irrigated rice, bovine milk and meat, swine and avian production and wild-caught fish. Special attention should be paid to rural communities engaged in family farming, since they constitute a weak link in the production chain, given the challenges of climate change (Camargo et al., 2016).

e. Main agricultural and livestock imports and exports

Agriculture, fishing and forestry contributed 0.2% to the 2015 GDP, with decreases of approximately 0.6% being recorded in 2013 and of 0.6% in 2014 (INEC, 2015). Agricultural Gross Added Value (AGAV) reported a slight increase of 0.4% over the previous year, mainly in rice cultivation, which rose by 3.5%, and banana and melon production, which grew on the order of 4.7% and 17.9%, respectively.

The Gross Added Value of livestock production increased by 3.0%, due to a 6.2% increase in the slaughter of poultry and a 4.8% increase in that of swine (INEC, 2015). Cattle slaughter and the number of liters of milk obtained naturally fell by 2.8% and 1.8%, respectively. Since domestic production of grains such as rice, corn and beans fails to cover domestic demand, the shortfall is imported. Most grain corn imports are allocated to animal feed. However, local production meets human consumption needs (Capital Financiero, 2014).

Squash accounts for 41% of the production of farmers who planted 112 ha and harvested 1413.57 t during the 20132014 period (MIDA, 2015).

The rainfed production system includes several export crops such as bananas, pineapple, coffee and by-products from palm oil and sugar cane. Pineapple generated a return of 31% (MIDA, 2015), with 80% of production being assigned to the international market and the rest to domestic consumption.

According to data from the Comptroller General of the Republic, in 2013, banana exports totaled approximately B/. 90.6 million and in 2014, an increase of approximately B/. 92.8 million was recorded. This is due largely to the technification of farming methods, which yielded 1,800 boxes/ha.

Sugar production constitutes one of the main lines in agroindustrial activity for both sugar mills and the country as a whole. This commercial activity is regarded as a pillar of Panamanian industry. For many years, Panama has exported sugar, molasses and its derivatives to the US market. In 2013, 51.152 net t of sugarcane were exported with an FOB value of B/. 23,973,576.00.

Although increased private investment in the country has had positive consequences for the national economy, the management of the production areas of these agricultural commodities has negatively affected agricultural ecosystems.

f. Contributing factors to the instability of food security

Globally, the change in land use is one of the greatest threats to biodiversity, as it involves the loss of plant cover and the disruption of ecosystems. The expansion of the agricultural

[1] Bruno Zachrisson, Agricultural Entomology (Biological Pest Control), Agricultural Research Institute of Panama (IDIAP), Corresponding Author, bazsalam@gmail.com **[2] Ismael Camargo,** Genetics and Plant Breeding, IDIAP, camargo.ismael@gmail.com **[3] Carlos Him,** Soil Conservation and Water and Water Basin Management. Agricultural Science Faculty (FCA), University of Panama, drcarloshimg@gmail.com **[4] Enrique Murillo,** Biochemistry and Human Nutrition. Faculty of Natural and Exact Sciences, University of Panama, emurillo29@hotmail.com **[5] Rodrigo Cambra,** Agricultural Economics, FCA, University of Panama, rocambra@hotmail.com **[6] Dimas Arcia,** Forest and Natural Resources, FCA, University of Panama, dimas_arcia@yahoo.es

frontier is another variable to consider in the change of land use. Thus, 25% of the country (1.8 million ha) is suitable for agricultural and livestock activities. However, the actual use of land in these productive activities was estimated at between 2.8 and 2.9 million ha.

According to the INEC (2011), changes in land use indicate a decrease of approximately 70,000 ha of farmland between 2000 and 2011. The country's economic development has reduced the areas used for planting crops, which have been displaced by housing construction and urbanization.

River and sea pollution is caused by domestic and industrial waste, including agrochemicals from agricultural activity which reach the sea through runoff. In the soil, water sources and in areas adjacent to protected areas, one of the main causes of the pollution of these ecosystems is the use of agrochemicals which, as a result of leaching, are discharged into waste water of domestic, industrial and commercial origin. Villarreal et al. (2013) determined the soil quality index in areas under banana cultivation in Panama as a means of managing agricultural and environmental activity in cultivated soil in the Panama Pacific.

Mining activity also contributed to the pollution of soil, surface and groundwater, increasing erosion and therefore the sedimentation of rivers.

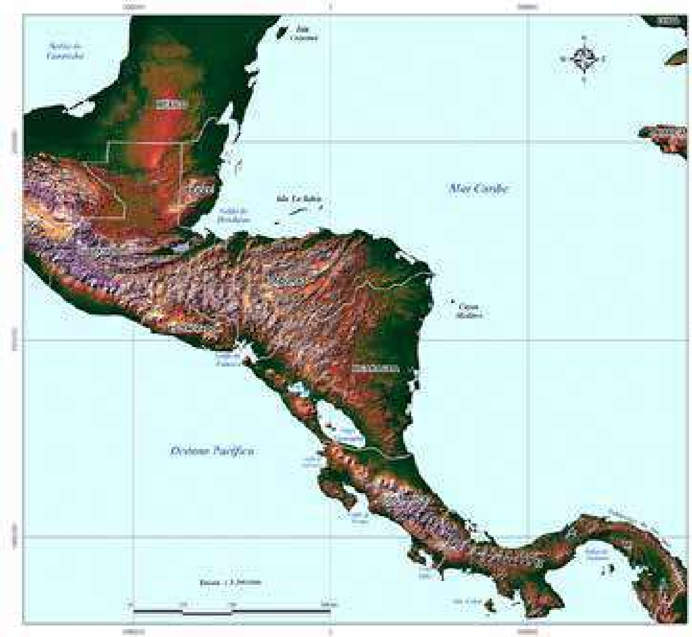
The main sources of instability affecting food security in Panama are related to climate variability and the lack of land-use regulations owing to the absence of adequate economic policies for sustainable food production. Thus, as a result of climate change, temperatures will increase, irreversibly affecting the demand for water in crop production.

g. Major challenges in food production

Climate change may increase dependence on food imports and exacerbate food insecurity in the most vulnerable groups and countries (FAO, 2002).

Integrating the government and private sectors into the search for mechanisms to provide solutions to these problems is a priority action, since Panama faces major challenges with regard to climate change (Mora et al., 2010).

Map 1. Geographical Position of Panama



Source: Atlas Ambiental de la República de Panamá, 2010.

2. Institutional Framework

a. National Agricultural Research System

i. Research capabilities that need further development

Designing a State Science, Technology and Innovation (CTI) Policy is an essential step toward CTI capacity building in Panama, which will allow this process to continue. Accordingly, the challenges currently faced by the country will be harnessed to improve the effectiveness of the policy and the instruments for its implementation, and increase its contribution to the development of science, research, technology and innovation.

Strengthening and empowering the National Secretariat of Science, Technology and Innovation (SENACYT) to determine the Science-Technology-Innovation policy (STI) supports the existing regulatory framework and increases investment in STI (PENCYT, 2015).

Panama's universities generally have limited research capacity since their professors are solely dedicated to teaching in higher education.

Moreover, collaborative research is scarce and lacking in multi- and transdisciplinary approaches.

A small number of researchers together with limited financial resources are a common denominator of these study centers. The creation of postgraduate, master and doctoral programs follows a logic of Market Trends in Continuing Education, which excludes creativity in the Research, Development and Innovation (R & D) process, contributing very little to STI capacities.

There are only a small number of professionals at the doctoral level in scientific areas, trained in various specialties (PENCYT, 2015).

ii. Local areas of strength

The SENACYT scholarship program, whose results are reflected in the programs offered by international, bilateral and multilateral cooperation, has enabled a total of 220 researchers to obtain doctoral degrees, 70% of whom have joined the country's labor force. Despite this, the number of human resources for the operability of National System of Science, Technology and Innovation (SNCTI) is still small. The country has a total of just 142 researchers per million inhabitants, a significantly lower figure than in Costa Rica, Brazil, Uruguay and Colombia. The evolution over time of the number of full-time researchers is proportional to the number of scientific papers listed in the *Web of Science*. It has been determined that the critical mass of researchers required to transform a country's economy is based on the knowledge generated by approximately one thousand full-time scientists per one million inhabitants.

A fundamental aspect that prevents the renewal of specialized human capital, based on the need to recruit young scientists who have completed their graduate studies, lies in the difficulty of creating job positions at universities and government and/or private organizations.

iii. Scientific collaboration networks inside and outside the country

International conventions linked to Plant Genetic Resources and Biodiversity have provided benefits in the regeneration of threatened *ex situ* samples, increased genetic enhancement, the expansion of the genetic base and support for seed production and distribution.

The most significant international conventions ratified by Panama are based on the conservation and use of natural resources and biodiversity, such as the United Nations Convention on Biological Diversity, the Cartagena Protocol on Biosafety, the Nagoya Protocol and the International Treaty on Genetic Resources for Food and Agriculture (ITPGRFA).

National Genetic Resources Operating Plans have also been developed, whereby each country promotes interaction through national commissions. Specifically, the AGROSALUD consortium includes various state institutions working on the development, evaluation and dissemination of biofortified crops in Latin America and the Caribbean, through the coordination of the International Center for Tropical Agriculture (CIAT). The purpose of this collaborative network is to improve the nutritional content of key crops for the nutrition of the Panamanian population. Accordingly, research has focused on crops such as rice, beans, yams, corn and potatoes in rural areas with severe malnutrition problems.

The Institute of Agricultural Research of Panama (IDIAP) is the leading research and innovation institution for the development of biofortified crops. Part of the initial funding for this project was provided by SENACYT, in conjunction with the Ministry of Agricultural Development (MIDA), the National Nutrition Service Trust, the Ministry of Health (MOH) and various farmers' organizations.

With respect to the collaboration of international centers, the International Potato Center (CIP) provides germplasm for potato and yam varieties for their evaluation in Panama.

The mechanism of access to rice germplasm through the International Center for Tropical Agriculture (CIAT), through the Latin American Fund for Irrigated Rice (FLAR), has permitted access to seeds in this area as a result of collaborative research. Thus, through competitive funds obtained from FONTAGRO projects, advanced lines of rice biofortified with iron and zinc have been created in addition to hybrids and interspecies crossing to expand the genetic basis with genes from wild species.

Collaboration between IDIAP and CIAT resulted in the project designed to create bean cultivars (*Phaseolus vulgaris*) biofortified with iron and zinc, adapted to Panama's production areas.

The Maize Germplasm Evaluation Program, run by the International Maize and Wheat Improvement Center (CIMMYT), provides IDIAP with varieties in order to evaluate their adaptability and stability in various agricultural ecosystems and production systems, making it possible to generate and release varieties and normal hybrids with high-quality protein.

iv. Data maintenance and access to databases on agricultural systems

Information on IDIAP's collections is not systematized in a unified database. Most of the data on the characterization, evaluation and regeneration of materials is found in scattered electronic Excel files.

Since 2010, the Project for Research and Innovation on the Collection, Characterization, Evaluation and Conservation of Plant Germplasm has promoted the entry of data on all of IDIAP's collections into the BDGermo database. However, the small number of crops that have been characterized by biochemical (isoenzymes) and molecular markers has been limited to Creole rice and improved varieties.

b. Universities and Research Institutes

IDIAP, established through Law 51 on August 28, 1975, is the government institution responsible for research to generate, adapt, validate and disseminate knowledge and agricultural technologies, framed within the policies, strategies and guidelines of the agricultural sector. IDIAP therefore focuses its actions and responds to the problems facing Panamanian agribusiness through mechanisms to involve customers, users and partners in the processes of identifying environmental, social, economic and technological demands, problems and challenges.

According to Stads and Beintema (2009), agricultural research is distributed as follows: 44% concerns agricultural production, 42% livestock production, 7% preservation and conservation of the environment and natural resources, and 1% aquaculture and fisheries. The rest of the productive sectors, equivalent to the remaining 6%, are grouped into activities involving agribusiness, management and agricultural marketing.

i. Scientific development and infrastructure

IDIAP, the institution responsible for agricultural research in Panama, has 18 sub-centers and nine research centers, distributed throughout the country. It also has ten laboratories with specialized equipment for research on applied molecular biology, soils, artificial insemination, plant protection and biological pest control, among other key areas. However, the need for technological innovation has meant that sufficient financial resources have been secured to meet the new challenges of the Panamanian agricultural sector. The implementation of a periodically updated Institutional Strategic Plan has made it possible to achieve the goals set in an orderly, systematic manner. Thus the goal was set to develop and boost the competitiveness of the agricultural sector in a globalized economy, and ensure an adequate affordable supply of healthy food for all Panamanians. Moreover, environmentally friendly agricultural knowledge and technology have been produced in order to preserve natural resources.

ii. Inter- and transdisciplinary research capacities and assimilation of technological innovations

Panama has a research and transfer system in which a number of agents interact such as IDIAP, which produces most of the country's agricultural research. The Faculty of Agricultural Sciences, the Promega Institute and the Faculty of Veterinary Medicine which belong to the University of Panama- and the Center for Agroindustrial Production of the Technological University of Panama also contribute to the development of research in this field of science. Other government institutions -such as the Aquatic Resources Authority of Panama (ARAP), MIDA and MIAMBIENTE- have also contributed to the country's agricultural research.

However, the transfer and adoption of technology has yet to reflect the impact of the technology generated by the research projects undertaken.

c. Development of a skilled workforce and the state of national education systems

In 2015, a total of 324 professionals were estimated to be engaged in agricultural research, 48% of whom were affiliated with government research institutions, as opposed to the 36% cited in the data presented by higher education centers, and 16% of whom were employed by private companies and non-governmental organizations.

The fact that academics are solely engaged in teaching at higher education centers is a variable that limits the development of agricultural research in Panama. Updated reports indicate that 10% of researchers hold doctorates, 47% master degrees and 43% bachelor degrees, and that the average age of Panamanian researchers is 55.

SENACYT has developed and implemented various scholarship programs for academic excellence, primarily designed for master and doctoral programs at universities abroad, and former grant holders are employed by government institutions and state higher education institutions.

d. Contributions by the public and private sector

Most of the funding for agricultural research has been from the government sector, although the latter's public expenditure on agricultural research has not exceeded 0.5% of the national budget.

Investment in agricultural research in Panama has shown a negative growth rate that has gradually increased over time.

e. Future outlook

In 2017, the IDIAP budget is B/. 19.5 million, accounting for 0.16% of the national budget, 65% of which corresponds to salaries and running costs. However, construction has begun on several facilities to strengthen agricultural research. Conversely, the Faculty of Agricultural Sciences at the University of Panama has seen a significant decline in government funding since 2010. This could reduce the sustainability of national agricultural research, given the importance of training specialized human resources and the development of research programs.

3. Characteristics of Resources and Ecosystems

a. Water Resources

Panama is regarded as one of the countries with the most abundant water resources, with more than 50,000 m³ of water per capita, enabling it to operate an interoceanic canal for over 100 years. Although it receives copious rainfall during the rainy season, during the dry season, it experiences water deficits, which have increased due to Climate Change and/or Variability. Accordingly, the National Water Security Plan was implemented, which was approved by Cabinet Resolution no. 114 of 08.23.2016. The map of Panama's isohyets (Figure 1) defines the areas with a significant water deficit in Panama's Dry Arc, shown in bright red.

According to the World Development Indicators (World Bank, 2014), Panama has 35.32 cubic meters of freshwater per capita, more than twice the continental average. The dry season has historically been critical and, since the El Niño Southern Oscillation (ENSO) phenomenon in 1997, there have been recurrent water crises beginning in the Dry Arc and spreading to other regions. Increased human intervention alters the hydrological cycle, reduces infiltration and increases runoff.

Groundwater is not properly evaluated, due to the lack of a piezometric monitoring network, making it impossible to accurately gauge the amount of existing aquifers, their recharge areas and yield potential. During the last ENSO event in 2015, the water crisis affected the availability of water in 75% of the total area in the country, for various everyday activities involving human consumption and food production. Sustainable water management to cope with the growing water crisis is a challenge the country must systematically and efficiently address.

National agricultural production will be significantly affected, as a result of the growing water crisis due to climate change.

Future scenarios confirm the need for the implementation of an effective Integrated Water Resource Management Policy (WRMP).

b. Soil characteristics and challenges

Panama's soils are mostly acidic leached soils, corresponding to ultisols/oxisols and alfisols (FAO, 2013). There are more fertile soils associated with more fertile parent materials and intermediate precipitation regimes. Regarding the soils' capacity for agrological use, only 19.5% of the land is suitable for farming, whereas approximately 80% is suitable for the development of forest species and/or conservation. Agrological limitations have led to severe conflicts over land use, causing significant erosion and leading to soil degradation.

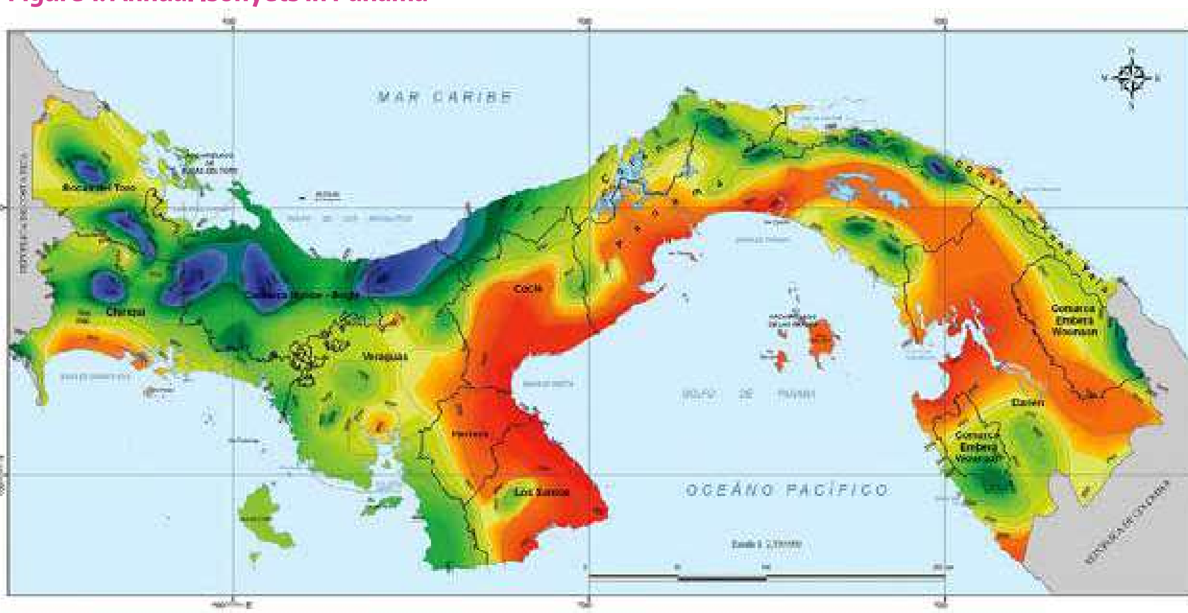
The use of forest soils with slopes unsuitable for mechanized agriculture produces considerable soil loss due to erosion. This is compounded by the reduction of fertility and water pollution due to sediment loads as a result of poor land use.

The challenge for the future is to produce more food within the limitations of soil assigned for agricultural use and existing production systems. Sustainable land management, through the use of management practices and soil conservation in keeping with their capacity for use, is the only option for ensuring food production in sufficient quantity and quality, in the medium and long term, which guarantees the environmental and and productive sustainability of soils.

c. Energy resources

In 2014, Panama's energy sector had a total installed capacity of 2,828.57MW (National Secretariat of Energy, 2016), 57.4% of which (1623.41 MW) corresponds to hydroelectric power stations using approximately 16,000 Mm3 of water annually and 40.6% (1147.8 MW) to

Figure 1. Annual Isohyets in Panama



Isohyets — Average annual rainfall values in millimeters

1,275-1,500
1,501-1,800
1,801-2,100
2,101-2,400
2,401-2,700
2,701-3,000
3,001-3,300
3,301-3,600
3,601-3,900
3,901-4,200
4,201-4,500
4,501-4,800
4,801-5,100
5,101-5,400
5,401-5,700
5,701-6,000
6,001-6,300
6,301-6,600
6,601-6,900
6,901-7,000

Source: Hidrometeorología, ETESA (2007).

thermal plants using different technologies, while the remaining 2% corresponds to wind energy, which began to be used in 2013. Solar energy began to be utilized in early 2014.

The period 1970-2013 saw an eleven-fold increase in electricity consumption in the country, while the use of petroleum derivatives increased by a factor of four and a half.

Increased energy consumption has led to greater reliance on oil imports, causing negative effects for the economy and the local and global environment. The main source of energy is hydropower and in recent years, wind energy. The main challenge for the energy sector is the diversification of the energy matrix. Thus, the National Energy Plan achieves electricity savings of 39.8% through rational, efficient energy use as well as design and construction improvements.

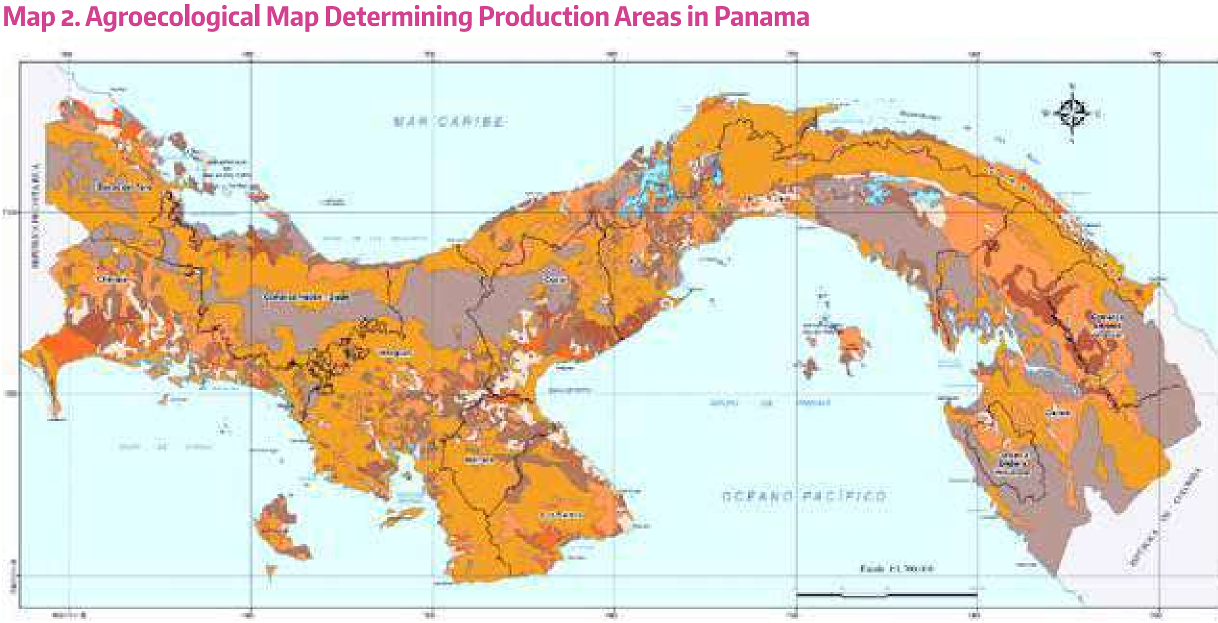
Diversification of the energy matrix is a clear objective of the national energy policy, which envisages the promotion and use of renewable energy, and increased use of wind and solar energy as a rational, efficient long-term measure.

d. Biodiversity

According to the Fourth National Report on Biodiversity (ANAM, 2010), Panama is one of the countries with the greatest biodiversity of species in the Central American region, and serves as a natural connector between North and South America. Four percent of the vascular plants reported for Panama are endemic. Biodiversity contributes to human welfare in many respects biodiversity, as regards both the production of raw materials and health.

According to UNEP (2011), the past 50 years have seen the rapid loss of biological species. Recent temperature variations, caused by climate change, have already had a significant impact on the biodiversity and ecosystems, increasing the risk of extinction of species. The main threats to the country's biodiversity are: a) river and lake pollution; b) habitat loss and fragmentation; c) deforestation; d) the introduction of exotic species and their adaptation to natural ecosystems; e) the adaptation of invading species to ecosystems; f) species extraction, and g) poor land use.

Map 2. Agroecological Map Determining Production Areas in Panama



Agroregions of Panama

II Arable, some limits on plant selection

III Arable, severe limitations on plant selection

IV Arable, very severe limitions on plant selection

V Non-arable, low risk of erosion

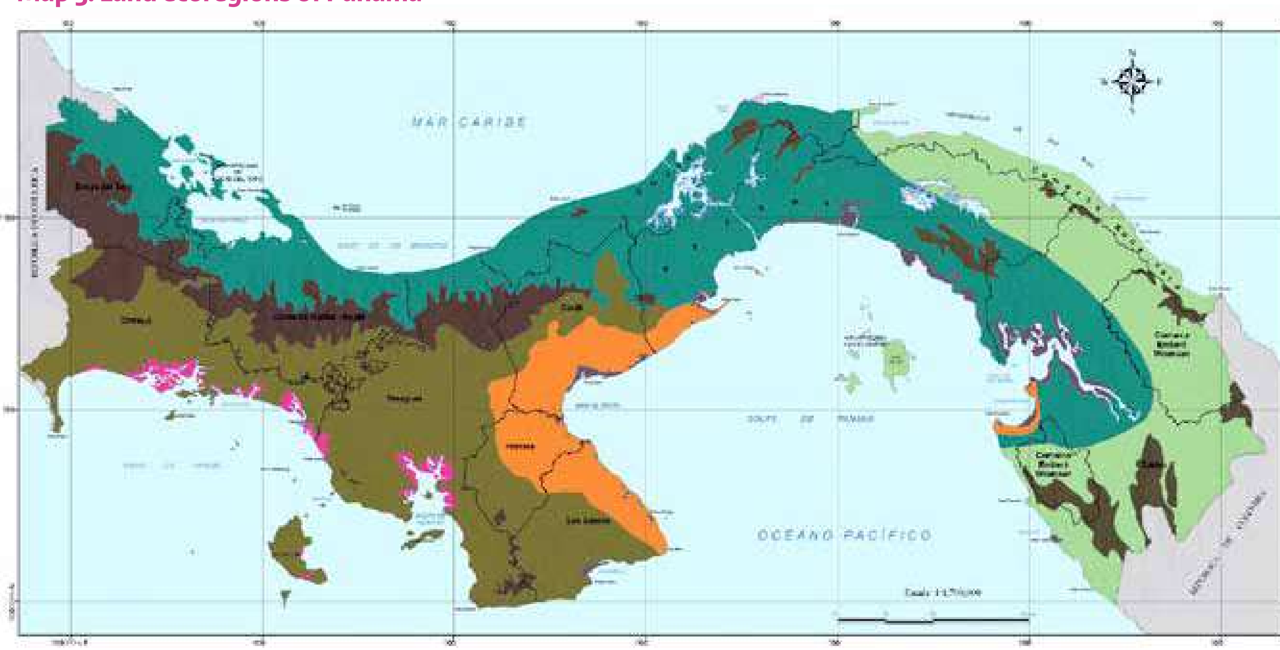
VI Non-arable, with severe limitations

VII Non-arable, with very severe limitations

VIII Non-arable, with limitations preventing their use in commercial plant production

Source: Atlas Ambiental de la República de Panamá, 2010.

Map 3. Land ecoregions of Panama



Land ecoregions of Panama

Humid forests of Chocó/Darién	Montane forests of Talamanca	Mangroves of Bocas del Toro-Isla Bastimientos-San Blas
Humid forests of the Atlantic side of the Isthmus	Montane forests in the east of Panama	Mangroves on the humid Pacific coast
Humid forests on the Pacific side of the Isthmus	Dry forests of Panama	Mangroves in the Gulf of Panama

Source: Atlas Ambiental de la República de Panamá, 2010.

The implementation of a general land-use plan and the establishment of the monitoring and evaluation framework for the conservation of biodiversity should promote options for the preservation of species in ecosystems.

e. Forest resources

Panama's forest resources are characterized by mature forest cover, intervened and secondary forests, which accounted for 61.9% of the land area in 2014. All these forests play an important role in protecting the country's watersheds, offering multiple eco-systemic services such as the regulation of water resources, biodiversity conservation, soil protection and the stabilization of erosion.

Prior to 2000, the annual deforestation rate was estimated at about 50,000 ha. Subsequently, the records indicated that by 2014, forest cover had been reduced to 30% of 2000 figures.

As a result of the commitment made at the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in 2015, Panama committed to the establishment of an International Center for Tropical Forest Management, whose Panama office promoted the Alliance for a Million Reforested Hectares Initiative, projected for 2035.

f. Potential impacts of climate change

Global climate change is the greatest threat facing food production systems and natural ecosystems (IPCC, 2015). Rising temperatures directly proportional to evapotranspiration and water demands affect crops, livestock production and the health of the human population.

g. Building resilience to extreme events

The occurrence of more frequent and intense extreme weather events is associated with climate change, and requires technological adaptation and the creation of mechanisms of resilience to provide vulnerable rural communities with alternatives for coping with the increasing scale of natural disasters and their impact on feeding the population. The first step to building resilience is to reduce vulnerability to climate variability and climate change in the medium and long term.

Building resilience to extreme events such as floods, hurricanes and landslides and providing access to water is implemented through the adoption of available technologies and the efficiency of production systems. Prioritized technologies are designed to achieve the sustainable use of farmland and efficient water use (drip irrigation and micro sprinklers) and storage. Forestry and agroforestry systems increase resilience by establishing production systems with a high biodiversity of species in the various forms of mixed production, such as agroforestry and silvopastoral and agro-silvopastoral systems.

The role of national and international institutions and government policies is crucial to building systems resilient to extreme events. Training qualified human resources and securing the funds required to meet the goals set are also essential.

Figure 2: Guaymí Bull in IDIAP's genetic resource conservation program

h. Future outlook

In 2009, the International Food Policy Research Institute indicated that climate change would not only reduce the yields of agricultural crops and animal products, but also increase food prices. Consequently, it is predicted that by 2050, the reduced availability of calories needed for child development will be reflected in 20% of child malnutrition.

4. Technology and Innovation

Knowledge of genetic diversity, sources of resistance, biology and the behavior of plant and animal species, nutritional quality, medicinal properties of plants and resilience are advances in science, technology and innovation that have permitted the conservation, assessment and use of wild foods as a genetic basis for the improvement of agricultural products. Moreover, one of the key points in CTI is the assessment of nutritional quality through the use of technologies that promote the development of new products from wild foods. Producers prefer to use improved cultivars, which have higher yields and are pest- and disease-resistant, among other features, without ruling out the cultivated plants traditionally used by indigenous communities.

a. Plants

The progress of STI has positive effects on the production of wild foods. Moreover, undertaking projects has made it possible to determine nutritional quality and envisage new products extracted from wild species. However, farmers prefer to use improved cultivars, such as Creole rice, and varieties of maize, wild tomato, roots and tubers (IDIAP, 2016).

b. Livestock

As for the genetic improvement of livestock, progress has been made in assessing the nuclei of Creole cattle, which permitted the establishment of eight core conservation zones for Guaymí (**Figure 2**) and Guabalá Creole cattle. This group is located in the IDIAP experimental field in Ollas Arriba, Capira, Panama, with a livestock population of 191 head of cattle.

Improving tools for the diagnosis of Enzootic Bovine Leukosis (EBL) made it possible to declare all herds technically free of this disease, a significant achievement in the field of animal health. The results presented by this project made it possible to establish the Enzootic Bovine Leukosis protocols with GAG, TAX and ENV genes for cattle. The diagnostic protocol was adjusted by PCR in real time for Bluetongue in cattle and sheep (IDIAP Annual Report, 2016).

c. Pests and diseases

Mixed production systems can be promoted through the implementation of rational management strategies together with the application of agrochemicals. Rainfed crop production systems include management of the Panicle Rice Mite (*Steneotarsonemus spinki*), which caused significant losses in rice production (IDIAP Annual Report, 2016).

Tomato growing involves major economic investment, because the *Begomovirus* complex has caused significant economic damage, due to its association with *Bemisia tabaci* vector biotypes, since it is identified with the genetic diversity of the virosis of polymerase (PCR) and the fragments amplified by PCR were subjected to a Single Strand Conformation Polymorphism analysis (SSCP). This made it possible to identify the presence of *Begomovirus* in 135 samples collected in the provinces of Chiriquí, Herrera, Los Santos, Veraguas and Panama. These results strengthen genetic improvement programs for tomatoes designed to achieve resistance to these viroses (IDIAP, 2016).

In recent years, IDIAP technicians have morphologically identified 29 isolates of native entomopathogenic fungi (17 isolates of *Beauveria bassiana*, one of *Isaria lilacinus* and one of *Trichoderma* sp.), by performing pathogenicity tests on insects-pests of horticultural crops under abiotic, laboratory-controlled conditions. They also molecularly characterized various strains collected from these pest species (IDIAP, 2016).

Other technological innovations that create cleaner production alternatives include the use of biological pest agents, such as *Trichogramma pretiosum* and *Telenomus podisi*, egg parasitoids of the species complex of *Pentatomidae* and *Lepidoptera*, respectively (IDIAP Annual Report, 2016). This reduces the pollution of water sources and protects the biodiversity associated with agricultural ecosystems.

d. Outlook for novel agricultural products

Corn with high protein quality carries the opaque-2 gene, rich in lysine and tryptophan, which has doubled the concentration of amino acids in the varieties in this category (IDIAP, 2016). The germplasm used was provided by CIMMYT, creating four varieties of biofortified corn (IDIAP MQ-02, IDIAP MQ-07, IDIAP MQ-12, and IDIAP MQ-14).

e. Opportunities for new management technologies

The water crisis, which will be exacerbated in the coming years as a result of climate change, has confirmed the existing water deficit in our agricultural ecosystems. Accordingly, drip irrigation, micro sprinklers and fertigation systems have been developed, permitting water savings of up to 95%. In Panama, this technology is available and operating efficiently in production systems.

Vertical agriculture, with climate-controlled systems, is being employed in horticultural products, although use of this technology is limited by its high cost and lack of funding. However, the training of specialized personnel for its operation has not been ruled out.

f. Development of aquaculture and marine resources

As one of the basic components of the Panamanian diet, the aquaculture production system affects the health and quality of farmland, as well as water sources. However, economic growth has fueled projects involving shrimp farming for export. Science and technology have generated key information in the quest for sustainability in the production of these species.

5. Improving the efficiency of the food system

a. Increasing agricultural production based on technological expectations

Banana and sugar cane crops, which are economically important for the country, utilize extensive irrigation systems. In the 2015 crop year, it was estimated that existing irrigation projects used approximately 50% of their potential.

Fruit and vegetable production in controlled settings is on the rise. As a result, producers have begun to engage in vertical-farming *Farm Factories* as a result of a cooperation initiative between Chiba University, Japan, and the University of Panama.

IDIAP has also undertaken significant research on greenhouse production in various ecological zones throughout the country, especially in horticultural areas.

b. Infrastructure for storing food and logistics for transporting it to distribution markets

The Panamanian State has created the Executive Secretariat for the Cold Chain, through Executive Decree No. 20 issued on July 2, 2009. This agency is responsible for planning and implementing this system, designed to extend the shelf life of agricultural products through low temperature storage, preventing losses estimated at between 10% and 60%, depending on the agricultural product, locality and efficiency of the logistics system. The program focuses on 24 perishable goods such as onions, lettuce, tomatoes, broccoli, beans, carrots, cassava, yams, otoes and potatoes. There are currently four collection centers, called Postharvest centers, located in three places: Volcano, Cerro Punta and Dolega, all in the province of Chiriquí, 400 kilometers from the capital. This part of the country produces 80% of the vegetables consumed nationwide. In addition to the collection centers in the province of Chiriquí, another center has been set up in the center of the country in the town of El Ejido in the province of Los Santos to store 12% of national horticultural production. The purpose of this project is to have retail public markets in all the capitals of the provinces of Panama. At present, there is one operating in the market in the city of David, in the province of Chiriquí.

The purpose of this government initiative is to strengthen the transportation logistics of these agricultural products, reducing postharvest losses.

6. Health Considerations

a. Nutritional deficiency as a precursor of diseases

Its humid tropical climate means that the country offers conditions for the survival and multiplication of microbial and parasitic agents that may contaminate food, affecting consumer health. The occurrence of food poisoning must be reported to the authorities in the industry, governed by Decree 268, issued on August 17, 2001 (Cedeño et al., 2009).

b. Overconsumption of food

In 1982, the prevalence of obesity in men and women was 3.8% and 7.6%, respectively. By 2003, these figures had risen to 14.4% in men and 21.8% in women. Moreover, it is estimated that obesity-related diseases were responsible for the deaths of 8,517 Panamanians, accounting for 49% of the total number. **Table 1** presents data on the nutritional status of adults from 2003-2014, where high rates of overweight and obesity were recorded (Sasson et al., 2014).

Table 1. Nutritional Status of Adults (2003-2014)

Domain	1997	2003	2008
National	16.7	22.2	19.1
Not Poor	5.01	11.0	6.8
Not extremely poor	12.51	19.5	16.1
Extremely poor	38.4	43.3	46.2

c. Malnutrition indicators

The Human Development Index (HDI) is an indicator of countries' average progress in terms of longevity, encompassing health, education and quality of life. The most recent Global Human Development Report confirms that Panama is ranked 60th of 188 countries, placing it among the countries with high human development (UNDP, 2015).

d. Malnutrition in marginalized areas

Despite Panama's economic development in recent years, malnutrition and food insecurity persist in rural areas, where there are high levels of poverty and extreme poverty.

Table 2 confirms the direct relationship between poverty and malnutrition among children under five (MINSA, 2009).

Table 2. Prevalence of Chronic Malnutrition in Children under Five (1997-2003)

Domain	1997	2003	2008
National	16.7	22.2	19.1
Not Poor	5.01	11.0	6.8
Not extremely poor	12.51	19.5	16.1
Extremely poor	38.4	43.3	46.2

Poverty directly affects access to food, therefore food security. A number of surveys conducted in 2008 reported that approximately 32.7% of people are poor, and that poverty rates are higher in rural areas (50.7%) (Dieguéz, 2016).

7. Policy considerations

a. Distortions created by subsidies and other agricultural policy models

Agricultural policies in the 1960s and 1970s, as well as the first half of 1980, prioritized self-sufficiency in commodities together with the expansion of traditional and nontraditional export goods. The agricultural Gross Domestic Product (GDP) rose to 20%, which led the creation of specialized agricultural institutions, such as the Institute of Agricultural Marketing, the Agricultural Research Institute of Panama, the National Agricultural Machinery Company, the Agricultural Insurance Institute and the Institute of Renewable Natural Resources (now MiAmbiente), among others. The Institute for Agricultural Development was renamed the Agricultural Development Bank. This confirms the interest in food security and sovereignty, which formed the backbone of national agricultural development.

The commercialization of agricultural goods took place in a market with high levels of intermediation, operating costs and post-harvest losses.

b. Promotion of sustainable agriculture, with healthy products that provide nutrients to the diet, at affordable prices

IDIAP is promoting a national program for the biofortification of food, in order to increase consumption of vitamins and minerals in basic food items. The Agricultural Marketing Institute (IMA) has implemented the Food Solidarity Program, which seeks to produce food at lower prices, using open markets or the direct selling of products as a platform, avoiding intermediation.

In 2014, in order to address food inflation, the government installed a program to freeze prices for the main basic food items, which included rice, onion, tomato, certain cuts of meat, eggs, milk and beans, among other products.

c. International trade agreements

In 1984, national economic policy underwent a significant change due to the introduction of macroeconomic measures designed to achieve structural adjustment and reduce state intervention in the economy. The agricultural sector was reoriented toward technical assistance and focusing on non-traditional export crops. Moreover, redefinition of the objectives of the state agricultural institutions has been reinforced on the basis of the premises of the free market and trade liberalization. This process promoted the conversion of agricultural production guided by demand and linked it to agricultural exports. That is why they have promoted free trade agreements and trade with Central America, Taiwan, Mexico, Chile, Singapore, USA, Canada, Peru and the European Union, regarding trade as the basis for this initiative. The Strategic Government Management Plan 2015-2019 sought to improve the competitiveness and productivity of the primary sector. For the first time in decades, the premise of recovering food sovereignty, which is not sustainable, was considered.

d. Policies for the adaptation of technological innovations

The Science, Research, Technological Development and Innovation for Sustainable Development implemented by SENACYT focuses on the creation of a permanent dialogue on the problems of food security. In this process, it is essential to understand the dynamics of social behavior with respect to problems and solutions regarding development, which defines the need to implement research projects based on production systems and their relationship with water, soil quality and health, with a view to guaranteeing food security in order to integrate and analyze the elements required to mitigate climate change (PENCYT, 2015).

8. Executive Summary

In Panama, climate change has affected the agricultural sector and the population's food security. The analysis of the development of both variables is directly linked to the implementation of research and projects focused particularly on the adaptation of biodiversity and agricultural areas to climate change, with an approach aimed at water resource management and increasing resilience to climate variability.

Agriculture and food are key issues in the Millennium Development Goals. In addition, from this approach, the perspective of alleviating poverty confirms the need to generate knowledge by strengthening national agricultural research institutes (INIA). However, this does not exclude the implementation of national innovation systems in the current political, economic and social scenario faced by the country and the world.

Nowadays, indicators that include the political factor focus on the change of era, linking it to agricultural development. Thus, the reduction of incentives in development strategies is essential to addressing challenges such as the development of sustainable farming systems and food production.

Knowledge generation and the innovation of agricultural technology are key elements in defining the emerging scenarios required to implement the necessary changes. Global trends propose the implementation of agricultural policies focusing on technological innovation, which are incorporated into the development of the food sector. The technological upturn linked to the development of value chains, integrated markets and proper distribution at the level of production systems is one of the strategies required to optimize the use of national and international markets. However, there is very little investment in agricultural research, coupled with a lack of specialized human resources. In this respect, the appropriate scenario is not proportional to the level of opportunity mentioned earlier.

The role in the generation of technological innovation of National Agricultural Research Institutes (INIA) must be reframed on the basis of certain objectives, such as: a) describing the challenges they face and consolidating the scientific basis within the political, social and economic framework; b) contributing ideas that support the changes that must be made to leverage opportunities and meet the current challenges, and c) identifying the specific processes required for the practical implementation of the transformations required.

References

Autoridad Nacional del Ambiente (2010). Cuarto Informe Nacional de Panamá ante el Convenio sobre la Diversidad Biológica Panamá. 110 pp.

World Bank (2016). Available at: http://datos.bancomundial.org/indicator/AG.LND.AGRI.ZS?locations=PA&view=chart

Camargo Buitrago, I., Bieberach, C.Y., Villalobos A. & González P. (2016). Estado de la biodiversidad para la alimentación y la agricultura en Panamá. Instituto de Investigación Agropecuaria de Panamá. Departamento de Edición y Publicaciones Panama, 2016. 286 pp.

Capital Financiero (2014). Evolución del mercado agrícola de Panamá y la competitividad. Available at: http://www.capital.com.pa/evolucion-del-mercado-agricola-de-panama-y-la-competitividad/

Cedeño, H., Bolaños, R. & Pinzón, J. (2009). Situación de las enfermedades transmitidas por alimentos (ETAS) en Panamá. Ministry of Health, ICGES.

Dieguéz, J. (2016). Medición de la pobreza y bienestar en Panamá. Report. Ministry of Economy and Finance, May 11.

FAO (2015). Plataforma de Seguridad Alimentaria y Nutricional. Available at: http://plataformacelac.org/storage/app/uploads/public/568/c23/fad/568c23fadf069324915081.pdf

FAO (2013). The Agricultural Outlook 2016-2025, Organization for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO). 116 pp.

FAO (2002). Agricultura Mundial: Hacia los años 2015/2030. Brief Report. Rome, Italy. 97 pp.

IDIAP (2016). Memoria Anual 2015. Panamá, Panamaá: IDIAP.

INEC (Instituto Nacional de Estadística y Censo) (2014). Estimación de la población total en la República, según sexo y grupos de edad: Años 2010-14. Contraloría General de la República de Panamá.

Instituto Internacional de Investigación sobre Políticas Alimentarias (2009). Cambio Climático: El impacto en la agricultura y los costos de adaptación. IFPRI; Washington, D.C. 19 pp.

INEC (Instituto Nacional de Estadísticas y Censo) (2011). Censo Nacional Agropecuario, 2011. Panamá, Panamá: INEC.

MIDA (Ministerio de Desarrollo Agropecuario) (2015). Memoria 2015. 132 pp.

Ministerio de Salud (MINSA) (2009). Estado nutricional de niños y niñas menores de cinco años-República de Panamá-Encuesta niveles de Vida 2008. 37 pp.

Mora, J., Ramírez, D., Ordaz, J.L. & Acosta, A. (2010). Panamá: Efectos del Cambio Climático sobre la Agricultura. Comisión Económica para América Latina y el Caribe (CEPAL). México. 74 pp.

Panel Intergubernamental de Expertos en Cambio Climático, IPCC (2015). Quinto Informe del Grupo de Trabajo II. Cambio Climático Impactos, adaptación y vulnerabilidad. 30 pp.

Secretaría Nacional de Ciencia, Tecnología e Innovación (SENACYT) (2015). Política Nacional de Ciencia, Tecnología e Innovación de Panamá (PENCYT). 150 pp.

Programa de las Naciones Unidas para el Desarrollo (PNUD) (2015). Informe sobre Desarrollo Humano 2015. Editorial PNUD.

ENV (2008). República de Panamá. Principales Resultados Encuesta de Niveles de Vida 2008 (MEF, CONTRALORIA, INEC, BANCO MUNDIAL).

Sasson, M., Lee, M., Fontes, F. & Motta, J. (2014). Prevalence and associated factors of obesity among Panamanian adults. 1982–2010. PLOS ONE 9(3): e91689. doi:10.1371/journal.pone.0091689

Secretaría Nacional de Energía (2016). Balances energéticos y Plan Energético Nacional 2015-2050: "Panamá, el Futuro que Queremos". 314 pp.

Stads, G.J. & Beintema, N.N. (2009). "Investigación Agrícola Pública en América Latina y el Caribe; tendencias de capacidad e inversión". ASTI, Informe de síntesis, Washington, D.C., y San José, Costa Rica: IFPRI e IICA.

Villarreal, J., Pla-Sentis, I., Agudo-Martínez, L., Villaláz-Pérez, J., Rosales, F. & Pocasangre, L. (2013). "Índice de calidad del suelo en áreas cultivadas con banano en Panamá". Agronomía Mesoamericana 24(2): 301-315.

Acknowledgments

The authors are grateful for the support of the **Inter-American Network of Academies of Sciences** (IANAS), **Adriana de la Cruz** and Dr. **Mike Clegg** in the publication of chapter on "Food and Nutritional Security for Panama: Challenges and Opportunities for this century. The careful choice of specialists by the **Panamanian Association for the Advancement of Science** (APANAC) was crucial to the successful completion of this initiative promoted by IANAS.

The collaboration of professionals and national institutions involved in the collection of the bibliographic information, drafting and revision of the final text was essential to the completion of the task.

Dr. **Ismael Camargo** and Dr. **Bruno Zachrisson** are grateful to the **National Research System of Panama** (SNI) and the **National Secretariat of Science, Technology and Innovation** (SENACYT) for their support in the development of the technological innovations presented in this chapter.

Food and Nutritional Security in Peru

Winayhuayna, Inca ruins of agricultural center, Machu Picchu, Peru © Shutterstock

Peru

[1] Gustavo F. Gonzales
[2] Ana Colarossi
[3] Nicole Bernex
[4] Verónica Rubín de Celis
[5] Lidia Sofía Caballero-Gutiérrez
[6] Fernando Álvarez

Although **Peru** has made great strides in the past 20 years regarding the rational use of fishery, land and water resources, environmental conservation, genetic reserve and mitigating the negative impact of climate change, it has not sufficed to **guarantee the food security, health and quality of life of today's inhabitants and future generations**

Summary

Peru is one of the countries with the greatest diversity of ecosystems and species. It is home to 84 of the 117 life zones recognized in the world, included in a wide range of climates, geoforms and types of vegetation. It is an agricultural and livestock country par excellence, contributing 80% of the food consumed by its population, meaning that it needs to import the remaining 20%. It has a capacity to develop agricultural crops above 4000 masl and is internationally recognized for its production of "superfoods" such as quinoa, kiwicha, cañihua, maca, yacón, Inca nut, anchovy, camu camu, purple maize and soursop. Peru is among the top ten food exporters, meaning that is on the way to becoming the world's pantry.

Although the availability of resources is wide and varied, a significant percentage of the population is exposed to food insecurity, particularly as a result of climate change and natural disasters. The state promotes agricultural, livestock and aquaculture development through the enactment of laws and economic investment for the promotion of human resource research and training for the technological generation and innovation, agricultural production and export. It also promotes the rational use of fishery, land and water resources, conservation of the environment and genetic reserves and mitigation of the negative impact of climate change. Although over the past 20 years, the country has had many achievements, these are still insufficient to guarantee the food security, health and quality of life of its inhabitants and future generations.

1. The Characteristics of Peru

a. A land of contrasts

The third largest country in South America with an area of 1'285,215.60 square kilometers, straddling the steep, rugged Andes and culminating at 6,768 meters above sea level, Peru enjoys an exceptional situation since it is part of the Pacific watershed, with 3,080 km of marine coast and the Amazon basin, offering a myriad of landscapes, resulting from the impressive climatic and biological diversity created by slopes of over 6,000 meters. With 96 (Pulgar Vidal, 2014: 225) of the world's 104 life zones, 12 climate zones[1] and eight natural regions, Peru is one of the ten countries in the world with greatest mega-diversity. It depends on and uses most of its biodiversity. The population uses approximately 5,000 of the country's 25,000 plant species (10% of the world total), of which at least 30% are endemic, for a variety of purposes: food (782); medicine (1,400);

1. According to Köppen.

decoration (1,608), timber and construction (618); fodder (483) and dyes and coloring (134) (MINAM, 2008). The seven food baskets also reflect the abundance and diversity of local food resources, the current possibilities of using them and the centuries-old wisdom of the indigenous peoples (**Box 1**).

Farmers in ancient Peru domesticated 25 species of edible roots and tubers. These crops can be of global significance such as the potato (*Solanum tuberosum*), olluco (*ullucus*), oca (*Oxalis tuberosa*), mashua (*Tropaeolum tuberosum*), Peruvian parsnip (*Arracacia xanthorrhiza*), daisy (*Smallanthus sonchifolius*), Mauka (*Mirabilis expansa*), arrowroot (*Canna edulis*), Andean yam bean (*Pachyrhizus ahipa*) and maca (*Lepidium meyenii*). These crops have a high tolerance to pests and diseases and nutritional efficiency,

Box 1. The Seven Food Baskets (Javier Pulgar Vidal, 2014)

The contents of the "basket" differ at each level; but together, they meet all the biological needs of the population and reflect both the efforts to successfully acclimate the species needed and to tame the slope and ensure water availability.

- **La Chala (0-500 m).** Animal protein predominates in the La Chala food basket (fish and seafood: anchovy, bonito, sardine, mackerel, mackerel, tuna, sea bass, sole) as well as sweet potato, various types of bean, corn, squash, cabbage, lettuce, cauliflower, spinach, cucumber, leek, peas, caigua, vainita, tomato, onion and fruits such as grapes, fig, banana, guava and plums.
- **La Yunga (500 a 2,300 m).** This basket mainly contains poultry, guinea pig, eggs and various fruits: avocado, custard apple, lucuma, passion fruit, papaya, tumbo, plums, palillo, cactus pear, pitahaya; introduced citrus fruits (orange, lime, sweet and sour lemon, cider, kumquat and grapefruit); sweet potato, canna, beans; and condiments such as various kinds of chili and an aromatic herb known as chincho.
- **La Quechua (2,300 a 3,500 m).** This basket consists mainly of guinea pig meat and poultry, trout and dry-salted fish; maize, potatoes, parsnips, pumpkin, shupe, beans, numia, pashullo, all kinds of vegetables, herbs, a variety of seasonings and typical and acclimatized fruit.
- **La Suni or Jalca (3,500 a 4,000 m).** The basket comprises guinea pig meat, llama jerky, dried fish; quinoa, cañigua, tarhui, potato varieties, oca, mashua, olluco, various vegetables; condiments such as shill-shill which is similar to Guacatay, anise and pachamuña. The fruit basket is rounded out by Layan fruits, burro-shillanco and blackberry.
- **La Puna (4,000 a 4,800 m).** The local food basket consists of dried meat and the fresh meat of camelidae, sheep, pig, cattle and wild or domestic guinea pigs; lagoon or stream fish; bitter potatoes turned into chuño, non-bitter potatoes, maca, watercress, cushuro, potaca, huagoro fruits and occasionally non-bitter potato berries.
- **La Janca (4,800 a 6,768 m).** This food basket is mainly found at the lower levels.
- **La Rupa-Rupa (400 a 1,000 m).** The diet of humans living in the high jungle is dominated by forest meat, as well as beef, mutton, goat's meat, pork, guinea pig meat, poultry and river fish. It also features pituca, cassava, chuncho bean, a type of bean known as frejol de palo, millet, maize, cocoa and peanuts; condiments such as annatto, turmeric, palillo de palito, various peppers, vanilla, and tea, matico, pucherí and sharamasho infusions.
- **La Omagua or Selva Baja (80 a 400 m).** This area has a food basket consisting of bush meat, Amazonian cattle, water buffalo, sheep without wool, common goose and guinea fowl; river fish, river and land turtles; cassava, pituca, bananas, yams, cantaloupe, watermelon, native fruit and cultivated vegetables.

[1] Gustavo F. Gonzales, Senior lecturer at the Cayetano Heredia Peruvian University and member of the National Academy of Sciences, gustavo.gonzales@upch.pe **[2] Ana Colarossi,** Associate Professor at the Cayetano Heredia Peruvian University. Director of the Nutrition Degree Program. Head of the Micronutrient Laboratory of the Research and Development Laboratories (LID-UPCH), ana.colarossi@upch.pe **[3] Nicole Bernex,** Senior lecturer at the Pontifical Catholic University of Peru, Academic Director of the Center for Research in Applied Geography CIGA-PUCP and member of the National Academy of Sciences, nbernex@pucp.edu.pe **[4] Verónica Rubín de Celis,** Senior Lecturer at the Ricardo Palma University. Director of the Laboratory of Genomics and Evolutionary Molecular Biology. Member of the National Academy of Sciences, verónica.rubindecelis@urp.pe.edu **[5] Lidia Sofía Caballero-Gutiérrez,** Senior Lecturer at the National University of the Altiplano, Puno. Puno Coordinator of the Research Circle on Plants with Health Benefits, lidia.caballero.g@upch.pe **[6] Fernando Álvarez,** Associate professor at the Daniel Alcides Carrión University , Pasco, and Researcher in the Research Circle on Plants with Effects on Health, falvarezr@undac.edu.pe

Table 1. Agricultural area by natural region in hectares, 2012

Natural region	Total	%	Agricultural	Non agricultural
Coast	4 441 453,92	11,5	1 686 778	2 754 376
Mountains	22 269 270,66	57,5	3 296 008	18 973 263
Rain forest	12 032 040,10	31,1	2 142 222	9 889 818
Total	38 742 464,68	100,0	7 125 008	31 617 457

Source: INEI. IV Censo Nacional Agropecuario 2012

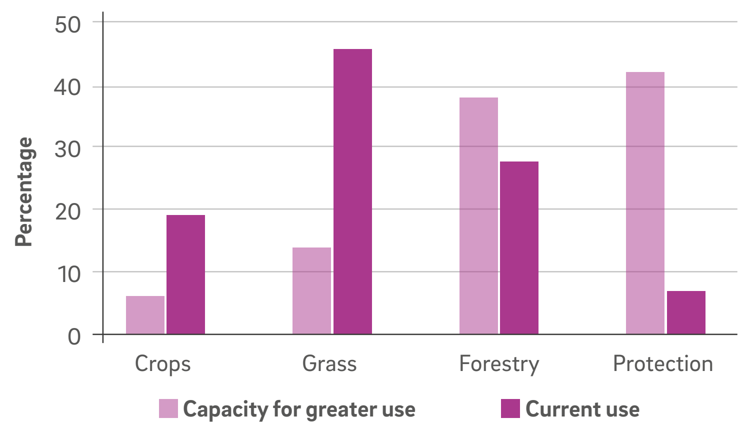
because of their degree of adaptation to extreme environments (CONDESAN, 1997). Pulses include the lupin (*Lupinus mutabilis*) while grains include quinoa (*Chenopodium quinoa*) and amaranth (*Amaranthus caudatus*), both with a great nutritional value (Repo-Carrasco-Valencia, 2014).

This impressive biodiversity is distributed very unequally throughout three geographical regions as follows; the desert coast, dotted with fertile oases (11% of the territory, 52% of the population); the sierra with its enormous latitudinal and altitudinal complexity (30% of the territory, 36% of the population) and the extensive tropical forest with its contrasting diversity (59% of the territory, 12% of the population). The impressive diversity of the Peruvian sea is vastly undervalued. A total of 750 fish, 872 mollusk, 412 crustacean, 45 echinoderm and 240 algae species have been identified, together with turtles, cetaceans and mammals, of which only a small fraction are commercially exploited (MINAGRI, 2017).

Despite having such a vast territory and being one of the centers of origin of cultivated plants (Brack, 2004), Peru's agricultural potential is reduced to 5.9% of the country's total area, most of it suitable for seasonal crops (3.8%) and the remainder for permanent crops (2.1%), with protected lands accounting for 42% of the national territory. **Table 1** shows that the coast is the region with the lowest amount of farmland and pastures. Demographic pressure and other circumstances forced populations to indiscriminately use soil beyond its capabilities (**Figure 1**), causing severe desertification and land degradation that compromise 26.76% of the total national territory (34'384,796 ha) (MINAM, 2014: 151).

This overwhelming diversity, combined with the multiple constraints of a land of contrasts, explains why, since ancient times, Peruvians have

Figure 1. Greater land use capacity and current use (%), 2015



Source: INEI, Anuario de Estadísticas Ambientales, 2015, and ONERN, 1985

sought and found solutions to evaluate the environmental supply and reverse the problems of desertification and degradation of plant cover, building galleries, canals and pipelines, controlling erosion (water, wind, thermal) through ridges, waru-waru and extensive platforms currently being restored (**Table 2**). Also, at present, the area under irrigation represents 2.6 million ha (36.2%) of a total of 7.1 million ha, while 4.5 million are rainfed (63.8%) (INEI, 2012).

b. Continuous, uneven population growth

With a total population of 31,488,625 on July 11, 2016, Peru has moderate annual population growth of 1.5% (1993-2007), low average density of 24.60 inhab/square kilometers and a large urban population (76.7%), 41% of which is concentrated in the metropolitan capital of Lima (9'901,107 inhabitants). Population dynamics are characterized by a double asymmetry by natural region and occupation (urban/rural), together

Table 2. Conservation status and current use of platforms in the provinces of southern Peru in hectares, 2012

Province	Total	Well conserved		Moderately well conserved			Destroyed		
		PU	TU	PU	TU	WAU	PU	TU	WAU
Total	**256955**	**13565**	**11025**	**31005**	**76160**	**105**	**400**	**84305**	**40390**
Apurímac	22620	-	-	25	6260	-	-	15430	905
Arequipa	48345	3260	6775	10195	11855	-	-	6120	10140
Cusco	23675	875	430	4395	2990	105	90	13610	1180
Ica	3345	-	-	160	915	-	310	960	1000
Lima	79380	3055	945	4950	28315	-	-	28405	13710
Moquegua	19390	4965	450	4500	2830	-	-	910	5735
Puno	46720	-	2425	-	20895	-	-	17715	5685
Tacna	13480	1410	-	6780	2100	-	-	1155	2035

Key: PU=Permanent use, TU= Temporary use, WAU= without agricultural use. Source: MINAGRI (INEI, 2015).

with a large indigenous population (25% of the national total) that is culturally and ethnically diverse, with 70.1% living in the mountains, 25.8% on the coast and 4.1% in the forest.

The demographic dynamic is characterized by a drop in the Overall Fertility Rate (from 2.6 children/woman in the 2005-2010 five-year period to 2.22 children/woman at present) and the child mortality rate (from 21,00/1,000 live births for the 2005-2010 five-year period to 16,60/1,000 live births) and an increase in life expectancy at birth (73,12 for the 2005-2010 five-year period to 75,07 at present) (INEI, 2016).

The agricultural sector accounts for 25% of the Economically Active Population (EAP) nationwide and in 2014, it accounted for 5.3% of the national Gross Domestic Product (GDP). With the exception of Lima, approximately 40% of the economically active population is engaged in agriculture (in the mountains, this figures rises to 55%) and represents between 20% and 50% of the regional GDP (Zegarra and Tuesta, 2009; Dragonfly, 2010; MINAM, 2016). The 2012 census recorded 2,260,973 farmers in Peru, 63.9% of these in the highlands, 20.3% on the coast and 15.8% in the forest (INEI, 2015).

c. Food insecurity, poverty and vulnerability

In 2010, MIDIS conducted a first detailed measurement of food insecurity in terms of availability, accessibility, food utilization and stability (time), noting that 47.5% of the total population is at risk of food insecurity, the most severely affected regions being Huancavelica, Huánuco, the Amazon and Puno (**Map 1**).

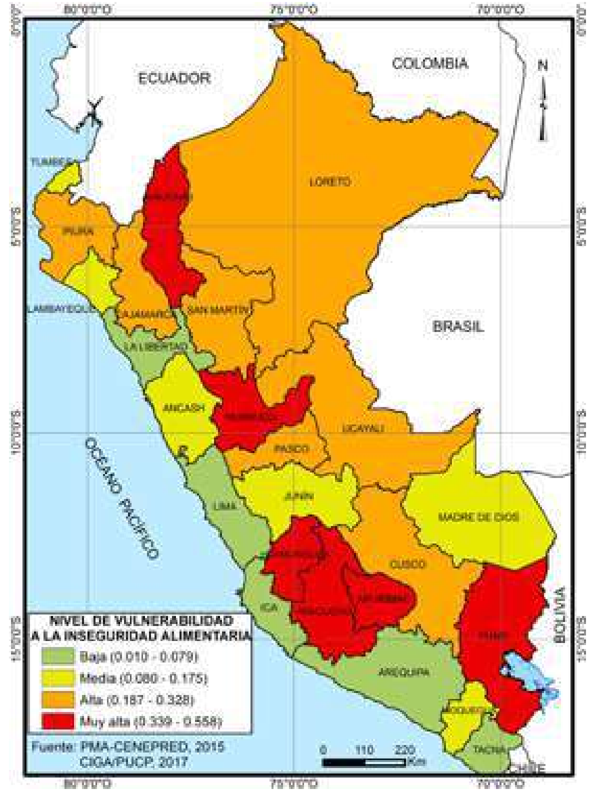
In 2015, 459 districts nationwide- in other words, 3.7 million people (INEI, 2014)– were exposed to Extreme Vulnerability to Food Insecurity in the event of natural phenomena (VIAFFNN). A total of 460 districts (with 3.4 million people) have a 37% probability of experiencing VIAFFNN with regard to food and nutrition insecurity. The most vulnerable provinces are Puno, Huancavelica, Ayacucho, Apurimac, the Amazon and Huánuco (**Map 2**).

In 1994, 49.6% of Peruvian households were unable to cover their basic consumption basket, and by 1997, this percentage had dropped to 44.3% (Vásquez, 1999). In 2001, a process of recovery and economic growth began (4.2% from 2001 to 2005) (Mendoza, 2006), reaching 7.2% in the 2006-2010 period (MEF, 2010; 2011).

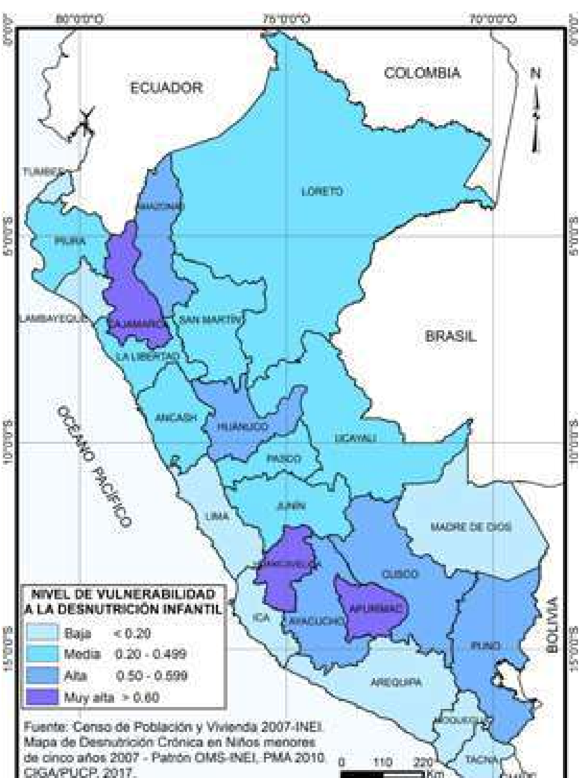
However, a very high rate of chronic child malnutrition due to inadequate food intake and disease can be observed, mainly in the highland regions (Huancavelica, Apurimac and Cajamarca) (**Map 3**), coinciding with the INEI poverty map where the three regions mentioned always lead the poverty or vulnerability rankings (MIDIS, 2012). Likewise, of the 2,087 Amazonian indigenous peoples (RM 321-2014-MC), 1,749 (85%) experience high and very high VIAFFNN, with towns in the Loreto, Amazon and Ucayali regions being the most severely affected (**Map 4**).

Map 1. Vulnerability to food insecurity

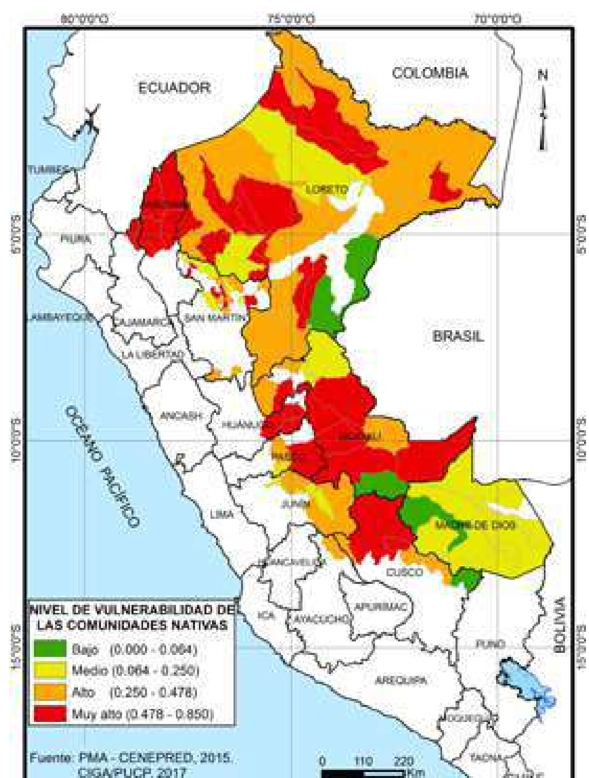
Map 2. Level of vulnerability to food insecurity



Map 3. Vulnerability to child malnutrition



Map 4. Vulnerability of native communities



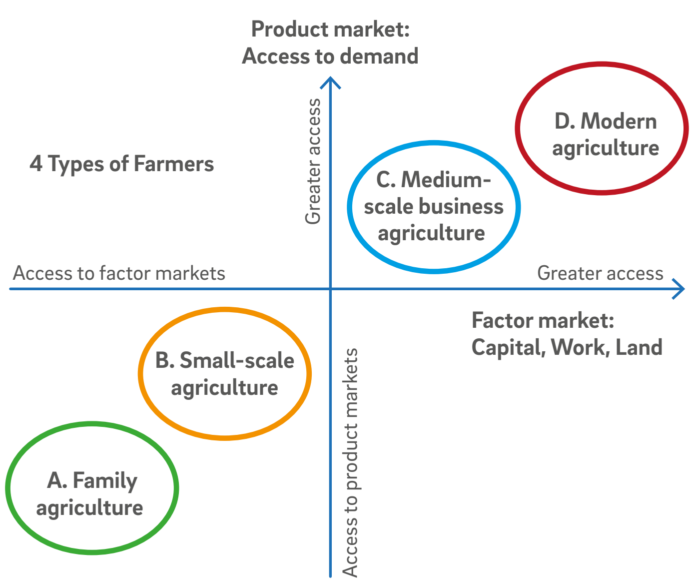
d. Types of agriculture

The Ministry of Agriculture and Irrigation (MINAGRI) defines four types of agriculture in Peru: family farming (formerly known as subsistence farming); small-scale agriculture; medium-sized corporate agriculture and modern agriculture, depending on the degree of access to demand, capital, labor and land (**Figure 2**). Most farmers are legal (99.4%) persons, with only 0.6% registered as legal entities. This figure corresponds to the characteristics of agricultural units and their fragmentation, in contrast with production by large companies. Agriculture in Peru is characterized by its low organizational capacity. Whereas in 1994 only 3% of farmers were associated, by 2012, this figure had increased to a mere 5% (MINAGRI/COMSAN, 2013). Other problems include both the lack of property deeds and the management of climate factors and pests that can affect crops and changes in the type of agriculture.

Since the 1990s, a greater impetus has been placed on the development of two types of agriculture. The first is agriculture with an export potential that still needs more state support to create technology and reach the investment levels required for the development of amaranth, cañihua, tarwi, tara, heart of palm, inchi sacha, yacon, camu camu and maca. The second is non-traditional export agriculture that uses high technology and has high investment levels because of its access to credit, enabling it to develop crops such as asparagus, paprika, citrus, artichoke, mango among others, occupying about 100 thousand ha at present, with an upward tendency (Rendón Schneir, 2010). This type of agriculture leverages the competitive advantages in fruit growing and horticulture, but is practiced by a smaller percentage of farmers. Consequently, the current agrarian structure provides an overall picture of an uneasy coexistence between two types of economies: a commercial one, mobilizing large amounts of capital, export-oriented and generating rural employment, and one based on family, small or medium production, managed by domestic units and creating agricultural self-employment (Ten, 2014: 26) units. However, the link among the number of cultivated hectares, access to irrigation and chronic malnutrition rates remains (**Table 3**).

In response to this situation, in recent years, the Peruvian government chose to promote the development of family farming in order to increase crop areas and improve the quality of life

Figure 2. Types of agriculture in Peru



Source: MINAGRI, 2013: 3.

Table 3. Link between chronic malnutrition rate, hectares of cultivated land and land with irrigation technology

Provinces with CM rates	N ° of Provinces	CM%	Land for cultivation (ha)	Land under irrigation (ha)
<10%	16	7.1	5.8	5.0
10-<20%	48	15.2	6.6	2.8
20-<30%	63	25.5	3.6	1.4
≥30%	64	35.0	2.9	0.7

CM: Chronic malnutrition. Adapted from Pintado 2012, based on data from the IV Agricultural Census (2012) and MINSA malnutrition rates (2014).

Figura 3. Characteristics and types of family agriculture

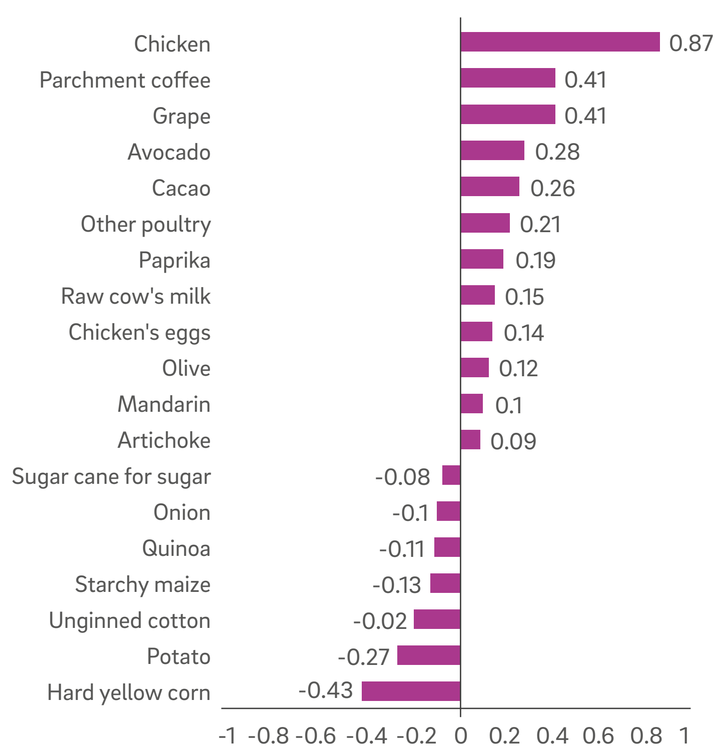
Source: Compiled by Nicole Bernex

of families who depend on this type of farming characterized by limited land resources, the important role of women, reciprocity and the community dimension. It has also acknowledged the fact that family farming is the backbone of rural communities by encouraging families' attachment to the land, the preservation of ancestral knowledge and traditions and the care of the plants and animals in each region. Although family farming accounts for 97% of all livestock farms, it has different degrees of development, meaning that it can be classified into three major types (**Figure 3**).

Agricultural production

As a result of various state programs and innovations, agricultural production overall has shown slow but steady growth. Thus, in the January-December 2016 period, agricultural production grew by 1.8% in comparison with the same period in 2015, due to the increased production of certain products that were particularly important (grape, parchment coffee, cacao, avocado, paprika, olive, tangerine, artichoke and chicken, eggs and raw cow's milk) (**Figure 4**) (MINAGRI 2016). The 1.4% decrease in the agricultural subsector (maize, potato, onion, quinoa, sugar cane) is overshadowed by the 4.3% increase in production in the livestock

Figure 4. Main products that contributed to the growth of the Agricultural Sector: January-December 2016 (percentage points)



Gross Production Value -Agricultural GPV January-December 2016= 1.8%

Platforms in Moray, Cuzco. Photo: Wendy Gonzales.

subsector. Production of coastal crops usually predominates and, by the end of 2016, sugar cane production had reached 10,211,900 t; potatoes, 4,712,400 t; alfalfa, 6,635,100 t; rice, 3,137,000 t; banana, 2,072,100 t; yellow corn, 1,438,600 t; and cassava 1,230,000 t, to mention just some of the wide range of plant foods produced by Peru (MINAGRI, 2016).

Agriculture over 4,000 meters above sea level
Peru's proximity to the equator means that its populations can live above 4,000 meters above sea level (masl). These areas with difficult weather conditions have managed to grow plants such as bitter potato, oca, olluco, mashua, maca, kañiwa and quinoa, known as extremophile plants.

Some species are tolerant to low temperatures and are highly adapted to extreme environmental conditions, such as maca (Lepidium meyenii Walp.), characterized by its high protein and

Platforms in Machu Picchu, Cuzco. Photo: Wendy Gonzales.

Box 2. Maca: a Crop or a Miracle of the Peruvian Andes?

Lepidium meyenii (maca) is a cruciferous (Brassicaceae) vegetable cultivated exclusively at between 4,000 and 4,500 meters above sea level (masl) in the Peruvian Central Andes. Maca is traditionally used because of its nutritional and allegedly medicinal properties.

Maca occurs in different varieties depending on its external color. Maca is used mainly after its hypocotyls have naturally dried and is consumed mainly in juice, showing the mixture of different colors of the hypocotyls. Experimental scientific evidence has shown the effects of maca on nutrition, fertility, osteoporosis, memory and mood. Black maca has a better effect on sperm production, memory and fatigue whereas red maca reverses prostate hyperplasia in rats and mice and osteoporosis in female rats and has immunomodulatory effects.

Subjects in Carhuamayo (4,100 masl) who do not consume maca decrease their HRQL score as their age increases, while those consuming maca have a high HRQL score at 40 years of age, which they maintain up to the age of 75. It seems as if these people do not age (Figure 1) (Gonzales, 2010). A double trial controlled by placebo showed that extracts of red maca or black maca increase people's HRQL score (Figure 2) (Gonzales-Arimborgo et al., 2016).

Although maca was declared in danger of extinction in 1982 (National Research Council, 1989), its sustainability has increased significantly since the 1990s. The government of Peru has made an enormous effort to increase its cultivation and promote the product in foreign markets. Since 2001, the number of international publications by Peruvian scientists on maca in peer-reviewed journals has increased together with interest in the properties of maca in international markets. Since 2005, it has been considered a Peruvian flagship product. The main problem with maca, which has been documented since the time of the Spaniards' conquest of Peru, is related to intellectual property rights. Policies must be developed to increase support for research on medicinal plants and develop strategies to patent results obtained from research on Peruvian medicinal plants.

Woman farmer in Pasco at a height of 4,200 m
Photo: Wendy Gonzales

Gustavo F. Gonzales

energy content. In 1982, it was declared an endangered species and now, thanks to scientific research, it has become a food of worldwide interest, because of its numerous biological properties (**Box 2**) (Gonzales et al., 2014).

Other species cultivated at a high altitude include the bitter potato, where its transformation into chuño (a natural lyophilisate) has been one of the most important achievements of the Andean people, since it enables it to be preserved for years. Frost- and drought-tolerant crops include kañiwa (*Chenopodium pallidicaule* Aellen), characterized by its protein content with a high biological value (15.7-18.8%), carbohydrates (63.4%), vegetable oils (7.6%), unsaturated fats, iron, calcium and dietary fiber (Apaza, 2010). Quinoa (*Chenopodium quinoa*) is a strategic crop because of its nutritional quality, since it contains phenylalanine, threonine and tryptophan, with broad genetic variability, adaptability and low production costs (FAO/PROINPA, 2011).

Animal Agriculture

The sierra is suitable for pasture land despite its limitations (such as temperature, soil erosion and degradation and water shortage) coupled with overgrazing and mismanagement (burning). Like the coast, it has an enormous potential for livestock production, with the areas planted with alfalfa, chala maize, feed barley, fodder oats, elephant grass, signalgrass and ryegrass expanding annually. This increases livestock

Maca farmer in Junín (4100 m).

Maca hypocotyl. Photos: Wendy Gonzales.

Maca selection in Pasco (4200 m). Photo: Wendy Gonzales.

Maca shrub in Pasco. Photo: Wendy Gonzales.

Livestock in the mountains. Photo: Wendy Gonzales.

Table 4. Population of cattle, sheep, pigs and poultry (in thousands), by natural region

Region	Cattle	Sheep	Pigs	Poultry
Total	**5,156.0**	**9,523.2**	**2,224.3**	**121'394,062**
Coast	612.9	482.5	853.0	104'329,347
Mountains	3,774.3	8972.2	1,135.8	6'321,891
Rain forest	768.8	68.5	235.5	10'742,824

Source: IV Censo Nacional Agropecuario 2012.

production and although cattle, sheep and pigs predominate in the mountains and birds on the coast, the regions with the largest share of beef production are Cajamarca (15, 8%), Huánuco (10.1%), Puno (7.5%), Metro (6.9%), Lima provinces (5.0%), the Amazon (4.9%) and Junín (4, 6%). Raw cow's milk production is steadily increasing, particularly in the regions of Cajamarca (18.8%), Aréquipa (18.8), Lima Province (13.4%) and Metropolitan Lima (4.5%). There has also been a significant rise in the production of chicken eggs around major urban centers, the regions with the highest production being Ica (39.1%), La Libertad (17.5%), Lima Province (16.3%) and Metropolitan Lima (10.7%), showing a clear orientation toward an urban market, away from the poorest areas such as high-Andean and forest areas (**Table 4**).

e. The challenge of agricultural self-sufficiency

Since the beginning of the 20th century, the challenge of Peruvian agriculture has been to meet internal demand, hence the ongoing effort to modernize agricultural infrastructure and the quest for technological and research innovations. Since the forest has very little agricultural land, it is less able to ensure food sufficiency and its inhabitants have the highest malnutrition rates, which is also due to their high poverty rates (Anticona and San Sebastián, 2014) and parasitosis (Casapía et al., 2007), together with limited access to health services and education (Anticona and San Sebastián, 2014). This pattern can also be observed in several high Andean areas (Cabada et al., 2015). Factors such as economic growth and nutritional intervention policies, however, have reduced food shortages in the poorest areas of the country (Huicho et al., 2016).

Although agriculture contributes 80% of the food, import dependence is approximately 20% for poultry and livestock feed inputs (such as yellow corn and soybean) and bread and pasta production (Villar-Castillo, 2008). In 2016, according to MINAGRI, Peru imported 90% of the wheat required and virtually 100% of the soybean oil and 65% of the hard yellow maize consumed in the country. Over the past 10 years, imports of agricultural products have tripled. This implies growing food dependency, which must be reversed in the future to ensure food and nutritional security. Global food-demand trends, the development of the biofuel sector and land degradation pose major threats to national food security.

f. More food exports/imports and markets

According to MINAGRI, Peru is among the top ten countries providing food to the world, with approximately 2.3 million farmers being affected by the low productivity of traditional agriculture. Many Peruvian foods have attracted worldwide interest. A case in point is the potato, which is native to Peru (Spooner et al., 2005). Due to the different climates in which it develops, it is possible to find cold-resistant genotypes (Condori et al., 2014). Main export products include asparagus, coffee, mango, olives, fresh grapes, fresh avocado, artichokes, dried peppers, beans, mandarin, ginger, beans, onion, fresh peas, quinoa, maca and blueberries, which have enormous nutritional value and numerous health benefits (**Table 5**).

The world's interest in Peruvian food is such that every five years the value of agricultural exports from Peru doubles, and by 2021, it is expected to exceed $10 billion USD (MINAGRI/COMSAN, 2013). Agricultural exports totaled

$4.849 billion USD between January and November 2016. The main export destinations are the US and the Netherlands, Spain, Germany and the UK. **Figure 5** shows that maca is Peru's most widely exported nutraceutical product.

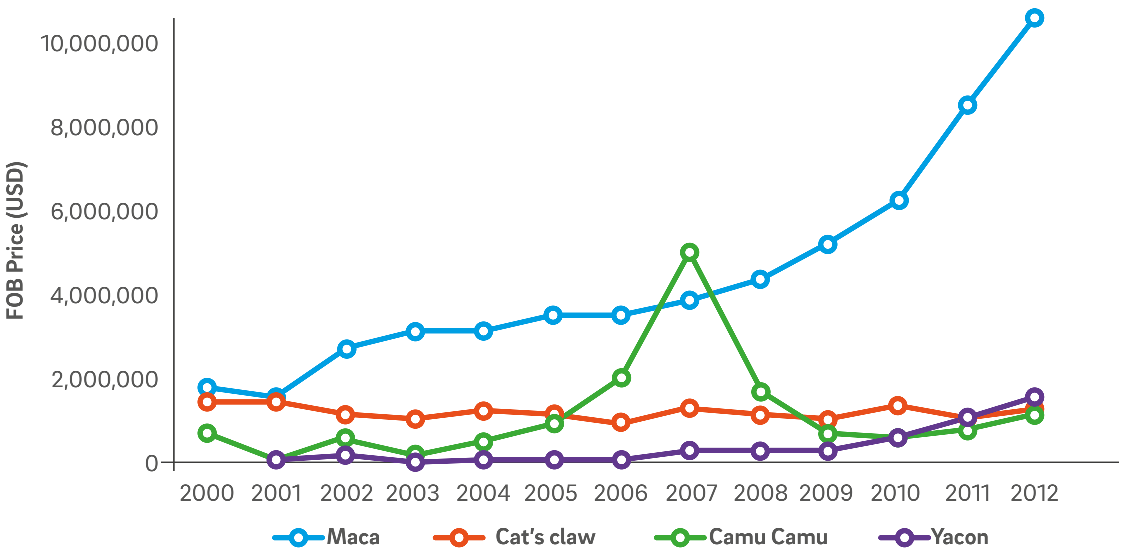
g. Potential sources of instability in food and nutrition security

Numerous factors can affect the stability of the food security actions that a country undertakes. These include the vulnerability of food production to climate change and changes in the international prices of food imports such as oil, soybeans, yellow corn, wheat and derivatives, which are part of the basic food basket (MINAGRI/COMSAN, 2013). Peru is one of the most vulnerable countries to the impacts of climate change, with risks to the sustainability of national development (MINAM, 2014: 33). Research has shown how climate change affected several societies during the

Table 5. Beneficial health effects of certain Andean-Amazonian crops

Crop	Beneficial effects
Quinoa *Chenopodium quinoa*	Metabolic, cardiovascular, and gastrointestinal health (Abderrahim et al., 2015, Graf et al., 2015).
Camu camu *Myrciaria dubia*	Antioxidant, anti-inflammatory and antimicrobial properties. High vitamin C content (Arellano-Acuña et al., 2016).
Yacon *Smallanthus sonchifolius*	Hypoglycemic and probiotic properties due to its high fructooligosaccharide content (Caetano et al., 2016).
Sacha inchi *Plukenetia volubilis*	Its oil has a high linolenic acid (omega 3) content, whose endogenous transformation permits the transformation into DHA, which has enormous biological importance (Gonzales et al., 2014a).
Aguaymanto *Physalis peruviana*	High provitamin A and ascorbic acid content, some B complex vitamins (thiamine, niacin and vitamin B12). It is also renowned for its high raw protein, phosphorus and iron content (Fischer et al., 2013).
Purple corn *Zea mays*	Antioxidant properties, beneficial for cardiovascular diseases (hypertension), cholesterol reduction, and combating diabetes (Guillén-Sánchez et al., 2014).

Figure 5. Exports of Peruvian nutraceuticals (Free On Board [FOB] price), 2000-2012 period



pre-Hispanic era. An important example was its impact on Caral, the oldest civilization of America, which developed along the north-central coast of Peru, in Supe Valley, between 2,800 and 1,900 BCE (Sandweiss et al., 2009). The inhabitants of Vichama, in Huaura Valley, adjoining Supe, left reliefs of 34 modeled figures for posterity, showing the ravages caused by famine on people's bodies (R Shady, personal communication).

In recent decades, as a result of climate change, the El Niño and La Niña phenomena has been both more frequent and severe, causing heavy rain and flooding on the north coast (Hernández-Vásquez et al., 2016A) and droughts in the south. By 2025, climate change could contribute to a 70% increase in the number of people experiencing enormous difficulty in accessing clean water sources; in 2050, 50 million people could be at risk of not having a sufficient supply of water for human consumption, hydro-energy or agriculture as a result of the deglaciation of the Andes (MINAGRI, 2013). Accordingly in 2012, with the support of FAO, MINAGRI drew up the National Plan for Risk Management and Adaptation to Climate Change for the Agricultural Sector for the 2012-2021 period (PLANGRACC-A).

h. Main challenges of agriculture

In response to increasingly frequent and severe episodes of rainfall, floods, frosts and droughts, MINAGRI, in conjunction with other sectors, launched the PLANGRACC-A, which prioritizes five strategic axes, directing and coordinating national and regional projects and/or programs concerning Disaster Risk Management (DRM) and Adaptation to Climate Change (ACC) for the agricultural sector (MINAGRI, 2012):

1. Research and information for DRM and ACC.
2. Emergency preparedness for and response to weather events.
3. Prevention and risk reduction considering climatic events.
4. Development planning in DRM and ACC.
5. Improving local capacities in DRM and ACC.

Due to the presence and magnitude of the El Niño and La Niña phenomena, there is a significant risk of agricultural losses and rising food insecurity during periods of rain or drought. Since 2015, the revitalization of the National Emergency Operations Center (COEN) has made it possible to more efficiently monitor disaster risks and act more quickly nationwide. At the same time, with the support of several institutions (European Union, DIPECHO Project, Welt Hunger Hilfe, Diakonie, Soluciones Prácticas and PREDES, among others), many Early Warning Systems (EWS) have been developed at the local and regional level.

2. Institutional context

a. National Agricultural Research System

The Ministry of Agriculture and Irrigation (MINAGRI), the agency responsible for setting the national agricultural policy, is in charge of the Agricultural Research System. It comprises entities such as the National Water Authority (ANA), responsible for national water resource management, the Agricultural Health Service (SENASA), an authority on agricultural health, seeds and organic production and the National Institute for Agrarian Innovation (INIA), in charge of incorporating technological change as a growth strategy for farming in a permanent, sustainable manner. Together with these institutions that undertake regional studies and research, the Research Institute of the Peruvian Amazon (IIAP), assigned to the Ministry of Environment (MINAM) in 2010, has a research system revolving around six major programs that contributes to sustainable management and biodiversity conservation, as well as knowledge of the Amazonian economy and social diversity.

Peru has many strengths through its programs such as AGROIDEAS, the Compensation Program for Competitiveness, a MINAGRI unit created in 2009, which provides resources to support business management, partnerships and the adoption of technology for small and medium producers' sustainable businesses to consolidate their market share.

Another strength is the incentive to promote Peru's main organic crops, such as coffee, cocoa, bananas, quinoa, maca and wild chestnuts.

There are over 100 certified products although they are only commercialized on a small scale.

Sierra Exportadora, established in 2006, contributes to economic growth in the Andean region through social and productive inclusion. It promotes exports, improving quality, volume and processes with a greater added value, in an open economy with a market perspective (*Sierra Exportadora*, 2013). As a result of Law 30495, it was transformed into the "*Mountain and Forest Export*" Program. By 2016, the program had trained 27,732 small farmers in the country's rural areas to enable them to obtain the quality products demanded by the global market.

The past 15 years have seen significant attempts to update science, technology and agricultural innovation institutions in order to provide them with a technological innovation approach. The creation of the INCAGRO program, the chain approach in agricultural promotion, the renewal of INIA, the Centers for Technological Innovation (CITE) and the Research Institute of Peruvian Amazonia (IIAP) constitute significant advances in the public sector. Among the main institutes in the private sector are the Peruvian Cotton Institute (IPA), the Peruvian Institute of Pulses, the Peruvian Institute of Natural Plants, the Peruvian Institute of Asparagus and Vegetables (IPEH), intergovernmental organizations such as the World Bank and the Food and Agriculture Organization (FAO), as well as agencies such as the Swiss Cooperation and German Technical Cooperation (GIZ) (Rendón Schneir, 2010; Libélula, 2011).

In Peru, the International Potato Center (CIP) has a genetic bank of varieties of potato, sweet potato and other Andean tubers. An important example of international collaboration is the work to determine the nearly 40,000 genes in the genome of the potato, the world's fourth most important food crop after soybeans, rice and corn. Scientists from 14 countries including Peru are currently working together to achieve this. They have set up a unique cooperation mechanism among countries in Latin America and the Caribbean, and Spain, which promotes family farming innovation, competitiveness and food security.

Peru has a number of geoservers in the Geographic Information System located in various ministries and institutes such as MINAGRI, MINAM, ANA, and MINSA that are available to the public at www.google.es/maps

One of the policy guidelines of MINAGRI's General Directorate of Agricultural Information (DGIA) is to strengthen and decentralize the National Agricultural Information System (SINFA) to support economic agents in making decisions on production and trade issues. SINFA contains agricultural and agro-industrial statistics on supplies and prices, agroclimatic issues, foreign trade and inputs.

b. Universities and Research Institutes

In Peru, there are several institutions dedicated to agricultural research, and socionutritional and health impact. These include, among others, the La Molina Agrarian University (Lima), the Daniel Alcides Carrión National University (Pasco), the National University of the Altiplano (Puno), the National University of the Amazon (Iquitos), the Pontifical Catholic University of Peru (Lima), the Ricardo Palma University (Lima) and the Cayetano Heredia Peruvian University (Lima), each dedicated to a specific task while maintaining interdisciplinarity.

In addition to the aforementioned CIP, INIA, IIAP in the forest and the Peruvian Sea Institute (IMARPE), a Ministry of Production agency oriented toward scientific research, the study and knowledge of the Peruvian sea and its resources, advises the state on decision-making regarding the rational use of fishery resources and the conservation of the marine environment.

Agrarian policy significantly changed during the first half of 2000, introducing the value chain approach and emphasizing technological innovation as a means of improving competitiveness (Rendón Schneir, 2010). However, although there are capacities with a critical mass at the country's universities and research institutes, a vision of multidisciplinary work among the science of agricultural crops, the science of postharvest, the functional activity of the product to be consumed by humans and marketing has yet to be achieved. Nevertheless, the La Molina Agrarian University has several research institutes: the Institute for Agroindustrial Development (INDDA); the Institute for Biotechnology (IBT); the Institute for Sustainable Small-Scale Production (IPPS); the Regional Development Institute of the Costa (IRD) and the Regional Institute for Forest Development (IRD).

The National University of San Marcos contains the Antonio Raimondi Institute of Biological Sciences Research (ICBAR), whose function is to produce scientific knowledge on biodiversity, biotechnology, ecology, health, biological resource management and the environment. The Natural History Museum has branches in IVITA-Pucallpa and IVITA-Iquitos. The Ricardo Palma University houses the Institute of Science and Technology (ICT), which studies biodiversity using classical taxonomy and molecular genetics. The Natural History Museum is dedicated to the knowledge and conservation of biological diversity as a key aspect that must be developed in our country. At the Pontifical Catholic University of Peru, the Institute of Natural Sciences, Planning and Renewable Energy (INTE) is an institute for research, academic training and the socioenvironmental and ecological promotion of biodiversity, territory and renewable energies. The Center for Research in Applied Geography (CIGA-PUCP) has several research groups on water, energy and food security, sustainable cities and rural development. Cayetano Heredia University houses the Institute of Tropical Medicine, the Institute of Height and the Laboratories of Marine Sciences where analyses of interstitial water are conducted on marine sediments, phytoplankton, sediments (organic matter) in coastal marine areas, siliceous remains in sediment, benthic foraminifera and oceanographic data.

Although Peru is one of the most economically developed countries in Latin America (OECD, 2016), the challenge for the future is to add value to its products. This requires skilled labor, which in turn is reflected in the increase in agricultural exports by large companies, particularly on the coast.

The problem is exacerbated in rural zones and subsistence farming, where farmers have less training. The creation of agricultural institutes near farming areas, particularly in the mountains and forests of Peru, will contribute to the training of skilled labor.

c. Relative contributions of the public and private sectors

Although state entities such as CONCYTEC, FONDECYT and INNOVATE PERU promote investment in Research and Technological Development (&D), public and private participation is still low.

In 2016, Peru invested 5 billion soles ($1.5 billion USD) in research and development, representing 0.2% of Peru's GDP. Only 24.6% of this amount was assigned to research in agricultural sciences. These aspects are indicative of the fact that a great deal of research remains to be done on the production and improvement of the nutritional content of native agricultural and aquacultural products from the coast, highlands and forest. Despite all this investment, it is still insufficient because there is much to study, many puzzles to solve and many species that have yet to be registered in Peru. National inventories of flora and fauna from the coast, highlands and forest must be drawn up to have a basis of taxonomic identification and undertake molecular studies of genomics, proteomics and metabomics. Moreover, scientific production on biodiversity is carried out at several national and private universities, such as UNMSM, UALM, UPCH, PUCP, URP and UFV.

d. Outlook for the future

Since 2013, there has been a significant increase in the budget for R&D from the National Council for Science, Technology and Technological Innovation (CONCYTEC).

In 2016, the System of Support for Research was incorporated, whereby companies can deduct up to 175% in income tax for their contribution to Research, Technological Development and Innovation (R-D-I). CONCYTEC designs the National Programs for Environmental Science and Technology and the Valuation of Biodiversity, which prioritize the research areas to be strengthened, as well as those in the area of "Climate variability and climate change," which is aligned with the Agenda for Environmental Research (MINAM, 2016). It is also important to protect and preserve human diversity with our ethnic groups, whose genome has scarcely been studied, and to promote respect for indigenous peoples. It is hoped that these efforts will improve food security in the coming years. More investment is required for the protection, conservation and management of biodiversity to ensure the conservation of genetic diversity, ecosystems and species.

It is important to place greater emphasis on biodiversity studies at centers of excellence such as universities and institutes. These institutions have produced key publications and scientific articles in scientific journals with enormous amounts of information on biodiversity, the basis of food security.

3. Resources and Characteristics of Ecosystems

a. Water resources and challenges for the next 50 years

Peru's average annual volume of water of 1,768,172 Million Cubic Meters (MCM) makes it one of the world's 20 richest countries in water. Its average annual runoff, representing nearly 5% of global runoff, makes it the country with the greatest freshwater availability per capita in Latin America. In other words, every Peruvian has 64,000 cubic meters of water per year. However, the natural distribution of this vital resource is asymmetric: 97.7% on the Atlantic slope (Amazon basin); 1.8% on the Pacific slope (53 basins), and 0.5% in Titicaca. These constraints are caused by the fact that the population is distributed in an inversely asymmetrical way to resources: 70% of the population is concentrated where 1.8% of the available surface water is located and 26% where 97.7% of water is found (Bernex, 2010; ANA, 2012).

There is also an imbalance in the distribution of water between productive sectors and the user population: the agricultural sector accounts for 86.8% of water use nationwide, followed by the population, which utilizes 11.2%, mining, which absorbs 1.4% and industry, which employs 0.6% (ANA, 2013).

b. Soil resources and challenges for the next 50 years

Soil suitable for agriculture is the country's scarcest resource (7% of the country), as well as that most threatened by deterioration processes, especially salinization on the coast, gradual erosion in the mountains and loss of fertility in Amazonia. A total of 8 million ha have been classified as severely eroded and 31 million as moderately eroded (MINAGRI, 2017). Despite these severe constraints, efforts have been made to recover degraded soils on the coast and in the highlands and forest to ensure food security. Even if the current scenario indicates a reduction in lands planted for human consumption and an increase in those for the production of manufactured goods (MINAGRI/CONSAM, 2013), it is essential to achieve integrated soil management in order to obtain agriculture resistant to climate change using a food and nutritional security approach (IICA, 2016; CEPES, 2011).

c. Energy challenges

The growing economic, social and environmental pressure on water, energy and food systems increases and highlights the various interdependencies and conflicts among these sectors, reminding one that the modernization of irrigation can save water while at the same time increasing energy consumption and threatening the sustainability of aquifers. Biofuel production can reduce oil dependence yet affects food production, making it more expensive. Likewise, lowered energy prices can increase agricultural production as well as leading to the overexploitation of aquifers (Jouralev, 2016). While it is true that in Peru, electricity production recorded sustained growth at an annual rate of 6.5% over the past decade (MINAM, 2016), at times of water shortage, it competes with the human population's use (INEI, 2015), even though energy production by thermal power plants increased by 12% and contributed 50% of all electricity production. Moreover, nationwide generating capacity increased by an average annual rate of 7% from 6,200 MW in 2005 to 12.251 MW in 2015. Regarding unconventional Renewable Energy Resources, 96 MW of solar power, 240 MW of wind power and 80 MW of thermal energy have been installed (MINAM, 2016). Nevertheless, there is an enormous disparity between backward rural zones and urban areas. Peru has large natural gas reserves constituting a major source of thermal energy. It is estimated that in 2013, they totaled 875,733 million barrels (INEI, 2015), with a proven reserve of 16 Trillion Cubic Feet (TCF), guaranteeing a 15-year supply for national consumption and export.

d. Conflicts and challenges of biodiversity

Together with Chile, Peru is the only country in the region with extensive, extremely arid -hyperarid- areas (81,000 square kilometers) receiving only 2% of the country's rainfall (MINAM, 2016). According to lNEl (2013), the five main reasons why agricultural land is not worked were (a) lack of water (48.9%), (b) lack of credit (24.1%), (c) lack of labor (11.3%), (d) erosion, salinity and poor drainage (5%), and (e) lack of seed (4.2%) (lNEl, 2012), which affect the coast, mountains and forest.

Although Peru has an extensive coastline and abundant maritime resources, industrial and artisanal overfishing is a constant. This particularly affects anchovies, the most economically important marine resource. In 2014, the Supreme Decree No. 005-2012-PRODUCE reorganized anchovy fishing and established new fishing areas, which led to a 41.9% reduction in the catch quota in comparison with 2013 (INEI, 2015). Another species controlled by the ban is the river shrimp. The Peruvian Sea Institute has undertaken wide-ranging studies to protect the populations of seagrass meadows that are mega-diverse ecosystems.

The national economy relies heavily on biodiversity, both in relation to agricultural production (65.0%), fishing (99.0%), cattle (95.0%) and forestry (99.0%) (INEI, 2015). Although Peru is one of the world centers of genetic reserves of wild species and biodiversity, a diversity that is unlikely to disappear in the short term, a depletion of genetic diversity due to human actions has been observed. It is therefore essential to draw up inventories and preserve the wild relatives of cultivated plant species, which represent reservoirs of genetic resources that promote food security (Tapia, 1993).

Peru is a land of forests. A total of 57.3% of its territory is covered by this resource and by 2014 there were only 16.8 million ha of permanent production forests, 4.3 million ha of which are under management plans (MINAGRI, 2015). However, between 2001 and 2014 1,653,255 ha of Amazon forest were lost in Peru, with a record average of 118,089 ha/year (Forest Program, 2015). Eighty-five percent of deforestation occurs because of the change in land use to family farming and small-scale farming, and although reforestation programs have been generated, the process is slow. By 2014, only 8,990 ha (INEI, 2015) had been replanted.

e. Potential impacts of climate change

Not only do the effects of climate change impact biophysical resources (water, soil, glaciers, vegetation) (CONSAM, 2013), they also entail concrete losses for the agricultural sector (decreased potato production on the coast and mountains, loss of agricultural land and soil salinization, reservoir silting and the destruction of productive infrastructure). High temperatures also lead to low meat and milk production, and the migration of marine and coastal fish (MINAM, 2016).

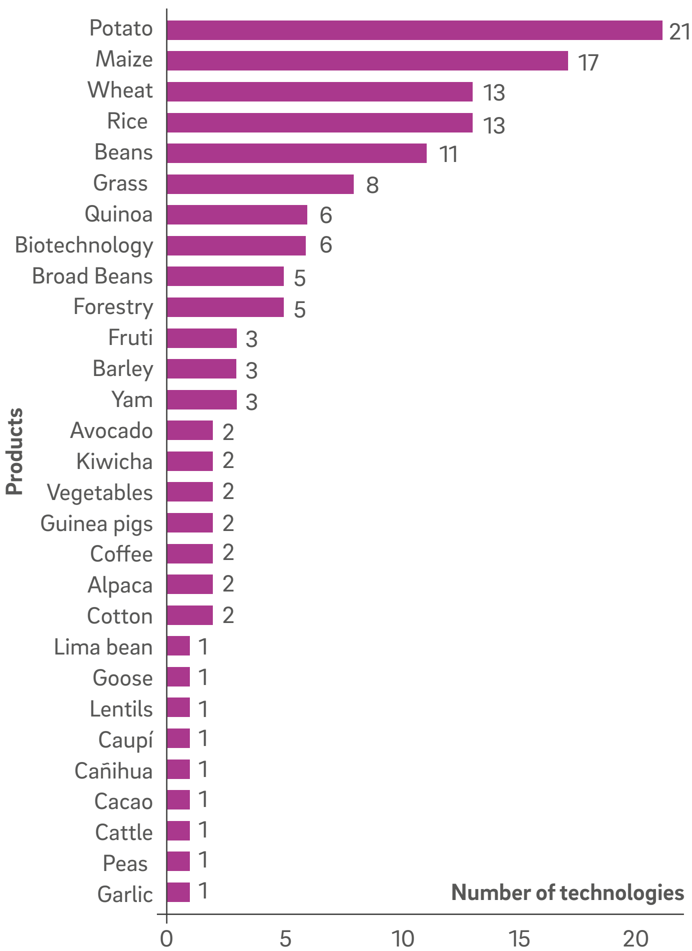
f. Building resilience to extreme events

In 2015, drawing up a map of Vulnerability to Food Insecurity, due to the recurrence of natural phenomena, identified areas where the population finds it harder to obtain food under these circumstances. Thus, of a total of 36,606 population centers with 50 or more persons each, approximately 25,700 (70%), in other words, a population of 4.35 million, are in predominantly rural areas with high or very high vulnerability to food insecurity (PMA and CENEPRED, 2015). The Central Government thereby hopes to improve intervention strategies through programs and projects that will reduce vulnerability, promote food security and nutrition and, at the same time teach citizens to deal with the various contingencies caused by these phenomena by creating interventions that boost the resilience of communities and ecosystems to current climate variability. Over the past six years, over 330 mitigation/adaptation-to-climate-change programs and project actions have been implemented (MINAM, 2016). However, rains and flooding in the north and center of the country in early 2017 showed that these systems remain fragile.

g. Outlook for the future

Peru's main challenge is to achieve sustainable development for people, the planet and prosperity (Agenda 2030) and to promote the adoption of a resilience-to-climate-change approach (MINAM, 2016). The investment gap to achieve these goals is enormous. The current scenario justifies the urgent need to design programs to identify, describe and characterize biodiversity as soon as possible so that appropriate conservation and mitigation measures can be implemented. It is essential to emphasize the importance of using modern techniques in the study model of integrative taxonomy, including the study of the evolutionary processes associated with areas with greater diversity and endemism and the effects of climate change on Peruvian biodiversity (Von May et al., 2012).

Figure 6. INIA. Technologies released by product during the 1991-2011 period



Source: Compiled by Nicole Bernex.

4. Technology and Innovation

According to the assessment of the Technology Transfer Index (ranging from +2 to -2), countries with the greatest technology transfer are those in East Asia (+0.8), followed by industrialized countries (+0.4). Conversely, Latin American countries, including Peru (-0.3), have a technology transfer deficit (CONSAM, 2013) that must be reversed.

a. Role of biotechnology

Worldwide, nearly two billion people lack food security. By 2050, the demand for food will have increased by 70% (FAO, 2009). Biotechnology has been used since ancient times. A clear example is the preparation of Chicha de Jora (Peruvian Corn Beer), the recipe for which was handed down from generation to generation without people's realizing it was a biotechnological process. The year 1960 saw the Green Revolution, characterized by an increase in the productivity of varieties of staple crops and the introduction of methods for analyzing genetic sequences and the identification of genetic markers. The use of recombinant DNA makes it possible to identify, select and modify DNA sequences to accomplish specific genetic characteristics (WHO, 2005).

In Peru, academic institutions, together with the International Center for Tropical Agriculture (CIAT) and international organizations, developed a type of weevil-resistant bean (*Zabrotes subfasciatus Boheman* and *Acanthoscelides obtectus Say*), and tubers such as sweet potato resistant to the nematode *Meloidogyne incognita*, with higher nutritional content in two native varieties. Progress has been made in the production of maize with twice the concentration of lysine and tryptophan, together with improvements in the production and nutritional value of rice under different water availability conditions (UNALM/AGROBANCO, 2014: 8-11).

INIA develops and transfers quinoa seeds tolerant to adverse climatic factors, with higher performance and improved grain quality, which are suitable for agroindustrial processing and resistant to diseases and pests. It has also developed the production of genetic garlic, potato and virus-free vine seeds, improving their potential yield (MINAGRI/INIA, 2009; 2012a; 2014b). It works on the agricultural innovation of plant genetic resources, Andean crops, fruit, vegetables, maize, avocado, roots and tubers (MINAGRI/INIA. 2012a).

Among its technology transfer activities, INIA has released 137 technologies, 106 of which correspond to improved cultivars, 23 to management technologies, six to biotechnology protocols and two to genetic compounds (**Figure 6**) (MINAGRI/INIA, 2012a).

INIA undertakes animal husbandry activities such as embryo transfer, *in vitro* fertilization, insemination, animal health, and the genetic improvement of tropical cattle, High Andean cattle, camelids and guinea pigs (MINAGRI/INIA, 2011a; 2011b; 2012b). Despite this, building new biotechnological capacities remains an urgent pending issue for the country.

SENASA is the authority responsible for the control and management of pests and diseases in the most economically important crops and livestock. It ensures the safety of food for human consumption and domestic or foreign production (SENASA, 2016).

Intervention strategies, begun in 2006, have enabled Peru to have fruit fly-free zones and be 100% free of Foot and Mouth Disease (FMD) without vaccination, producing savings in the cultivation and breeding processes. There are over 1,000 identified pests and diseases that should not enter Peru. Of this total, 947 are plant pests such as the Guatemalan potato moth, which, if allowed to enter, would affect more than 400,000 ha of crops, damaging up to 80% of production (SENASA, 2014; 2017).

The application of biological control has reduced losses in agricultural production as a result of pests in crops such as sugar cane, citrus fruit, bananas, coffee and various fruits and vegetables by using biological control (SENASA, 2014).

IMARPE analyzes the composition and abundance of zooplankton associated with water bodies, in order to extend the patterns and variability of their distribution and abundance, thereby providing food for other trophic levels. It monitors the presence of biological zooplankton indicators associated with the water mass.

b. Outlook for new agricultural products

In Peru, INIA is the main agency dedicated to the development of new plant varieties resistant to adverse factors and with higher yield. Another important institution in the research of new plant varieties is the La Molina Agrarian University, which has developed nationally important varieties. As mentioned earlier, it has research laboratories in different institutions.

The International Potato Center collaborates with INIA, the La Molina National Agrarian University and other universities to undertake research to obtain new varieties of agricultural interest.

c. Opportunities and obstacles to the management of new technologies (e.g., irrigation and water or fertilizer management)

Peru generally uses imported fertilizers. In 1993, it imported 303,807 t and in 2013, it imported 905,198 t, with urea being the most commonly used fertilizer in 2013 (365,085 t). The organic fertilizers it uses include worm humus, chicken manure and island guano. Peru produced 19,700 tons of island guano in 2012 and 23,604 t in 2013. In 2012, of the total of 2,213,500 agricultural units, 833,600 used chemical insecticides, 118,800 non chemical or biological insecticides, 521,200 herbicides and 600,000 fungicides (INEI, 2015).

There is a water transfer system that provides water for certain areas for the benefit of agriculture, although it is a source of conflict among populations. Peru has 14 water dams on the north coast, most of which are used for agriculture. Where there is no storage infrastructure, groundwater is exploited, as in the valleys of Ica-Villacurí, Caplina, Chilca, Motupe and Asia (ANA, 2012).

d. Development of aquaculture/ marine resources

Fishing activity can involve both extraction and transformation. There are two types of fishing: artisanal, for direct consumption, and industrial, which transforms products into preserves and fishmeal. Both pose a threat to the sector's sustainability due to overfishing.

In 2013, 5,949,000 metric tons of hydrobiological resources were caught, 23.9% more than in 2012. Anchovy accounted for 79.9%, while the remaining species included horse mackerel, mahi mahi, mackerel and bonito (INEI, 2015).

Trout, from the family of salmonids, is raised at fish farms in the Peruvian highlands and is an important protein source for High Andean populations. It is found in Ayacucho, Huanuco, Pasco, Lima, Aréquipa and the Amazon. In Lake Titicaca, the introduction of silver smelt from Argentina and rainbow trout has had a negative impact on native species. In the forest, there are fish farms that breed paiche (*Arapaima gigas* Cuvier), an emblematic fish from the Amazon measuring an average of 2.5 m and weighing 250 kg.

Mechanisms have been set in place to preserve species for the mass consumer market such as anchovy, hake and shrimp, among others.

5. Increased efficiency of food systems

a. Outlook for increased technology-based agricultural production

In 2010 and 2011, less than 1% of the country's farmers received information on the existence and importance of the use of new agricultural technologies. Moreover, the percentage of farmers nationwide who received technical assistance on the proper use of agricultural input was 3.8% between 2008 and 2010 and 2.6% between 2009 and 2011 (MINAGRI/COMSAN, 2013). This obviously delays the optimization of agricultural processes designed to increase productivity.

Limited access to financing by small and medium farmers and artisanal fishermen constitutes an obstacle to increasing the efficiency of food production (MINAGRI/COMSAN, 2013). The only type of agriculture that has increased its production through the use of modern technologies is run by business groups located on the coast.

b. Infrastructure needs (e.g., transport systems)

The national road network comprises a total of 156,792 km, an increase of over 78,000 km since 2000. Railways, however, are less extensive and have been reduced over the years. In the Amazon region, most of the population uses river transport for its various activities (MINAM, 2016).

According to Webb (2012), the road network over the past 50 years has increased by 372%. The highway construction boom began in 2000. However, it is not yet an efficient, integrated system that meets all the requirements. In 2012, the five provinces with greatest road length are Cusco, Puno, Arequipa, Ancash and Cajamarca. Conversely, the province with least road length is Loreto, the largest province in Peru (MINAGRI/CONSAM, 2013).

c. How to ensure food use with minimal losses

By 2015, it is estimated that 2.3 million people in Peru were food insecure. According to the FAO, food wastage amounts to seven million t per year. Peru has committed to halving food waste per capita by 2030, particularly at the retail and consumer level. It is estimated that Peru annually loses more than 500 million soles (US $151.5 million) in food at supermarkets.

To minimize food loss, the civil society created the Food Bank of Peru (BAP) in 2014. The BAP receives foods from private companies that cannot be marketed for various reasons yet are still useful. They are delivered to places such as schools, shelters and soup kitchens. On August 2, 2016, the law promoting food donation was passed.

d. Conflicts between food production and energy and fiber production

One reason why the area planted with crops for direct human consumption has not increased in line with demand has been the expansion of other crops (asparagus, sugar cane, peppers, paprika, grapes, coffee and cocoa) for agroindustry and agro-exports. This causes problems in the continued growth of crops for direct feeding (MINAGRI/CONSAM, 2013). There is also an obvious risk of affecting food security in the event that farmland is used for agrofuel production rather than crops for human consumption. To prevent this situation, FAO promoted the Bioenergy and Food Security Project (BEFS), which analyzed the way the development of bioenergy can become a tool for increasing productivity in the agricultural sector without compromising food security (García, 2010).

6. Health Considerations

Food has implications for health, either directly through its components or indirectly, since it carries chemicals and/or microorganisms that may damage health.

a. Foodborne diseases

Food can indirectly affect people's health. The use of pesticides to preserve agricultural crops and irrigation with sewage or contaminated water can influence the health of those who consume these foods.

Pesticides

Many plant foods are treated with pesticides in order to maintain crops and increase their yield. These pesticides are impregnated in food and may be consumed by people or livestock, which are then used for human consumption, or may contaminate water and expose the human population to risk. Organophosphorus pesticide applicators in Majes (Aréquipa) were found to have lower-quality seminal fluid, which constitutes an occupational health problem (Yucra et al., 2006). Acaricide, fungicide and herbicide exports increased between 2007 and 2013 (INEI, 2015), significantly increasing health risks, since protective measures have not improved.

Heavy metals

Since Peru is a mining country, part of the population is exposed to contamination by heavy metals. Water is the main vehicle, in that it is used both for crop irrigation and postharvest processing, washing vegetables prior to their sale at consumer markets or consumption by livestock, which are then consumed by humans.

There are areas such as southern Peru where metals such as arsenic (As) are naturally present in river water or underground aquifers (geogenic origin) (George et al., 2014). Although arsenic pollution is associated with health problems, there is no research to suggest that the speciation of arsenic in southern Peru is associated with diseases prevalent in the area (Schlebusch et al., 2015).

Parasites

Parasitosis is still a problem in Peru, particularly in the mountains, forest and marginal areas of the urban coast. The presence of parasites has been reported in the consumption of contaminated food, such as fasciolasis in alfalfa juice (Mark et al., 2006). Liver fluke infections are common in High Andean regions (Cajamarca and Cusco) (Rinaldi et al., 2012; Cabada et al., 2014), in both humans and cattle (Cabada et al., 2014). In general, children with moderate to severe infections with helminths suffer from chronic malnutrition (Gyorkos et al., 2011), hence the importance of deworming programs for children in highly endemic areas.

Pork tapeworm infections require health interventions in both humans and livestock. Vaccinating and treating sick livestock in endemic areas has proven to prevent the transmission of infection (García et al., 2016).

Mycotoxins

Mycotoxins are produced by fungi and can infest food. The presence of mycotoxins such as ochratoxins has been associated with gallbladder cancer. These mycotoxins are present in grains and in the Andes region, they have been found in red peppers (Ikoma et al., 2015).

b. Overconsumption

In Peru, as in other countries, the improvement of the economy and the implementation of programs to reduce child malnutrition have increased childhood overweight and obesity rates. This is exacerbated by the extensive advertising of high calorie foods such as sugary soft drinks and fast food, decreased physical activity, fewer hours of sleep and inactivity associated with the number of hours in front of the television or computer (Poskitt, 2009). Similarly, the increase in household expenditure, based on recent economic growth, has driven up the consumption of foods of animal origin (Humphries et al., 2014).

Childhood overweight and obesity are predominant on the Peruvian coast and in urban areas. A spatial analysis found a higher prevalence of overweight in 199 districts (126 urban and 73 rural) and of obesity in 184 districts (136 urban and 48 rural) (Hernández-Vásquez et al., 2016). The risk of obesity is also high in adult populations in urban areas and higher in migrants from rural to urban zones (Antiporta et al., 2016). Peru has a 61.86 prevalence rate of overweight/malnutrition (Méndez et al., 2005). Feeding programs have helped reduce malnutrition in Peru since 2005 (Pérez-Lu et. et al., 2016). However, these programs should specifically target people in need, since adult women who participate in these programs are at an increased risk of overweight and obesity if they live in households without poverty indicators (Chaparro et al., 2014; Carrillo-Larco et al., 2016).

c. Expected changes in consumption patterns (and implications for food imports)

According to the FAO, approximately 7,000 of the world's plants have been domesticated for food purposes, but food security is based on 30 crops that provide 95% of the calories in a person's diet. Wheat, rice and maize provide more than 50% of the calories consumed by Peruvians (Salaverry, 2012).

Pattern of food consumption on the Peruvian coast

In ancient Peru, the coast was interspersed with valleys with extensive hills, where large herds of camelids were bred and wildlife proliferated. This area was devastated by the introduction of sheep and goats, coupled with overgrazing, which created arid soils and the growth of low, sparse vegetation (Antúnez de Mayolo, 1981). The ancient inhabitants' diet was more than balanced by the consumption of marine species such as fish, shellfish and sea lions.

This eating pattern subsequently evolved, with increasing dependence on imported food such as wheat, sugar, vegetable oil and dairy products, and the progressive decline of products of vegetal and indigenous origin (FAO, 2000). At the same time, food resulting from social policies was incorporated (World Bank, 2007). Franchises were opened, leading to an increase in fast food consumption from 12% in 2001 to 35% in 2015 (Arbaiza, 2014) and a greater tendency to eat outside the home (Arbaiza, 2014; PAHO, 2015).

Five traditional products have been identified in the family budget: milk; bread; chicken; egg and rice (IEP, 2010), coupled with non-traditional food (olives, mango, sugar cane, paprika, avocado, hard yellow maize, coffee and asparagus) (MINAGRI, 2014; 2015). Currently, consumption is mostly based on carbohydrate, fat and lower fiber intake with a slightly lower average intake of vegetables (INEI, 2014; 2015a).

Consumption pattern in the Peruvian highlands

The Andean people enjoyed a wide variety of foods domesticated thousands of years ago, such as quinoa (*Chenopodium quinoa*), one of the first plants with crops in an extremely effective terrace system, which currently does not equal the area under cultivation in ancient Peru (Salaverry, 2012). The food pattern was vegetarian, based on maize, quinoa, kañiwa, beans, potatoes and mashua, occasionally supplemented by fish from lakes and rivers, hunting birds and camelids such as llamas and alpaca. They processed camelids' meat as jerky (dried, salted meat) (Cieza de León, 1995), eating up to four meals a day.

The Peruvian Andes currently practices eating habits associated with the production and consumption of local animals, such as alpaca meat and beef, dried meat and animal offal. The consumption of Andean foods such as olluco and quinoa predominates during the harvest season, in a variety of traditional dishes, including potato, maize and Andeanized crops (bean, barley) as additional ingredients (Tapia, 2000; 2007). Food consumption patterns in the urban highlands have been modified by the increasing introduction of non-native foods.

Before 2000, 46% of households had access to one or more food-aid programs (INEI, 2000). This probably explains the progressive decline of local products, which, together with the entry of fast food franchises in the 1990s (Arbaiza, 2014) modified eating patterns (MINSA, 2006).

Consumption pattern in the Peruvian forest

Little is known about current consumption patterns in the forest. Native communities base their diet on cassava (95.1%) and bananas (98%), supplemented by the consumption of rice, eggs, worms, fish (carachama) and certain vegetables, with considerable consumption of carbohydrates. The bulk of the food budget is spent on fish, poultry and rice (Huaman and Valladares, 2006). Caloric deficiency in the forest is 23.1% as opposed to 33% in Lima. Poor fat intake in the forest is lower (53.7%) than on the coast (74.2%) and urban highlands (71.8%). A total of 33.1% of the country's inhabitants have poor animal protein intake and have vitamin A and iron deficiency (MOH/INS/CENAN, 2012).

Caloric intake has risen from 1,980 kcal in 1983 (Parillón et al., 1983) to 2,100 in 2016. Current diets consist mainly of carbohydrates coupled with fried foods and industrial meat byproducts (Caballero and Gonzales, 2016a). There is a growing tendency to eat outside the home, accounting for 32.4% of food spending, slightly less than in coastal and highland areas (INEI, 2014).

Direct effect of food on health

By contributing primary metabolites such as carbohydrates, lipids, proteins, vitamins and minerals, food has a direct effect on human beings' growth, development and health. Deficient food intake produces chronic malnutrition, iron deficiency and anemia, together with a deficiency of other micronutrients such as iodine, vitamin A and folic acid.

Mountain and forest populations are sensitive to iodine deficiency and have shown a high rate of endemic goiter for years. The Ministry of Health's programs have eradicated iodine deficiency and endemic goiter through salt iodization (Pretell et al., 2017).

In the case of folic acid, although the World Health Organization (WHO) recommends consuming 2.6 mg/kg of fortified wheat flour, Peruvian law recommends less than half this (1.2 mg/kg). This generates a neural tube defect rate of 18.4/10,000 (Ricks et al., 2012), which would be reduced by a change in the Peruvian legislation.

Anemia in children <6 years in Peru is regarded as a moderate public health problem and as a slight public health problem in expectant mothers (Mújica-Coopman et al., 2015). A study of 7,513 infants <6 months of age from 25 regions of Peru reported a prevalence of 10.2% for anemia (Gómez-Guizado and Munares-García, 2014), whereas in adults, there is a 17.1% prevalence of mild anemia, a 5.7% prevalence of moderate anemia and a 0.5% prevalence of severe anemia (Tarqui-Mamani et al., 2015).

Various studies report greater anemia rates at high altitudes than in coastal or forest areas, possibly because in the former, the cutoff point for defining anemia is corrected since hemoglobin increases at higher altitudes. Some studies suggest that hemoglobin should not be corrected in higher areas (Gonzales et al., 2014b).

Vitamin A deficiency (<20 µg/dl) is a public health problem with 11.7% prevalence in children, which increases in children under 5 months and in those living in rural areas and the forest (Pajuelo et al., 2015).

Various governments have implemented a range of maternal and child health policies. Although there is still room for improvement, Peru ranks first among 75 low- and middle-income countries in reducing neonatal mortality, and second in reducing mortality in children under 5. The decrease in the prevalence of chronic malnutrition and equity in the use of health care and health outcomes have significantly improved (Cotlear and Vermeersch, 2016).

In the 2000-2011 period, chronic malnutrition was reduced from 31.6% to 19.6%, acute malnutrition from 1.1% to 0.4% and anemia from 50.4% to 30.7% (Sobrino et al., 2014). However, chronic malnutrition is three times higher in rural than urban areas, affecting extremely poor children under 5 to a greater extent (MOH/INS/CENAN, 2015; Urke et al., 2014) and indigenous populations more than non-indigenous ones (56.2 vs. 21.9%) (Díaz et al., 2015).

Peru has seen changes in the population's nutritional status, with improvements in birth weight, resulting in an increase in normal weight in newborns from 74.6% between 2004 and 2006 to 92.5% in 2015, a situation that it is similar on the coast, highlands and jungle (**Table 6**). Furthermore, 14.9% of infants suffer from chronic malnutrition, while 7.3% are overweight, and 1.52% suffers from obesity (Apaza, 2014; Hernández, 2016; 2016b). A total of 32.4% of young people are overweight and 12.6% obese. In adults, the situation is more critical, since 46.1% are overweight and 23.8% obese (MINSA/INS/CENAN, 2015).

7. Political considerations

Reports published in late 2013 show that state subsidies for major projects have failed to achieve a significant impact on domestic agriculture, despite investments in irrigation mega-projects on the coast, privatized since 1990. The income earned by the state from the sale of new lands and other goods and services barely covered 7% of the public investment in these projects, meaning that the remaining 93% was provided by a state subsidy.

The agro-export sector would be the main taxpayer in the agricultural sector. However, the impact of taxation of this sector from 1998 to 2012 never exceeded 0.73% of the total collected in the country, which, in combination with the sugar subsector, barely reached 1%. This marginal contribution to Peruvian tax collection fails to reflect the importance of agriculture in GDP (Eguren, 2014).

Since 2000, in an attempt to meet the Millennium Development Goals, Peru implemented a number of social policy instruments for reducing poverty and achieving water, food and nutrition security. Thus, in 2012, the population's food and nutritional security was declared to be of national interest and a public need. Accordingly, the permanent Multisectoral Commission on Food Security and Nutrition attached to MINAGRI (Supreme Decree No. 102-2012-PCM) was created. Aware that the central problem is that the population does not permanently satisfy its nutritional requirements, the Commission undertook a diagnosis to recognize the causes and effects of this situation (MINAGRI, 2013). **Figure 7** shows the central government's concern and continuing effort in this direction.

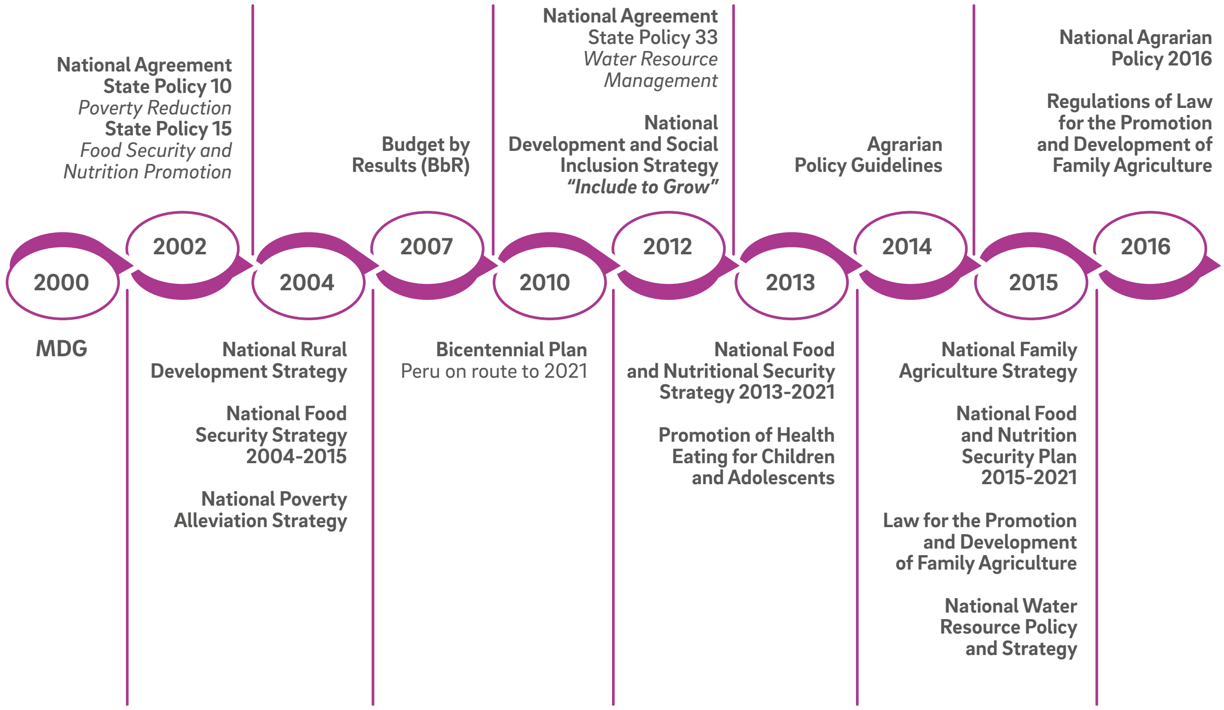
Meanwhile, realizing the challenges posed by food and nutrition security and in order to mitigate the degradation of biodiversity and the negative impact of climate change, Peru has incorporated the issue of risk management

Table 6. Percentage of births with adequate birth weight (≥2.5 Kg), by geographical area. 2004-2015

Years	Peru	Lima	Rest of coast	Mountains	Rain forest	Urban	Rural
2004-2006**a**	74.6	92.2	81.3	65.9	62.6	87.7	87.7
2007-2008**b**	79.5	92.7	83.8	72.5	74.2	89	89
2009**c**	83.2	93.9	89.3	77.2	73.0	89.8	89.8
2010**d**	82.8	92.5	88.1	77.6	73.1	89.6	89.6
2011**e**	84.9	93	89.4	80.7	75.0	91.1	91.1
2012**f**	86.2	93.1	89.9	81.2	81.8	90.7	77.7
2013**g**	85.9	92.8	88.6	81.5	79.0	90.4	76.3
2014**h**	87.6	94.4	90.3	84.1	78.6	91.9	77.3
2015**i**	92.5	93.2	93.1	91.3	92.0	92.7	91.9

Source: aINEI. ENDES. 2004-2006. bINEI. ENDES. 2007-2008. cINEI. ENDES. 2009. dINEI. ENDES. 2010. eINEI. ENDES. 2011. fINEI. ENDES. 2012. gINEI. ENDES. 2013. hINEI. ENDES. 2014. iINEI. ENDES. 2015.

Figure 7. Time line of Social Policy Instruments



Source: Compiled by Nicole Bernex.

through the passage of the National Disaster Risk Management Law. The following plans are currently being implemented:

- National Action Plan for the Conservation of Coastal and Marine Biodiversity in Peru (RM N° 039-2006-PCM).
- National Plan for Prevention and Attention to Disasters (DS No. 001-A-2004-DE/SG), comprising six strategies related to estimation, prevention, reduction, development planning, institution building, disaster prevention and emergency response.
- National Environmental Action Plan 2010-2021 (PLANAA) (DS N° 014-2011-MINAM). Contains the main goals to be achieved in the next ten years and will contribute to conservation, sustainable use of natural resources, improving environmental quality and the population's quality of life.
- Action Plan for Climate Change Adaptation and Mitigation (RM N° 238-2010-MINAM). At the level of regional governments, it suggests incorporating and institutionalizing the DRM and CCA approach in planning processes for the preparation of studies and the mapping of regional vulnerability and watersheds to cope with the effects of climate change.
- Bicentennial National Plan (DS N° 054-2011-PCM). It considers two strategic guidelines: "Encourage the adoption of mitigation strategies and ACC by the three levels of government, based on studies and scientific research with a preventive approach" and "Encourage vulnerability reduction and disaster risk within the framework of sustainable development and adaptation to mitigate negative effects and take advantage of the opportunities generated by the positive impacts of FEN".

For a decade, Peru's public sector institutions have engaged in a cross-sectoral effort to facilitate intersectoral and complementary integrated management processes. They facilitated the development of policies for technological innovation, human resource training and the promotion of healthy food consumption.

Policies that encourage technological innovation
The 29811 Law, enacted in 2011, which declared a ten-year moratorium on the admission and production of modified live organisms into national territory p put the debate on genetically modified seeds on the agenda. This law was not the first to limit the use of transgenic seeds. Since 2007, most regional governments in Peru have declared their region "GMO-free". This was done by the governments of Áncash, Aráquipa, Ayacucho, Cajamarca, Cusco, Huancavelica, Huanuco, Junín, Lambayeque, Lima Metropolitana, Lima Region, Loreto, Madre de Dios, Puno and San Martín.

In Peru, policies have been implemented to improve the social indicators of poverty, education and health. Educational and inclusion policies have reduced illiteracy rates and promoted women's participation in the country's government and productive activities. Many gaps remain in education, however, including the transfer of new agricultural technologies and training people to use them.

Law 30021 for the Promotion of Healthy Eating for Children and Adolescents (2013) and its Guidelines (2015) seeks to reduce and eliminate the diseases associated with overweight, obesity and chronic non-communicable diseases.

Other laws, such as the Consumer Protection and Defense Code (Law 29571), enshrine the right to consume safe food and establish the obligation to include labels, showing the composition and trans fat content of foods and indicating whether they contain genetically modified components. The Food Safety Law (DL No. 1062, 2008) ensures the hygiene of food for human consumption throughout the food chain.

Peru also has assistance programs such as the National School Meal Program (Qali Warma), which has provided food service for children at the initial and elementary level of public educational institutions throughout the country since 2013. The National Glass of Milk Program (PVL) covers the child population aged 0-6 and pregnant and breastfeeding women with a daily allowance from the State. Other programs, such as the National Additional Cradle and Together Program, contribute to food security.

Its location, morphology, enormous biodiversity, diversity of climates, soils and sociodiversity create large relative advantages for the country, enabling the production of an extraordinary variety of food, which has benefitted the food industry. Since 2000, Peru has achieved a cumulative growth of 116% in its GDP, making it an attractive market for domestic and foreign investment. Agricultural production rose from 1.4% in 2014 to 3.5% in 2016 and the fishing sector grew from 17.2% in 2015 to 18.1% in 2016 (MRE, 2015). However, there are also growing risks. Free Trade Agreements (FTAs) have increased the risks of chronic diseases due to the increased availability of processed foods. During the period of pre- and post-FTA ratification in Peru, soft drink production increased by 122%. The consumption of carbonated sugar-sweetened beverages increased (Baker et al., 2016), affecting the population's health. The challenge for Peru in the short and medium term is to reduce its dependence on imported products, develop innovative products and position itself competitively in unexplored market niches. Thus, several small- and medium-sized Peruvian companies are developing so-called "*superfoods*" with a high nutritional value (quinoa, amaranth, kañihua, maca, purple maize, yacon, camu camu, aguaymanto, carob, cocoa and Sacha inchi).

VIII. Final remarks

Peru is one of the world centers of genetic reserves of species and biodiversity, meaning that it has a great capacity for food production. The country has undergone social and economic changes that have contributed to increasing life expectancy and decreasing birth and death rates. At the same time, it has seen an increase in chronic non-communicable diseases as a cause of death and of eating patterns having been modified. The current diet involves high consumption of carbohydrates, saturated and trans fats, with a low intake of omega-3 polyunsaturated fatty acids, vegetables, fruits, legumes, fish and dairy products. The infant population has high rates of obesity and chronic malnutrition.

a. Some potential national agricultural scenarios for agricultural production in the next fifty years

In Peru, food availability has grown steadily in recent years. This improves the supply of calories and protein for its inhabitants. According to MINAGRI, in 2007, every Peruvian had 403 kg of primary foods and 176 kg of foods derived from cereals, milk, oils and fats, reflecting an average increase of 3% per year, whereby each inhabitant obtained 3,043 kcal (COMSAN, 2013). This scenario could be improved however, since problems associated with an increased reliance on food imports, climate change, low access to water and overexploitation of land can affect food and nutrition security.

b. High-priority actions to achieve agricultural sustainability

Efforts must be made to promote producer associations; develop technological institutes near to agricultural areas; provide technology training to producers to optimize their production; continue to develop climate change adaptation and mitigation programs; strengthen legislation on the development of modern biotechnology; and develop stronger legislation for the protection of biodiversity and reforestation.

References

Abderrahim F, Huanatico E, Segura R, Arribas S, González MC, Condezo-Hoyos L. (September 2015). Physical features, phenolic compounds, betalains and total antioxidant capacity of coloured quinoa seeds (Chenopodium quinoa Willd.) from Peruvian Altiplano. Food Chem., 183: 83-90.

Apaza D, Celestino S, Tantaleán K, Herrera M, Alarcón E, Gutiérrez C. (2014). Sobrepeso, Obesidad y la Coexistencia de Desnutrición Crónica en Niños menores de 5 años. Rev. Peru. Epidemiol., 18(2):E05.

Apaza, V. (2010). Manejo y mejoramiento de Kañiwa. Convenio Instituto Nacional de Innovación Agraria INIA-Puno, Centro de investigación de Recursos Naturales y Medio Ambiente –CIRNMA, Biodiversity International Fund for Agricultural Development-IFAD. Puno, Perú. 76 pp.

Anticona C, San Sebastián M. (2014). Anemia and malnutrition in indigenous children and adolescents on the Peruvian Amazon in a context of lead exposure: a cross-sectional study. Glob Health Action, 7:22888. Doi.org/10.3402/gha.v7.22888

Antiporta DA, Smeeth L, Gilman RH, Miranda JJ. (2016). Length of urban residence and obesity among within-country rural-to-urban Andean migrants. Public Health Nutr, 19:1270-1278.

Antúnez de Mayolo E. (1981).La Nutrición en el Antiguo Perú. Lima, Perú, Fondo Editorial Banco Central de Reserva del Perú.

Arbaiza L, Cánepa M, Cortez O, Lévano G. (2014). Análisis prospectivo del sector de comida rápida en Lima: 2014-2030. 1ª edición. Lima, ESAN Ediciones.

Arellano-Acuña, E, Rojas-Zavaleta I, Paucar-Menacho LM. (2016). Camu-camu (Myrciaria dubia): Fruta tropical de excelentes propiedades funcionales que ayudan a mejorar la calidad de vida. Scientia Agropecuaria, 7 (4): 433-443.

Autoridad Nacional del Agua (2012). Recursos hídricos en el Perú. 2da ed. 490 pp.

Autoridad Nacional de Agua (ANA) (2013). Compendio Nacional de Estadísticas de Recursos Hídricos. Lima. 190 pp.

Baker P, Friel S, Schram A, Labonte R. (2016). Trade and investment liberalization, food systems change and highly processed food consumption: a natural experiment contrasting the soft-drink markets of Peru and Bolivia. Global Health, 12(1):24 doi: 10.1186/s12992-016-0161-0

Banco Mundial (2007). Protección Social en el Perú. ¿Cómo mejorar los resultados para los pobres? 1ª ed. Lima, Perú.

Bernex, N., y Tejada, M. (2010). Cambio climático, retroceso glaciar y gestión integrada de recursos hídricos. Lima, PUCP-GWP-AEDES-Sociedad Geográfica de Lima. 132 pp.

Brack, A. (2004). Biodiversidad del Perú y su importancia estratégica. CHASQUI, 2(5):2-3.

Cabada, MM, Goodrich, MR, Graham, B, Villanueva-Meyer, PG, López, M, Arque, E, White, AC Jr. (2014). Fascioliasis and eosinophilia in the highlands of Cuzco, Peru and their association with water and socioeconomic factors. Am J Trop Med Hug., 91(5):989-993.

Cabada, MM, Goodrich, MR, Graham, B, Villanueva-Meyer, PG, Deichsel, EL, López, M, Arque, E, CWhite CA Jr. (Feb 2015). Prevalence of intestinal helminths, anemia, and malnutrition in Paucartambo, Peru. Rev Panam Salud Publica, 37(2):69-75.

Caballero-Gutiérrez, L, Gonzales GF. (2016). Alimentos con efecto anti-inflamatorio. Acta Med. Peruana, 33(1):50-64.

Caballero, L, Gonzales, GF. (2016). Patrones de Consumo Alimentario, Estado Nutricional y Características Metabolómicas del Habitante a Nivel del Mar y Altura del Perú. Lima, Perú, Universidad Peruana Cayetano Heredia. (Unpublished data).

Caetano, BF, de Moura, NA, Almeida, AP, Dias, MC, Sivieri, K, Barbisan, LF. (2016). Yacon (Smallanthus sonchifolius) as a food supplement: health promoting benefits of fructooligosaccharides. Nutrients, 8(7). Doi: 10.3390/nu8070436.

CENAN. Instituto Nacional de Salud (2006). Encuesta Nacional de Indicadores Nutricionales, Bioquímicos, Socioeconómicos y Culturales Relacionados con las Enfermedades Crónico Degenerativas. (27,33)

CEPES. Centro Peruano de Estudios Sociales (2011). Perú en 2021: los escenarios de seguridad alimentaria en el año del bicentenario. Revista Agraria, 132:8-10.

Cieza de León, P. (1995). La Crónica del Perú. 3ª ed. Lima, Fondo Editorial Pontificia Universidad Católica del Perú, Colección Clásicos Peruanos.

Carrillo-Larco, RM, Miranda, JJ, Bernabé-Ortiz, A. (2016). Impact of food assistance programs on obesity in mothers and children: a prospective cohort study in Peru. Am J Public Health, 106(7):1301-1307.

Casapía, M, Joseph, SA, Nulez, C, Rahme, E, Gyorkos, TW (2007). Parasite and maternal risk factors for malnutrition in preschool-age children in Belén, Peru using the new WHO Child Growth Standards. Br J Nutr; 98(6):1259-1266.

Código de Protección y Defensa del Consumidor, Ley 29571. https://goo.gl/7x4VNd

CONCYTEC. Programa Nacional Transversal de Biotecnología 2016-2021.

Comisión Multisectorial de Seguridad Alimentaria y Nutricional (COMSAN) (2013). Estrategia nacional de seguridad alimentaria y nutricional 2013-2021. Lima, MINAGRO, 1-73.

Condori, B, Hijmans, RJ, Ledent, JF, Quiroz, R. (Jan 2014). Managing potato biodiversity to cope with frost risk in the high Andes: a modeling perspective. PLOS ONE, 30,9(1):e81510. doi: 10.1371/journal.pone.0081510

Cooperación Alemana, implementada por la Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2016). Programa «Contribución a las Metas Ambientales del Perú» (ProAmbiente). Cambio de uso actual de la tierra en la Amazonía peruana. Avances e implementación en el marco de la Ley Forestal y de Fauna Silvestre 29763. Lima. 28 pp.

Cotlear, D, and Vermeersch, C. (Jun 2016). Peruvian lessons for the transition from MDGs to SDGs. Lancet Glob Health, 4(6):e353-e354.

Chaparro, MP, Bernabé-Ortiz, A, Harrison, GG. (2014). Association between food assistance program participation and overweight. Rev Saude Publica, 48(6):889-898.

Decreto legislativo 1062 Inocuidad de los Alimentos. https://goo.gl/8gtfDC

Díaz, A, Arana, A, Vargas-Machuca, R, Antiporta, D. (2015). Health and nutrition of indigenous and nonindigenous children in the Peruvian Amazon. Rev Panam Salud Publica, 38:49-56.

Díie, A (s/f). Perú: el problema agrario en debate. Sepia XV. Seminario Permanente de Investigación Agraria. 732 pp.

Eguren, L. Subsidios a la agroindustria costeña: cifras millonarias. PEdición N° 160 de LRA. Available at: https://goo.gl/CpsBzm

FAO. Organización de las Naciones Unidas para la Alimentación y la Agricultura (2000). Perú - Perfiles Nutricionales por países. Roma, Italia.

FAO (2009). 2050: Un Tercio Más de Bocas que Alimentar. Available at: http://www.fao.org/news/story/es/item/35675/icode/

FAO. Organización de las Naciones Unidas para la Alimentación y la Agricultura (2017). El Panorama de la Seguridad Alimentaria y Nutricional en América Latina y el Caribe. Santiago, Chile. Disponible en: www.fao.org/publications/es

FAO. PROINPA. Organización de las Naciones Unidas para la Alimentación y la Agricultura (Julio 2011). Promoción e Investigación de Productos Andinos La Quinua: cultivo milenario para contribuir a la seguridad alimentaria mundial. Available at: http://www.fao.org/quinoa-2013/publications/es/

Fischer, G., Almanza-Merchán, PJ, Miranda, D. Importancia y cultivo de la Uchuva (Physalis peruviana L.). Recebido em: 20-09-2013. Aceito para publicação em: 15-12-2013. Palestra II Simpósio Internacional de Fruticultura-Frutas Exóticas, 21 a 25 de outubro de 2013. Jaboticabal-SP.

García Bustamante, H. (2010). El panorama de la bioenergía y la seguridad alimentaria en Perú. Lima. Available at: https://goo.gl/nsWe4T

García, HH, González, AE, Tsang, VC, O'Neal, SE, Llanos-Zavalaga, F, Gonzálvez G, Romero, J, Rodríguez, S, Moyano, LM, Ayvar V, Díaz, A, Hightower A, Craig PS, Lightowlers MW, Gauci CG, Leontsini E, Gilman RH; Cysticercosis Working Group in Peru (2016). Elimination of Taenia solium transmission in northern Peru. N. Engl. J. Med., 374(24):2335-2344.

Garcilazo de la Vega (1945). Comentarios Reales sobre los Incas. II vols. Editorial Ángel Rosenblat. 2ª ed. Buenos Aires, Emecé Editores.

George, CM, Sima, L, Árias, MH, Mihalic, J, Cabrera, LZ, Danz, D, Checkley, W, Gilman, RH. (Aug 2014). Arsenic exposure in drinking water: an unrecognized health threat in Peru. Bull World Health Organ, 1,92(8):565-572.

Gómez-Guizado, G, y Munares-García, O. (2014). Anemia y estado nutricional en lactantes de dos a cinco meses atendidos en establecimientos del Ministerio de Salud del Perú, 2012. Rev Peru Med Exp Salud Publica, 31(3):487-493.

Gonzales, GF, Villaorduña, L, Gasco, M, Rubio, J, Gonzales, C. (2014). Maca (Lepidium meyenii Walp), una revisión sobre sus propiedades biológicas. Rev Peru Med Exp Salud Publica, 31(1):100-110.

Gonzales, GF, Gonzales, C, Villegas, L. (2014a). Exposure of fatty acids after a single oral administration of sacha inchi (Plukenetia volubilis L.) and sunflower oil in human adult subjects. Toxicol Mech Methods, 24(1):60-69.

Gonzales-Arimborgo, C, Yupanqui, I, Montero, E, Alarcón-Yaquetto, DE, Zevallos-Concha, A, Caballero, L, Gasco, M, Zhao, J, Khan, IA, Gonzales, GF. (Aug 2016). A randomized, double-blind placebo-controlled study on acceptability, safety and efficacy of oral administration of extracts of black or red maca (Lepidium meyenii) in adult human subjects. Pharmaceuticals (Basel), 18;9(3). pii:E49. Doi: 10.3390/ph9030049

Gonzales, GF. (2010). Maca: Del alimento perdido de los Incas al milagro de los Andes: Estudio de seguridad alimentaria y nutricional. Segurança Alimentar e Nutricional, Campinas, 16-17(1):16-36.

Gonzales, GF, Tapia, V, Gasco, M. (2014b). Correcting haemoglobin cut-offs to define anaemia in high-altitude pregnant women in Peru reduces adverse perinatal outcomes. Arch Gynecol Obstet, 290:65-74.

Graf BL, Rojas-Silva P, Rojo LE, Delatorre-Herrera J, Baldeón ME, Raskin I. (2015). Innovations in health value and functional food development of quinoa (Chenopodium quinoa Willd.). Compr Rev Food Sci Food Saf, 14(4):431-445.

Guillén-Sánchez, J, Mori-Arismendi, S., Paucar-Menacho, SM. (2014). Características y propiedades funcionales del maíz morado (Zea mays L.) var. Subnigroviolaceo. En: Scientia Agropecuaria, 5:211-217. Trujillo: UNT.

Gyorkos, TW, Maheu-Giroux, M, Casapía, M, Joseph, SA, Creed-Kanashiro, H. (2011). Stunting and helminth infection in early preschool-age children in a resource-poor community in the Amazon lowlands of Peru. Trans R Soc Trop Med Hyg, 105(4):204-208.

Hernández-Vásquez, A, Bendezu-Quispe, G, Díaz-Seijas, D, Santero, M, Minckas, N, Azañedo D, Antiporta DA. (2016). Análisis espacial del sobrepeso y la obesidad infantil en el Perú, 2014. Rev Per Med Exp Salud Publica 33(3):393-396.

Hernández-Vásquez, A, Bendezú-Quispe, G, Santero M, Azañedo, D. (13 de septiembre de 2016). Prevalencia de obesidad en menores de 5 años en Perú, según sexo y región, 2015. Rev Esp Salud Publica, 90:e1-e10.

Huicho, L, Segura, ER, Huayanay-Espinoza, CA, de Guzmán, JN, Restrepo-Méndez, MC, Tam, Y, Barros, AJ, Victora, CG; Peru Countdown Country Case Study Working Group (2016). Child health and nutrition in Peru within an antipoverty political agenda: a Countdown to 2015 Country Case Study. Lancet Glob Health., 4(6):e414-e426.

Humphries, DL, Behrman, JR, Crookston, BT, Dearden, KA, Schott, W, Penny, ME (2014). Young lives determinants and consequences of Child Growth Project Team. PLOS ONE, 9(11):e110961.

IEP. Instituto de Estudios Peruanos. Díaz RV. (2010). Análisis económico de la ingesta de alimentos en el Perú. Lima, Perú. 59 pp.

Ikoma, T, Tsuchiya, Y, Asai, T, Okano, K, Ito, N, Endoh, K, Yamamoto, M, Nakamura, K. (2015). Ochratoxin a contamination of red chili peppers from Chile, Bolivia and Peru, countries with a high incidence of gallbladder cancer. Asian Pac J Cancer Prev, 16(14):5987-5991.

Instituto Interamericano de Cooperación para la Agricultura (IICA) (2016). Manejo integrado de suelos para una agricultura resiliente al cambio climático: sistematización del ciclo de foros virtuales en el marco del Año Internacional de los Suelos (AIS) 2015, Lima. 29 pp.

INEI. Instituto Nacional de Estadística e Informática (2006). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2004-2006.

INEI. Instituto Nacional de Estadística e Informática (2008). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2007-2008.

INEI. Instituto Nacional de Estadística e Informática (2009). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2009.

INEI. Instituto Nacional de Estadística e Informática (2010). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2010.

INEI. Instituto Nacional de Estadística e Informática (2011). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2011.

INEI. Instituto Nacional de Estadística e Informática (2012). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2012.

INEI. Instituto Nacional de Estadística e Informática (2013). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2013.

INEI. Instituto Nacional de Estadística e Informática (2014). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2014.

INEI. Instituto Nacional de Estadística e Informática (2015). Perú Encuesta Demográfica y de Salud Familiar. ENDES. 2015.

INEI (2015). En el año 2014, el 33% del gasto en alimentos de los peruanos son realizados fuera del hogar. Nota de Prensa N° 116 -04 agosto 2015. Lima, Perú.

INEI. Instituto Nacional de Estadística e Informática (1999). Diferencias regionales en los patrones de consumo en el Perú. 19. Lima, Perú.

INEI. Instituto Nacional de Estadística e Informática (2000). Impacto de los Programas de Apoyo Alimentario. Lima, Perú.

INEI. Instituto Nacional de Estadística e Informática (2014). Perú Enfermedades no Transmisibles y Transmisibles, 2013. Lima, Perú. 82 pp.

INEI (2015). Perú Enfermedades no Transmisibles y Transmisibles, 2014. 1-145. Lima Perú.

INEI (2012). Anuario de Estadísticas Ambientales 2012, Lima, Instituto Nacional de Estadísticas e Informática.

INEI. Instituto Nacional de Estadística e Informática (Diciembre de 2015). Perú: Anuario de Estadísticas Ambientales 2015. Lima, Perú. 594 pp.

INEI. Instituto Nacional de Estadística e Informática. Información pública. Available at: https://goo.gl/D4TQMZ

INEI (2013). IV Censo Nacional Agropecuario-CENAGRO 2012. Resultados definitivos. pp. 3-5.

Jouravlev, AS. (Septiembre de 2016). Introducción a la temática nexo agua, energía y alimentación. Reunión de Expertos "Gobernanza del Nexo Agua, Energía y Alimentación: Desafíos de la Agenda 2030 en Agua y Saneamiento". Antigua, Guatemala, 6 al 7 de septiembre de 2016. At: https://goo.gl/UDuxX1

Ley de Seguridad Alimentaria y Nutricional. https://goo.gl/4rFTxZ

Ley 29664. Ley del Sistema Nacional de Gestión de Riego de Desastres (SINAGERD) http://www.indeci.gob.pe/norma_leg/ley_sinagerd.pdf

Ley 29811 de moratoria al ingreso y producción de organismos vivos modificados al territorio nacional https://goo.gl/BjkhBt

Ley 30021, Ley de promoción de la alimentación saludable para niños, niñas y adolescentes. https://goo.gl/uMGgJq

Ley 30355. De Promoción y Desarrollo de la Agricultura Familiar. https://goo.gl/y8fH2W

Libélula. Diagnóstico de la agricultura en el Perú. Peru Opportunity Fund. https://goo.gl/YX9dTZ 2011. 1-71.

Marcos, L, Maco, V, Samalvides, F, Terashima, A, Espinoza, JR, Gotuzzo, E. (2006). Risk factors for Fasciola hepatica infection in children: a case-control study. Trans R Soc Trop Med Hyg, 100(2):158-166.

MEF. Ministerio de Economía y Finanzas (2010). Marco macroeconómico multianual. Rev. 2011-2013. Lima, Perú. Available at: www.bcrp.gob.pe/docs/...Economico/MMM-2011-2013-agosto.pdf

MEF. Ministerio de Economía y Finanzas (2011). Marco macroeconómico multianual. Rev. 2012-2014.

MIDIS (2012). Mapa de vulnerabilidad a la inseguridad alimentaria, 2012. Lima. 150 pp.

MRE. Ministerio de Relaciones Exteriores (2015). Guía de Negocios e Inversión en el Perú 2015/2016. Lima, Perú. Ediciones EY.

Méndez, MA, Monteiro, CA, Popkin, BM. (2005). Overweight exceeds underweight among women in most developing countries. Am J Clin Nutr, 81(3):714-721.

Mendoza, W., García, J. Perú (2006). 2001-2005: Crecimiento económico y pobreza. Documento de Trabajo 250. Lima, Perú, PUCP. At: https://goo.gl/yktbxU

MINAGRI. Ministerio de Agricultura y Riego (2014a). Valor Bruto de la Producción Agropecuaria. Edición Agosto-14. Lima, Perú.

MINAGRI (2014b). Estrategia Nacional de Agricultura Familiar 2015-2021. Lima. 126pp.

MINAGRI. Ministerio de Agricultura y Riego (Diciembre de 2015). Valor Bruto de la Producción Agropecuaria. Lima, Perú.

MINAGRI. Ministerio de Agricultura y Riego (2015). Lineamientos de Política de Inversión Pública en Desarrollo Forestal 2015-2021. Lima, Perú.

MINAGRI. Ministerio de Agricultura y Riego (2015). La zonificación ecológica económica. Lima, Perú.

MINAGRI. Ministerio de Agricultura y Riego (2015). Plan Estratégico Regional Agrario de Amazonas 2009-2015. Lima, Perú.

MINAGRI (2014). Estrategia nacional de agricultura familiar 2015–2021. Lima. 126 pp.

MINAGRI. Comisión Multisectorial de Seguridad Alimentaria y Nutricional (2013). Estrategia nacional de seguridad alimentaria y nutricional 2013 – 2021. Lima. 72 pp.

MINAGRI (s/f). Recursos Naturales. https://goo.gl/tfrDfr

MINAGRI. Plan de gestión de riesgo y adaptación al cambio climático en el sector agrario, período 2012-2021 (PLANGRACC-A) Documento resumen aprobado por R.M. 0265-2012-AG del 06.08.12. Lima. 33pp.

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (Agosto de 2009). Técnica de Producción de Semilla Genética y Básica de Ajo (Allium sativum L.) Libre de Virus. Serie Folleto N°6-09. Lima, Perú.

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (Marzo de 2011a). Transferencia de Embriones en Camélidos. Plegable N° 1. Lima, Perú

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (Diciembre de 2011b). Técnica de Multiovulación y Transferencia de Embriones de Ganado Bovino en Condiciones de Trópico del Perú. Plegable N° 12. Lima, Perú

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (2012a). Lo que el INIA hace por el Perú. Lima, Perú, Ed. INIA.

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (Agosto 2012b). Conservación de Alpacas de color en la Región Puno. Hoja divulgativa N°4. Lima, Perú.

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (Febrero de 2014a). Innovación Tecnológica en Quinua. Díptico N° 1. Lima, Perú.

MINAGRI/INIA. Ministerio de Agricultura y Riego.

Instituto Nacional de Innovación Agraria (Junio de 2014b). Importancia de los virus en el cultivo de la vid. Díptico N° 3. Lima, Perú.

MINAGRI/INIA. Ministerio de Agricultura y Riego. Instituto Nacional de Innovación Agraria (Agosto 2014c). Papa INIA 323 Huayro Amazonense. Plegable N° 7. Lima, Perú.

MINAM. Comisión Nacional de Diversidad Biológica (CONADIB) (2008). Perú: País Megadiverso, p. 2. 16pp. http://sinia.minam.gob.pe/documentos/peru-pais-megadiverso

MINAM (2014). Informe Nacional del Estado del Ambiente 2012–2013. Lima, Ministerio del Ambiente, Dirección General de Políticas, Normas e Instrumentos de Gestión Ambiental. 324 pp.

MINAM (2016). Estrategia nacional de lucha contra la desertificación y la sequía 2016-2030. Lima. 178 pp.

MINAM (2016). El Perú y el Cambio Climático: Tercera Comunicación del Perú a la Convención Marco de las Naciones Unidas sobre Cambio Climático. Perú. pp. 1-329.

MINSA (2006). Encuesta Nacional de Indicadores nutricionales, bioquímicos, socioeconómicos y culturales relacionados con las enfermedades crónicas degenerativas. Lima, Perú. 163 pp.

MINSA/INS/CENAN (2012). Sala Situacional Alimentaria y Nutricional. Consumo Alimentario. Lima, Perú. 81 pp.

MINSA/INS/CENAN (2015). Estado nutricional por etapas de vida en la población peruana. 2013-2014. Lima, Perú.

MINSA/INS/CENAN (2015). Estado nutricional en el Perú por etapas de vida; 2012-2013. Lima, Perú.

Mujica-Coopman, MF, Brito, A, López de Romaña, D, Ríos-Castillo, I, Coris, H, Olivares, M. (2015). Prevalence of anemia in Latin America and the Caribbean. Food Nutr Bull, 36(2 Suppl):S119-S128.

National Research Council (1989). Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation. The National Academies Press. Doi: https://doi.org/10.17226/1398. 482 pp.

OECD (2016). Skills Strategy Diagnostic Report. Executive Summary, 1-10. Perú.

OMS. Organización Mundial de la Salud (2005). Biotecnología moderna de los alimentos, salud y desarrollo humano: estudio basado en evidencias. Suiza.

ONERN (1981). Mapa de capacidad de uso mayor de las tierras del Perú. 1 mapa en 8 pliegos, col. 62 x 77 cm. y una guía explicativa. Lima.

OPS (2015). Alimentos y bebidas ultraprocesados en América Latina: Tendencias, efecto sobre la obesidad e implicaciones para las políticas públicas. Washington, D.C., USA. 76 pp.

Pajuelo, J, Miranda, M, Zamora, R. (Apr-Jun 2015). [Prevalence of vitamin a deficiency and anemia in children under five years of age in Peru]. [Article in Spanish]. Rev Peru Med Exp Salud Publica, 32(2):245-251.

Parrillón C, Karp E, Leonard J, Araujo F, Harrell M, Franklin D. (1983). Un Análisis de la Situación Alimentaria Nutricional en el Perú. USA: Sigma Corporation. 147pp.

Pérez-Lu, JE, Cárcamo, C, Nandi, A, Kaufman, JS (2016). Health effects of 'Juntos', a conditional cash transfer programme in Peru. Matern Child Nutr. Doi: 10.1111/mcn.12348.

PMA y CENEPRED (2015). Mapa de vulnerabilidad a la inseguridad alimentaria ante la recurrencia de fenómenos de origen natural 2015. Lima. 222 pp.

Poskitt, EM (2009). Countries in transition: underweight to obesity non-stop? Ann Trop Paediatr, 29:1-11.

Pretell. EA, Pearce, EN, Moreno, SA, Dary, O, Kupka, R, Gizak, M, Gorstein, J, Grajeda, R, Zimmermann, MB. (Jan 312017). Elimination of iodine deficiency disorders from The Americas: a public health triumph. Lancet Diabetes Endocrinol, pii :S2213-8587(17)30034-300037.

Pulgar Vidal, J. (2014). Geografía del Perú. Las ocho regiones naturales. Ed. Nicole Bernex. Lima, INTE-PUCP. 250 pp.

Quesada-López, LE (2011). La agricultura en el Perú. https://goo.gl/LxH3xH

Rendón-Schneir, E. (2010). La gestión pública de la innovación agraria en el Perú: antecedentes y perspectivas. Cuadernos de Investigación EPG, UPC, 11:1-20.

Repo-Carrasco-Valencia, R. (2014). Valor Nutricional y Compuestos Bioactivos en los Cultivos Andinos. Redescubriendo los Tesoros Olvidados. Lima, Perú, Editorial UNALM, 1997. 112 pp.

Ricks, DJ, Rees, CA, Osborn, KA, Crookston, BT, Leaver, K, Merrill, SB, Velásquez, C, Ricks, JH (2012). Peru's national folic acid fortification program and its effect on neural tube defects in Lima. Rev Panam Salud Publica, 32(6):391-398.

Rinaldi, L, González, S, Guerrero, J, Aguilera, LC, Musella, V, Genchi, C, Cringoli, G. (2012). A One-Health integrated approach to control fascioliasis in the Cajamarca valley of Peru. Geospat Health, 6(3):S67-S73.

Salaverry, O (2012). La comida en el antiguo Perú: haku mikumusum (¡vamos a comer!). Rev. Perú. Med. Exp. Salud Publica, 29(3):409-413.

Sandweiss, DH, Solís, RS, Moseley, ME, Keefer, DK, Ortloff, CR. (2009). Environmental change and economic development in coastal Peru between 5,800 and 3,600 years ago. Proc Natl Acad Sci USA, 106(5):1359-1363.

SENASA. Actividades de prevención y mitigación del SENASA frente al FEN (Fenómeno de El Niño)" 2015-2016. Available at: https://goo.gl/crNFWi

SENASA (Enero de 2017). Comunicándonos. BOLETÍN INSTITUCIONAL Servicio Nacional de Sanidad Agraria Edición N° 11.

SENASA (Noviembre de 2014). Comunicándonos. BOLETÍN INSTITUCIONAL Servicio Nacional de Sanidad Agraria Edición N° 1.

Schlebusch, CM, Gattepaille, LM, Engström, K, Vahter, M, Jakobsson, M, Broberg, K. (Jun 2015). Human adaptation to arsenic-rich environments. Mol Biol Evol, 32(6):1544-1555.

Sierra Exportadora (2013). La Riqueza Exportadora de Nuestra Sierra. Lima, Ed. Hernández-Aguilar Z. 109 pp. MINAGRI. www.sierraexportadora.gob.pe

Sobrino, M, Gutiérrez, C, Cunha, AJ, Dávila, M, Alarcón, J. (2014). Child malnutrition in children under 5 years of age in Peru: trends and determinants. Rev Panam Salud Publica 35(2):104-112.

Spooner, DM, McLean, K, Ramsay, G, Waugh, R, Bryan, GJ (2005). A single domestication for potato based on multilocus amplified fragment length polymorphism genotyping. Proc Natl Acad Sci U S A, 102(41):14694-14699.

Tapia, M, y Fries A (2007). Guía de campo de los cultivos andinos. Lima, FAO y ANPE.

Tapia, M (2000). Cultivos andinos subexplotados y su aporte a la alimentación. 2ª ed. Santiago, Chile, FAO.

Tapia, ME (1993). Semillas andinas El Banco de Oro. Lima, Perú, Consejo Nacional de Ciencia y Tecnología. 76 pp.

Tarqui-Mamani, C, Sánchez-Abanto, J, Álvarez-Dongo, D, Espinoza-Oriundo, P, Jordan-Lechuga, T. (2015). Prevalence of anemia and associated factors in elderly residing in Peruvian households. Rev Peru Med Exp Salud Publica, 32(4):687-692.

UNALM/AGROBANCO (2014). Mejoramiento genético y biotecnológico de plantas. Lima, Perú, UNALM-AGROBANCO-Promotora Lima, Col. Agrosaber del Banco Agropecuario.

Urke, HB, Mittelmark, MB, Valdivia, M (2014). Trends in stunting and overweight in Peruvian pre-schools from 1991 to 2011: findings from the Demographic and Health Surveys. Public Health Nutr, 17(11):2407-2418.

Vásquez, E, Cortéz, R, Parodi, C, Montes, J, Riesco, G. (1999). Revisión principales tendencias macroeconómicas y sociales desde 1980. Perú, Centro de Investigación de la Universidad del Pacífico. At: https://goo.gl/sxPJaJ

Villar-Castillo, F. (2008). La agricultura Peruana: Enfrentando el reto del cambio. At: https://goo.gl/16HfJq

Von May, R; Catenazzi, A, Angulo, A. Venegas, PJ, Aguilar, C. (Diciembre de 2012). Investigación y conservación de la biodiversidad en Perú: importancia del uso de técnicas modernas y procedimientos administrativos eficientes. Revista Peruana de Biología, 19(3):351-358. Lima, Perú, Universidad Nacional Mayor de San Marcos.

Webb. R (2012). Pobreza y dispersión poblacional. Lima, Instituto del Perú, USMP. pp. 1-275.

Yucra, S, Rubio, J, Gasco, M, Gonzales, C, Steenland, K, Gonzáles, GF. (2006). Semen quality and reproductive sex hormone levels in Peruvian pesticide sprayers. Int J Occup Environ Health, 12:355-361.

Zegarra, E, y Tuesta, J. Crecimiento agrícola, pobreza y desigualdad en el Perú rural. En: Boom Agrícola, Pobreza y Desigualdad en el Perú Rural. pp. 299-329. Roma, FAO.

Box 5

The Land of the superfoods

Gustavo F. Gonzales, Jefe del Laboratorio de Endocrinología y Reproducción, Facultad de Ciencias y Filosofía, Universidad Peruana Cayetano Heredia. Verónica Rubín De Celis, Directora del Instituto de Ciencia y Tecnología de la Universidad Ricardo Palma.

On February 2013, Luiz Costa Jr, Producer of from O´Globo Reporter, Brasil came to Peru with a group of reporters looking for a television report on Andean superfoods as *Lepidium meyenii* (maca), *Chenopodium quinoa* (quinoa), kiwicha, blue corn and *Smallanthus sonchifolius* (yacon) They were to each place in which these plants are produced and in Junín (4200 m) they interviewed to one of the coauthors (GFG) about the beneficial properties of maca, a plant growing over 4000 m in the Peruvian highlands, a place in which nothing grows. The program about Andean superfood was exhibited in Brazilian television on April 2013.

On December 2, 2014, the Wall Street Journal published a report by Kris Maher and Robert Kozak titled: The latest superfood? Peru´s maca root. Thereafter, on August 30, 2016 appeared in CBS New York a report titled "Peru: The land of superfoods" to characterize a variety of Peruvian agricultural products that promote healthy life. These superfoods characterized by its high nutritional value included by the journalist are *Physalis peruviana* (aguaymanto), *Lepidium meyenii* (maca), *Smallanthus sonchifolius* (sacha inchi), *Chenopodium quinoa* (quinoa), *Amaranthis caudatus* (kiwicha), *Chenopodium pallidicaule* (cañihua), blue corn, *Myrciaria dubia* (camu camu) among others.

The recognition that in Peru is produced a variety of crops qualified as "superfood" moved to authorities of the Peruvian government to launch in Wednesday Feb. 8, 2017 through the Peruvian Foreign Trade and Tourism Minister Eduardo

Maca shrub in Pasco. Photo: Wendy Gonzales.

Ferreyros the "Super foods Peru" campaign, a public-private initiative to further advertise the quality, variety and benefits of the Peruvian's food offer. The presentation occurred in Berlin within the framework of the fresh produce trade show Fruit Logistica 2017. The promotion strategy takes into account the latest trends among customers and their concern for a healthier lifestyle.

Peruvian superfoods

Why Peru produce a high variety of superfood?. The Peruvian nation enjoys a privileged status among global superfood producers because is one of the nations with highest biodiversity in the world. It has 84 of the 117 life zones of the earth and 17 of the 104 transitional zones present in the world. Agriculture in Peru is known almost 10,000 years ago, in which our ancestors domesticated the culture of the crops. Furthermore, Peru is the only country in which agriculture could be possible over 4000 m of altitude where may grow two important crops with nutraceutical properties like *Lepidium meyenii* (maca) and *Tropaeolum tuberosum* (mashua).

The particular geography of Peru allows diversity with different crops produced at the coast, mountain and jungle. Traditional Peruvian medicine includes an estimate of 1400 plants species; however, only a few have undergone scientific investigation (1-15).

Plants like *Lepidium meyenii* (maca), *Chenopodium quinoa* (quinoa), *Amaranthus caudatus* (Kiwicha), *Chenopodium pallidicaule* (cañihua), blue corn, and *Lupinus mutabilis* (tarwi) grows in the Andean region, whereas others as *Plukenetia volubilis* (sacha inchi), *Physalis peruviana* (aguaymanto) and *Smallanthus sonchifolius* (yacon) in the Amazonian region. According scientific studies, these superfoods have antioxidants, and secondary metabolites with healthy properties and some of them with anti-inflammatory, anti-cancer and anti-aging properties. We need to increase studies of genetic diversity.

In a recent review, the following plants, not all used as food, are included in the Traditional Peruvian Medicine: *Smallanthus sonchifolius* (yacon), *Croton lechleri* (sangre de grado), *Uncaria tomentosa/U. guianensis* (uña de gato), *Lepidium meyenii* (maca), *Physalis peruviana* (aguaymanto), *Minthostachys mollis* (muña), *Notholaena nivea* (cuti-cuti), *Maytenus macrocarpa* (chuchuhuasi), *Dracontium loretense* (jergon sacha), *Gentianella nitida* (hercampuri), *Plukenetia volubilis* (sacha inchi) and *Zea mays* (maiz). (Lock et al., 2016).

From these examples, it is clear thanks to its biodiversity, export capacity, as well as traceability and innovation through sustainable, transparent process chains, that superfood crops from Peru may be of importance for alimentary and nutrition security worldwide.

In summary, superfoods is a reality in Peru, a land with many life zones, diverse topography, world-renowned cuisine, and with a gift of the Incas, Machu Picchu considered one of the new seven Wonders of the World.

References

Abderrahim F, Huanatico E, Segura R, Arribas S, Gonzalez MC, Condezo-Hoyos L. Physical features, phenolic compounds, betalains and total antioxidant capacity of coloured quinoa seeds (*Chenopodium quinoa Willd.*) from Peruvian Altiplano. Food Chem. 2015 Sep 15;183:83-90.

Atchison GW, Nevado B, Eastwood RJ, Contreras-Ortiz N, Reynel C, Madriñán S, Filatov DA, Hughes CE. Lost crops of the Incas: Origins of domestication of the Andean pulse crop tarwi, *Lupinus mutabilis*. Am J Bot. 2016 Sep;103(9):1592-606.

Gonzales GF, Vasquez VB, Gasco M. The transillumination technique as a method for the assessment of spermatogenesis using medicinal plants: the effect of extracts of black maca (*Lepidium meyenii*) and camu camu (*Myrciaria dubia*) on stages of the spermatogenic cycle in male rats. Toxicol Mech Methods. 2013 Oct;23(8):559-65

Langley PC, Pergolizzi JV Jr, Taylor R Jr, Ridgway C. Antioxidant and associated capacities of Camu camu (*Myrciaria dubia*): a systematic review. J Altern Complement Med. 2015 Jan;21(1):8-14.

Leiva-Revilla J, Cárdenas-Valencia I, Rubio J, Guerra-Castañón F, Olcese-Mori P, Gasco M, Gonzales GF. Evaluation of different doses of mashua (*Tropaeolum tuberosum*) on the reduction of sperm production, motility and morphology in adult male rats. Andrologia. 2012 May;44 Suppl 1:205-12.

Food and Nutrition Security in the United States of America

Seasonal agricultural field workers, cut and package lettuce, directly in the fields of Salinas, California © Shutterstock

United States of America

[1] Michael F. Allen
[2] Peter L. Morrell
[3] Charles W. Rice
[4] Henry J. Vaux
[5] Clifford N. Dahm
[6] Rebecca R. Hernández

Agriculture plays a critical role in global food sustainability. Future production will be constrained by invasive pests and soil degradation, exacerbated by changes in climate and pollution. Addressing these issues requires the political will to support agriculture and natural resource infrastructure, including land-grant universities, agricultural research stations, international biological control centers, and an innovative private sector, interconnected with the international scientific network.

Summary

Globally, overall demand for agricultural products is expected to grow at 1.1% per year from 2005/2007-2050, down from 2.2% per year in the past four decades (Alexandratos and Bruinsma, 2012). Population growth, increases in per-capita consumption, and changes in diets leading to the consumption of more livestock products are the main drivers of expected changes.

Some potential national scenarios for agricultural production over the next fifty years

Increases in production are slowing due to a number of constraints. Land and water resources are much more stressed than in the past, both in quantity (per capita) and quality; there is soil degradation, decline in water quality, and competition from uses other than for food production. Growth of crop yields has slowed considerably. Climate change is a risk that would negatively affect agricultural production in many areas of the world. Questions are being asked about the sustainability of food production systems. As a result, "sustainable intensification" agriculture is now promoted (Royal Society, 2009; Nature, 2010; Godfray et al., 2010).

Over the next several years, the U.S. agricultural sector will adjust to lower prices for most farm commodities (USDA, 2015). For crops, production response to lower prices will result in reduced acreage planted. In the livestock sector, lower feed costs will provide economic incentives for expansion. Global meat consumption is projected to continue to increase, with poultry consumption rising faster than pork and beef consumption. Long-term developments for global agriculture reflect steady world economic growth and continued global demand for biofuel feedstocks. Those factors combine to support longer-run increases in consumption, trade, and prices of agricultural products. Reflecting these market adjustments and price projections, export values declined in 2015 and farm cash receipts fell in 2015-16 before both grew over the rest of the projection period. Farm production expenses will also increase after 2016, so driving net farm income will decline from recent record highs.

Technological improvements continue at an extraordinary rate. These developments are occurring not only in improving production, but also in improving efficiency. Any search of the web will show both classic companies and novel startups designing improvements in agricultural efficiencies. These efficiencies range from new genetic resources of production and disease resistance, to sensors that relate real-time information of soil fertility and water status to improve the effectiveness of irrigation and fertilizer applications, to self-driving machinery that can integrate sensor and remotely sensed environmental and plant status information into a computer-planned pattern of cultivation or harvest. The newer machinery can work using power

harvested from on-farm solar and wind renewable technologies rather than exclusively depend on large-scale inputs of fossil fuels that drive climate change and energy uncertainties. Precision agriculture is present, changing almost daily, and becoming integrated into real farming systems.

Newer applications of information and technology to work with our microbial partners, instead of destroying them, are beginning to allow for improving fertilizer and water use efficiencies and availabilities and attacking pests with reduced energy-inefficient pesticide applications that harm soils and people. Partnering among theoretical, university-based research, agribusiness, and farmers and ranchers is beginning to overcome the drop in research and development support as governments reduce support. These approaches have the potential to dramatically overhaul R&D and overall food security, across the U.S. and globally, for better or worse. The direction depends upon the approaches all parties take.

Finally, probably the cornerstone of sustainable agriculture is the attention to sustaining trade and creating an increasingly educated labor work force. Recent analyses of discussions of technological and social developments (Gopnik, 2017) point to the need to integrate R&D and social thought. As Gopnik (2017, p91) points out, "what separates modernity from antiquity... Guys who think big thoughts talking to guys who make cool machines- that's where the leap happens". We remain desperate for a comprehensive work force and international governmental awareness that understands the importance of international idea and commodity exchange, that focuses on the technologies that improve the environment while sustaining and enhancing agricultural production, and that takes the long view of worldwide human population growth and environmental, including climate, change, to create a sustainable global food production system. The Americas- the New World in many narratives- have the potential to provide both the leadership and the resources to create these integrative complexities. The alternative is not an option.

1. National Characteristics

The United States of America (U.S.) is the third largest country in the world in terms of physical size. Russia and Canada are both larger. Total area of the US is 9.8 M square kilometers, with roughly 685,000 square kilometers of water surface area (see https://www.cia.gov/library/publications/the-world-factbook/geos/us.html). Agricultural land makes up 44.5% of the country with 16.8% of this land designated as arable, 0.3% in permanent crops, and 27.4% in permanent pasture. Another 33.3% is forest. The majority of the U.S. lies within the temperate climatic zone, with small areas of tropical climate in Hawaii and the southern tip of Florida and arctic regions in northern Alaska. The country is environmentally heterogeneous, with most of the eastern half of the country having relatively high levels of rainfall, and a natural landscape dominated by temperate, deciduous forest. The central portion of the country has lower annual rainfall, with a landscape that is predominantly semi-arid to arid grassland. This gives way to arid and desert regions in the SouthWest quarter of the country. Major mountain ranges near the Atlantic Coast, in the West, and the western coastal region, and in an intermountain region, contain limited area that can be cultivated.

The U.S. is also the third largest country in terms of population, with roughly 323 M people. Both China and India have populations closer

[1] **Michael F. Allen,** University of California, Riverside. michael.allen@ucr.edu [2] **Peter L. Morrell,** University of Minnesota. pmorrell@umn.edu [3] **Charles W. Rice,** Kansas State University. cwrice@ksu.edu [4] **Henry J. Vaux,** University of California, Riverside. vaux0@att.net [5] **Clifford N. Dahm,** University of New Mexico. cdahm@sevilleta.unm.edu [6] **Rebecca R. Hernandez**, University of California, Davis. RRHernandez@ucdavis.edu

to 1.3 B people, so the U.S. is third in rank but has a much smaller population at a much lower population density than the two largest countries. The U.S. has a very racially diverse population and a relatively slow rate of population growth at ~0.8%. While U.S. gross domestic product per capita is high, inequality in wealth distribution contributes to considerable food insecurity. Roughly 42 M U.S. citizens face some degree of food insecurity, with the most frequent consequences including short-term hunger or persistent malnutrition. The problem of food insecurity appears to be increasing, partially due to stagnant wages for the working poor. Large governmental assistance programs and private charities are involved in addressing hunger and malnutrition, particularly in children.

Agriculture across the U.S. is also heterogeneous, but is predominantly industrial in scale. It is served by a large agricultural services sector that is chiefly composed of U.S.-based or European-based companies with major subsidiaries in the U.S. This includes equipment makers, fertilizer, seed, and chemical companies. Major crops include maize, soybeans, wheat, and alfalfa. Maize production has shifted heavily toward use in ethanol production, primarily as a light vehicle fuel, with the waste products of this process going to animal feed. Animal feed is one of the primary domestic uses of the two major crops, maize and soybeans. This contributes to a large animal agriculture industry that produces beef, pork, and poultry, including chicken and turkey. Poultry consumption, particularly chicken, has been increasing over the last several decades while pork consumption has remained constant and beef has seen a slow decline following a peak in the 1970s. U.S. beef production is somewhat unusual in that cattle are typically "finished" on grain in feedlots largely located near regions of extensive maize and soybean production.

The U.S. is self-sufficient in agriculture and is a major exporter of food and food products. However, because of a largely temperate climate, with distinct seasonality, the U.S. is also a major importer of food and food products. This includes a wide diversity of foods, including seafood, fresh fruits and vegetables (including many tropical fruits consumed in the U.S.), coffee, and specialty products including cheese, wine, and spices. Mexico and Central America are major sources of fresh fruits and vegetables, including both tropical fruits (e.g., banana, pineapple, and avocado) and crops that are "out of season" for much of the year in North America

2. Institutional Setting. National Agricultural Research Systems.

The U.S. has put into place a strong infrastructure to undertake research, evaluate and apply the results of fundamental research, and provide for training opportunities ranging from Elementary through Advanced Degree programs. Importantly, as issues such as climate change, invasive pests, ecosystem processes, and food production costs change, that structure can be augmented in multiple ways by topics outside of traditional agricultural programs, and by private initiatives. Some of these approaches are readily adaptable, others need support from agribusiness, education, and governmental programs.

There are multiple national agencies tasked with various aspects of food production and sustainability. The National Oceanic and Atmospheric Administration (NOAA) was initiated in 1807 under President Jefferson as the U.S. Coast and Geodetic Survey to survey and map the coastline for hazards and resources. It is now housed within the Department of Commerce. NOAA oversees the Sea Grant program focused on understanding and overseeing fisheries programs and sustainability. Given that the U.S. imports more seafood than it exports, and that seafood has been identified as an increasingly important resource, sustaining and reducing overfishing is clearly a critical element in the nation's sustainable food resources.

NOAA also manages climate and weather programs through the National Weather Service. Data range from predicting and tracking immediate-to-daily conditions and events to longer-range climate predictions and change analyses. Maintaining the infrastructure for this information and these datasets are essential for making short- and long-range planting, harvest, and crop choices for a sustainable resource.

An independent United States Department of Agriculture (USDA) was developed in 1862 to help small farmers, especially in newly (European) settled regions of the country. It officially became a cabinet-level agency in 1889. The Forest Reserve Act of 1892 initiated a management agency for the nation's forests through the Department of Interior, and was transferred to the USDA under the leadership of Gifford Pinchot and Theodore Roosevelt, as the US Forest Service in 1905 to concentrate on the nation's fiber production. Today there are over 90 Agricultural Research Service (ARS) labs in the U.S. and overseas and 67 U.S. Forest Research and Development laboratories organized into five regions plus the International Institute of Tropical Forestry in Puerto Rico, interconnected by a network of 80 experimental forests. Research and development in the broad areas of fiber and food production stretch across many topic agencies such as the Natural Resource Conservation Service (the old Soil Conservation Service), Research, Education and Economics (REE), the National Agricultural Statistics Service (NASS), and the Animal and Plant Health Inspection Service (APHIS). Together, these form the bulk of the agricultural and forestry R&D program across the U.S. and extend internationally.

Many other agencies have emerged to oversee specific tasks or agricultural issues. Frequently the missions of these agencies have shifted through the years. The U.S. Entomological Commission was founded, with $18,000 in 1876 within the Department of Interior in response to outbreaks of the Rocky Mountain Locust plagues. It was so effective that it apparently drove this particular species extinct (Lockwood 2004). This agency eventually became the U.S. Fish and Wildlife service, for managing wild populations of fisheries and game. These form the basis of subsistence food resources, managed by individual states, but supported through wildlife reserves, the Endangered Species Act, and other tasks to provide sustainable wildland resources.

The space program through the National Aeronautics and Space Administration (NASA) aimed its suite of tools and models toward sustaining food and fiber productivity, and eventually management through the Mission to Planet Earth, initiated in 1997. The National Science Foundation (NSF) funds research in basic science related to sustainable food and natural resource management, and more recently a number of public-private collaborative programs between NSF and such programs as the NSF-Bill and Melinda Gates Foundation Partnership has resulted in numerous high-profile efforts to boost agricultural production.

Universities and Research Institutes

The U.S. initiated a state-based agricultural research and assistance program in 1862, with the formation of Land Grant Colleges through the Morrill Act. Kansas State was the first such university in 1863, rapidly followed by Iowa State University, and agricultural programs at Yale, Cornell, and Rutgers Universities. The Morrill Act was followed in 1887 by the Hatch Act, which provided federal funding for Agricultural Experiment Stations (AES) in each state. The experiment stations provide some direct, but mostly collaborative funding and research connections between federal and state researchers focused in almost every agricultural activity nationally. In some states, such as California, there are three campuses of the University of California system that support AES, UC Riverside in southern California, and UC Davis and UC Berkeley campuses that maintain different specialties. Currently there are agricultural universities in every state and the District of Columbia plus associated territories (American Samoa, Guam, Northern Marianas, Puerto Rico, and Virgin Islands). At most of the universities, there are associated USDA research stations and facilities. Together these constitute a formidable research unit that addresses topics related to food and fiber production utilization, nutrition and transport. These range from biotechnology to remote sensing, to human nutrition, to agricultural economics and productivity. This system supports the most sophisticated network of modeling and instrumentation (sequencing, remote sensing) geared toward sustaining agricultural production in history. Just as important, by physically and remotely (using computer and satellite communication mechanisms) integrating university, state, and federal research facilities, inter- and transdisciplinary teams can address both immediate and long-range projected issues that emerge, or that arise from model predictions.

This research support was followed by the Smith Lever Act of 1914 that provided for the Cooperative Extension CE) Services in every state. The program was formed to ensure that research was translated from the research universities directly to growers and practitioners. In general, there are CE offices in every county, or group of counties, across the country. These are designed to address specific, local agricultural issues as they arise, and to provide a communications pathway to researchers to address emerging problems, such as those addressed elsewhere in this document.

Skilled work force development and the status of national education systems

Between 2015 and 2020, nearly 58,000 average annual jobs for graduates with bachelor's or higher degrees with expertise in food, agriculture, renewable natural resources, or the environment are anticipated. Almost half of the opportunities will be in management and business and 27% will be in Science, Technology, Engineering, and Mathematics (STEM), 15% in sustainable food and biomaterials production, and 12% in education, communication, and governmental services. Approximately 35,400 new U.S. graduates with expertise in food, agriculture, renewable natural resources, or the environment are expected to fill 61% of the expected 57,900 average annual openings. This leaves a deficit of 22,500 annual jobs openings which will be filled in related disciplines (biology, business administration, engineering, education, communications, and consumer sciences). Graduates with expertise in food, agriculture, renewable natural resources, and the environment are essential to our ability to address the U.S. priorities of food security, sustainable energy, and environmental quality. Graduates in these professional specialties not only are expected to provide answers and leadership to meet these growing challenges in the U.S., but they also must exert global leadership in providing sustainable food systems, adequate water resources, and renewable energy in a world of population growth and climate change. U.S. higher education programs have encountered challenges enrolling women and ethnic minorities in STEM specialties.

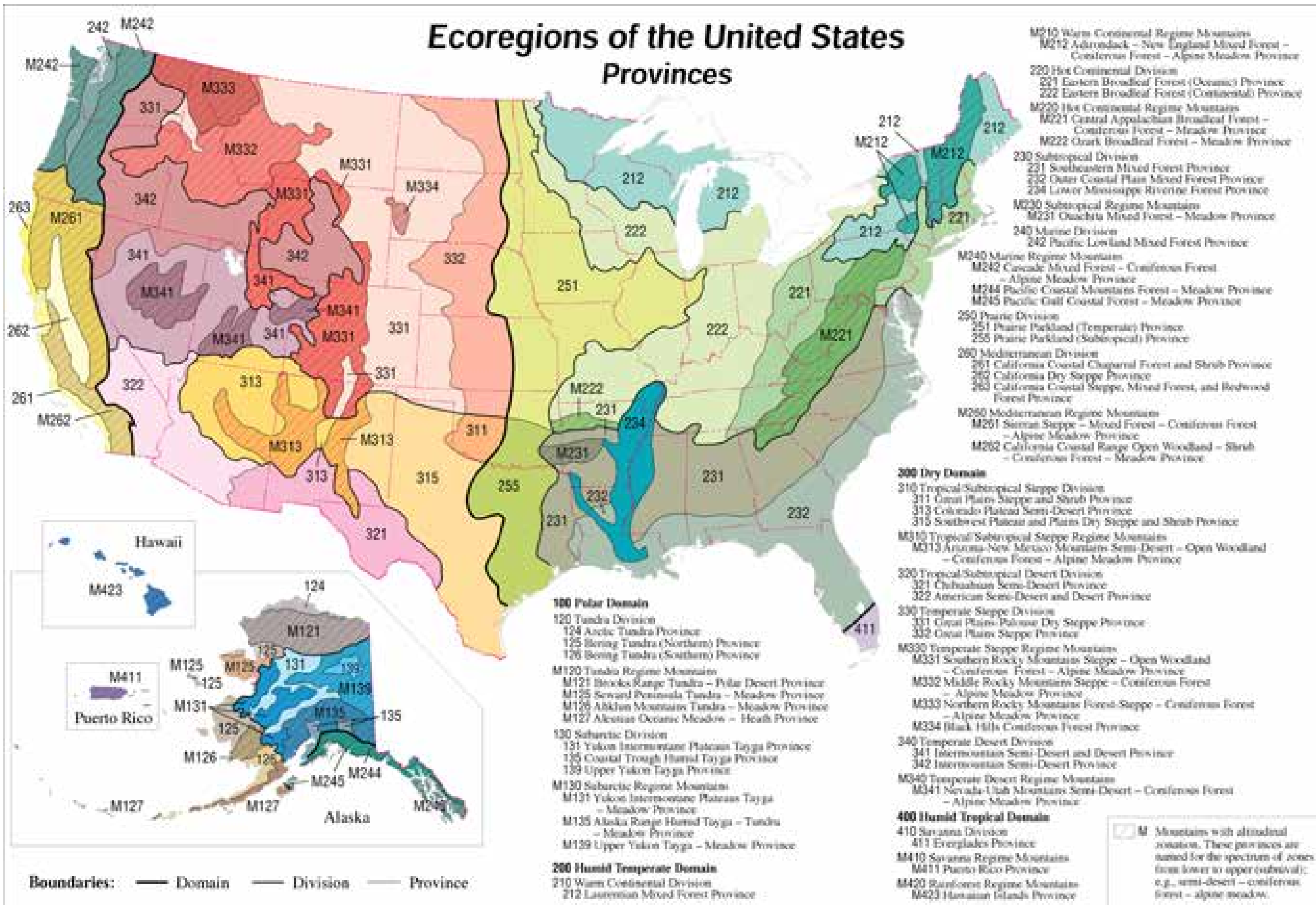
Relative contributions from public and private sectors

Federal and state support has formed the mainstay of agricultural Research and Development (R&D) since the mid-1800s. Over the past decade, federal funding has dropped within the U.S. However, overall support for R&D has remained stable, largely due to an increasing private sector (Fuglie and Toole 2014). In the past, most private investment in agricultural R&D was tied to postharvest and transport, machinery, and chemicals and fertilizers.

With the dramatic changes in variety developments, and the newer patent protection laws, rulings and federal and state support have dramatically changed the R&D landscape. As there is now patent protection for organisms and genes, R&D that is less transparent, and the greater difficulty to simply transfer from farmer to farmer has emerged. In Europe and scattered regions of the Americas, extensive grassroots objections have emerged to some applications of the transfer of genes between organisms. However, research continues to show that organisms, especially plants and microbes, naturally acquire genes from unrelated organisms, and newer CRISPR technologies that edit rather than transport new genes, may well address many of these concerns.

Future Outlook

We envision rather dramatic changes in institutional settings for agricultural R&D as we look across a 50-year timeline. These



Source: R.G. Bailey [Ecoregions of the United States, USDA Forest Service (scale 1:7,500,000, revised 1994)]

include a shift in local issues from the larger agricultural universities to smaller, often small colleges or community colleges. The research universities, in many cases the AES-associated universities and federal labs, will concentrate on larger, networked research questions, often in interspersed connectivity with industry. These will range from biotechnological approaches for seed production, and a biotech private-public partnership to manipulate, patent, and manage mutualistic microbial symbionts that reduce the need for pesticides and make efficient use of fertilizers. We also envision an increase in scaling of agriculture using government products such as remote sensing and a private industry interfaced with university engineers developing machinery that utilizes sensors and remote sensing outputs to improve land management efficiencies.

Two challenges for R&D include increasingly complex and cumbersome bureaucratic oversight and utilization of the results of R&D. Overlapping and often contradictory rulings ranging from health, to public interest, to transportation can hamper both R&D and the translation of R&D into the production sector.

Funding from the federal, state, local, and private sectors remains essential. The drop in federal R&D over the past decade may result in a drop in critical understanding of issues, especially pest evolution, which is emerging in the U.S. and globally. While the emergence of private funding has the potential to provide incredible new products and procedures improving food and fiber production, the detrimental impacts of patents and the potential for cost escalation remains of concern. Finally, support for continued training of future scientists both within the U.S. and internationally is essential to keep up with the world's still-growing population.

Within this realm, international cooperation and the creation and maintenance of scientific networks and open information exchange is critical for sustaining agricultural production.

3. Resource and ecosystem characteristics

Water resources and challenges over the next fifty years

Many of the world's aquifers are declining and are on a path many consider to be unsustainable (Richey et al., 2015). Current management, policies, and institutions in place are not sufficient to adapt to declining groundwater levels (Gold et al., 2013; Morton 2015). Groundwater policies, for example, vary by state and often lack adequate hydrologic and crop water use data to manage pumping rates (Wohlers et al., 2014). We lack an integration of scientific knowledge, policy scenario evaluation, and the political and social frameworks to extend the life of groundwater resources.

Soil resources and challenges over the next fifty years

Currently, U.S. soils experience soil degradation due to compaction, salinization, acidification, and contamination by anthropogenic compounds, but wind- and water-induced soil erosion that results in deteriorated physical properties, nutrient losses, and reshaped, potentially unworkable, field surface conditions remains the predominant driver (Karlen and Rice 2015). Adoption of conservation tillage helped reduce the potential for water and wind erosion. However, the overall average soil loss rate is one order of magnitude greater than estimated soil renewal rates, which are less than 1 Mg ha-1 per year (Alexander, 1988; Montgomery, 2007).

The second greatest threat to U.S. soils is loss of soil organic matter. Soil carbon levels are only about 50% of the level they were when land was converted from forests or prairies to farmland.

Transport of soil-derived Nitrogen (N) and Phosphorus (P) to waterways is a major problem, and excess application of N continues throughout much of the cropland in the U.S. Although a wide variety of best management practices for optimal nutrient application and erosion control have been developed and promoted, the problems of erosion and nutrient imbalance persist. The linkage of elevated soil N and P levels to water quality problems is exemplified by the seasonal hypoxia in the shallow coastal waters of the Louisiana shelf in the northern Gulf of Mexico (Alexander et al., 2008). The linkage between agricultural practices and N and P loads in waterways has been shown by many studies (Brown et al., 2011; Alexander et al., 2008).

The greatest uncertainty overall in our knowledge about the threats to soil functions lies in our limited understanding of the changes in soil biodiversity in the past and present and the implications of these changes for sustainable soil management. There is no reference baseline data for these organisms, nor do scientists have the ability to estimate the true numbers of soil organisms, particularly microorganisms. Many organisms have not been described and overall we need a better understanding of the biogeography of soil organisms in North America (Núñez and Dickie, 2014). As a result of our paucity of knowledge, assessing threats to soil biodiversity is very difficult. Regional- or national-level programs that monitor soil biodiversity are lacking in North America.

Energy challenges

Although concerns remain for the availability of fossil fuels for energy, we do not believe that this will be as important an issue as it has been for the past half-century. The emergence of new renewable energy technologies, especially for their application to agricultural lands, has tremendous potential in the future. Most farms and forests exist in areas with high potentials for solar, wind, or other renewable forms or combinations of energy-generating technologies. Local application of renewable energy for newly emerging machinery (electric vehicles) and the application of new microbial symbioses to overcome fertilizer limitations and replace pesticide needs has the potential to dramatically reduce the constraints imposed by limits on fossil fuels owing to climate change concerns, monopolizations, or limits on sustainable production.

Biodiversity conflicts and challenges

Agriculture in the U.S., and internationally, feeds the world using only a small fraction of the global plant and animal diversity. This diversity is largely comprised of species brought to the U.S. from elsewhere. Of equal significance, there are mutualisms and pests of pests (friends) that improve domesticated plant and animal production that we scarcely understand. Many of these species are uncharacterized. The greatest diversity of these potential partners exists in protected areas, semi-natural areas, or even around the edges of fields and forests. To sustain food and fiber production and simultaneously reduce fossil fuel, pesticide, and fertilizer overuse, we must improve the understanding, developing, and managing of these potential biological resources, to better manage all lands, including natural areas. This requires that we do a better job of researching and exploiting these potential resources all around us.

Only a few native U.S. animals and plants have been commercially utilized and fewer actually domesticated. Native Americans utilized a wide array of plant species, gathered a wide array of taxa, but farmed few native species. The primary agricultural crops were plant species imported from farther South. The exceptions are sunflowers, amaranths, and chenopods, annuals that grew well in disturbed soils similar to cropping of maize, beans, squash, and chilies. An exception may be pecans, an important nut tree, naturally growing in the southeastern U.S., but grown commercially in the southwestern U.S. There is an on-going discussion as to the potential for many more domestications among both plants and animals. There are no remaining large animals that could easily be domesticated. While bison is harvested and commercially sold, the actual domestication of bison is questionable; many researchers view bison ranches as more in common with wild rangelands. Importantly, extensive collections of pinōn, mushrooms, and other food sources indicate that there is a diverse array of potential crops that are less disruptive of soils and climate and that could potentially be domesticated. The preservation of biodiversity remains an important potential source of new agricultural productivity.

While the potential for new domesticated plants and animals continues to be debated, there is a strong potential for protection, selection, and utilization of mutualist symbionts that can increase the accessibility and efficiency of nutrients and water, provide pollinators, and provide protection from disease. Most of the mutualistic microbes employed (intentionally or not) in agriculture are from pre-agricultural ecosystems, or invade crops from surrounding ecosystems. Most crops and all trees depend upon mycorrhizal fungi for soil resources (nutrients, water), and almost none are intentionally transferred between countries. But most plants simply utilize the local microbial symbionts, regardless of source. source. A few microbes appear to have become invasive, such as *Amanita phalloides* and *A. muscaria,* and may well have both positive (nutrient acquisition) and negative (poisoning) attributes. Some N-fixing symbionts have also invaded agricultural systems and others (alfalfa, introduced from central Spain) are inoculated, wherein the original source populations are unknown. We do not know how diverse these populations are. For example, in analyzing the highly diverse ectomycorrhizal community only 69 of approximately 150 taxa could be matched, using a molecular approach, to known taxa with a 98% similarity criterion. Nearly two-thirds have similarity values as low as 85% and many are simply unknown. What we do know is that there is a vast array of responses from native and introduced populations from positive to negative. These responses often depend on the host, the soils, and the environment. In both the cases of mycorrhizal fungi and rhizobial N-fixers, there has been little selection or management among taxa to optimize plant production in the field. This means that there is a huge untapped microbial pool for enhancing resource acquisition as the environment shifts. *To reduce chemical and energy dependencies, symbiotic mutualisms hold a great deal of promise.*

In a similar vein, pollinators are absolutely critical to a vast array of crops. Most pollination is commercially undertaken by an industry managing European honeybees. Yet, because of many factors, including disease, mixing and migration of hives, and the use of pesticides, these commercial pollinators are becoming limiting to agricultural production. There are many native species that have enormous potential for improving crop pollination. Alkali bees are known to pollinate alfalfa fields in many regions across the western U.S. A vast diversity of bumblebees pollinate home gardens and commercial tomatoes. Work by many researchers have demonstrated that simply carefully managing field edges and waterways, along with neighboring wildlands, can sustain a diverse pollinator community and enhance crop productivity.

The vast biodiversity across the U.S. could improve disease resistance by providing pests of pests both within the U.S. and abroad. USDA European Biological control labs have provided numerous biological control agents for pests. Researchers across the country have found many pests of pests that can be utilized to sustain plant production. Examples include U.S. natural enemies of the Colorado potato beetle that are effective in beetle control both in the U.S. and in Europe. The glassy-winger sharpshooter is an insect native to the U.S. that transmits *Xylella fastidiosa* bacteria among a wide array of plants, including grapes, citrus, oleanders, sycamores, and even olives. The sharpshooter (*Homalodisca vitripennis*) is attacked by a native U.S. egg parasitoid, *Gonatocerus ashmeadi* (Hoddle and colleagues). This is an area that has only been marginally utilized for agriculture and has a remarkable potential to improve production while reducing pesticide dependency. Just as important, the potential to utilize native viruses, found in wildland ecosystems, to control disease microbes has not yet been effectively tapped. An example is the double stranded RNA (dsRNA) viruses. *Cryphonectria parasitica* is the causal agent of chestnut blight, changing a common and commercially important forest tree to an understory species that resprouts from older trees. dsRNA viruses can render *C. parasitica* hypovirulent and can facilitate tree regrowth. Many of these dsRNA viruses appear to be hybrids resulting from mixes of dsRNA from multiple sources. Importantly, dsRNA viruses are horizontally as well as vertically between hosts.

In general, there has been little effort to utilize natural biological resources in animal production. The isolation and application of bacteriophages for control of Salmonella is only one example of a search for biological controls. Moreover, an understanding of diseases in wild pig populations could prove to be a boon for the management of disease agents in domesticated pigs, thus for production. We predict that as antibiotic resistance increases, a clear need for alternative strategies could well come from the rich biodiversity surrounding all agricultural systems.

Broadly, there is an incredible biodiversity of useful insects and microbes, the potential for which has only been marginally tapped. Overexploitation of wildlands and loss of field and plantation margins in overzealous production efforts actually reduces or eliminates this diversity before it is studied and utilized. Maintaining wildlands, forests, rangelands, land margins, and riparian strips can play a critical role in sustaining future agricultural production. This will become even more apparent under climate change. We are already seeing a migration of mosquitos and mosquito-borne diseases northward, and with warming trends, expect an increased invasion by new pests of agricultural plants and animals. Understanding the ecology of these pests, their native host range, and especially their parasites and predators, is essential to designing new strategies to combat new emerging problems.

Implications of forestry trends

Forests in the U.S. have been a dominant feature of the North-American continent for millennia. Nevertheless, there have been dramatic shifts in cover, and utilization of forests, especially since European contact with the New World in 15th century. Following the heavy mortality in the human population in the Americas (including what is now the U.S.), there appears to have been a large reforestation of lands that reduced atmospheric CO_2 between 7 and 10 ppm – a dramatic shift in global CO_2 levels. In the 1630s, about 46% of the contiguous U.S. was forested land, which declined until the late 19th century where occupancy stabilized between 33-34% of the land area.

The forests are managed differently across the U.S., with 70% in public lands in the semiarid West (although the Pacific coastal forests are heavily privately owned) whereas the East is mostly privately held (81%) with public lands in highly dispersed patches, often in military-managed lands.

Importantly, non-lumber products are also important to local economies, including mushrooms, livestock, game, and arts and crafts. Forests are also crucial for ecosystem services, including sequestering 15% of the total greenhouse gases.

Growing forest tree stock volume is increasing in all areas, although especially in eastern U.S. Forests have played and continue to play a major role in ecosystem services. These include significant increases over the past two decades in carbon sequestration (15% of total greenhouse gas emissions), water production and purification (the Sierra Forests are described as water towers, providing irrigation water for the Central Valley and southern croplands of California), and biodiversity/endangered species protections.

Unlike agriculture, wood consumption has exceeded domestic production since the late 19th century. Although the 2008 recession reduced lumber production and consumption, still 79% of lumber was domestically produced and the remainder imported in 2011. That importation itself triggered the biggest threat to forest production through the continued import of disease agents. The chestnut blight fungus, *Cryphonectria parasitica*, is only one of the most dramatic examples, destroying the American Chestnut from the southern Appalachians to Michigan and New England. Many other serious diseases have come either from invasive microbes, such as *Phytophthora ramorum* in oaks (sudden oak death, moved through importing ornamental plants) or from (likely) native microbes spread by invasive insects, such as *Neonectria faginata* in beech, which rapidly spread by *Cryptococcus fagisuga*, a scale insect from Europe. Other insects are invading, ranging from the woolly adelgid Adelges tsugae of hemlock to the gypsy moths *Lymantria dispar* from Europe and Asia devastating to the northeastern oaks, to the goldspotted oak borer (*Agrilus auroguttatus*) being moved to southern California from Southeastern Arizona in firewood.

The largest impact on forest production into the future will emerge from the interactions of multiple threats, specifically invasive pests superimposed on pollution patterns and climate change. In the NorthEast, the woolly adelgid is migrating inland and northward as winter temperatures warm allowing greater survival of the insect. In the Sierras, ponderosa (*Pinus ponderosa*) and sugar pines (*Pinus lambertiana*) are showing massive mortality due to drought and bark beetles. Importantly, incense cedar (*Calocedrus decurrens*) appears to not be showing this mortality. Bark beetle damage is especially sensitive to drought stress. In an experimental nitrogen addition test, pinōn pines (*Pinus edulis*) were sensitive to N additions, simulating N deposition from air pollution, but not junipers (*Juniperus monosperma*). Importantly, junipers and incense cedar form arbuscular mycorrhizal symbioses, a primitive mycorrhizal symbiosis that appears to be less sensitive to drought and to high N than ectomycorrhizae found in pines. That the highest mortality is in the West slopes at the mid-elevation range, an area with high N pollution, presents a pattern reminiscent of the drought and tree mortality on the West-facing slopes of the transverse ranges of California in 2003. The drought impacts in both areas are exacerbated by forest fire suppression and subsequent stand densification. In the interior Rocky Mountains, a warming climate lengthens the drought period in Pinaceae forests and intensifies drought. With drought, warming, and fire prevention, bark beetle damage can be found from New Mexico to Montana. *A perfect storm of climate change, air pollution, invasive species, and mismanagement threatens the long-term production of forests of the U.S.*

Potential impacts of climate change

Population growth and the dynamics of climate change will also exacerbate other issues, such as desertification, deforestation, erosion, degradation of water quality, and depletion of water resources, further complicating the challenge of food security (Delgado et al., 2011). Increases in temperature coupled with more variable precipitation will reduce productivity of crops (Walthall et al., 2012). While the effects vary among regions of the U.S., all production systems will be affected to some degree by climate change. The continued degree of change in the climate by midcentury is expected to have overall detrimental effects on most crops and livestock. The predicted higher incidence of extreme weather events will have an increasing negative impact on agricultural productivity (Walthall et al., 2012).

Building resilience to extreme events

The vulnerability of agriculture to climatic change is strongly dependent on the responses taken by humans to moderate the effects of climate change. Adaptive actions within agricultural sectors are driven by risk, direct effects of climate change, and by changes in markets and policies, within the U.S. and worldwide. Effective adaptive action across the U.S. agricultural system offers potential to capitalize on emerging opportunities and minimize the costs associated with climate change. Delgado et al. (2011) listed several strategies to adapt to climate change in production agriculture including adjustments to inputs, tillage, crop species, crop rotations, and harvest strategies.

Future Outlook

We have known, since the classical studies of John Tyndall in 1861 and especially Svante Arrhenius (1895), that CO_2 molecules absorb re-radiated infrared radiation, retaining heat at the global scale. Global temperature data show that temperatures continue to increase, altering storm and ultimately precipitation temporal and spatial distributions. Every global-scale computer simulation model agrees that temperatures will continue to increase for a century or more at the least. Of greatest concern, not only the means are predicted to increase, but the variance also increases. Just as with any bell-shaped curve, the result is a dramatic increase in extreme events, such as extreme and prolonged high temperatures, and increased intensity and/or frequency of major storms. Pests are known to respond unpredictably to environmental change and extreme events. We project that novel pests, and increasing outbreaks from known pests, should be expected in the future. Agriculture must develop strategies to continue production under these conditions. It is important to recall that many of our beneficial organisms have existed under past spikes of high CO_2 and warmer environments caused by natural phenomena such as high volcanic activity (the Eocene Thermal Maximum). Working with the natural biodiversity capital of mutualistic organisms can provide new approaches and concepts to address the impacts of climate change and the overexploitation of land resources.

4. Technology and Innovation

Agriculture and food production have been impacted by many of the same trends that have resulted in rapid changes in general consumer products. For example, decreasing size and efficiency of microprocessors, sensors, and cameras that are used for mobile phones have found agricultural applications in pilotless "drone" aircraft. Drones are employed for remote sensing and collecting a wide variety of data in plant breeding and agronomic research. One advantage of drones for agricultural applications is that they are very inexpensive to operate; thus, they can be used with great regularity, resulting in time series data on crop field conditions. In a similar manner Light Detection and Ranging (LiDAR) that is being rapidly developed for use in self-driving cars can be employed in very similar precision agriculture applications. Agriculture is likely to continue to benefit from rapid technological advancement in areas such as artificial intelligence, real-time composite imaging from multiple cameras, and related technologies that have multiple applications for the general public and obvious extensions to agriculture.

Commercialization of biotechnology has developed more slowly. One of the most important early steps in the application of biotechnology to crop development began in 1994 with the commercial release of the Flavr Savr tomato. A large proportion of commodity crop production in the U.S. makes use of Genetically Modified Organisms (GMO) varieties. However, only four crops, canola, cotton, maize, and soybean, account for most of the production area planted with GMO. Insect resistance and herbicide tolerance are among the most common transgenic modifications, with virus resistance and altered oil compositions also found in two or more crops. The expense of development and of navigating the regulatory process associated with transgenic products, along with reluctance on the part of the general public to accept GMO products, have limited GMO applications.

The application of GMO technology to animals has been much more limited than in plants. Public acceptance certainly plays a role. Another consideration is that "single seed descent," self-fertilization, and high levels of backcrossing that are possible in plant inbred lines that are used for genetic transformation are not possible in mammals. In most animals, the presence of two distinct sexes and the detrimental effects of inbreeding mating designs will limit deployment of GMO. One notable exception with regard to a genetically modified animal is instructive. *Zebra danios*, a common freshwater aquarium fish that has been commercially available in the U.S. since 2003, has been modified with florescent proteins and is commercially available in a number of different colors. The Food and Drug Administration determined that because aquarium fish are not a part of the human food supply, they pose minimal risk to human health.

There is tremendous potential for novel agricultural products that build on the technological developments noted earlier. For example, DNA sequencing and genotyping of specific genetic markers has become much less expensive in the last decade. This has made it possible to identify large numbers of microbes by sampling soil, water, and even human and animal gut flora. The identification of much more diverse microbial flora in humans has resulted in novel treatments for gastrointestinal disorders. In a similar manner, the potential to survey soil microbes and microorganisms should make it possible to rapidly detect particular strains of plant pathogens and to more readily reintroduce or promote bacterial or fungal species that contribute to plant nutrition and productivity for particular crops. Sequencing also has many applications in detecting, tracking, and treating diseases in farm animals.

Targeted genetic modifications have the potential to result in a large variety of novel agricultural products. A much broader array of agricultural products are likely to be produced if organisms subject to a targeted genetic modification are treated as nontransgenic, thus not subject to standard GMO regulations. This is quite possible, because under many scenarios, an individual subjected to a targeted modification carries no evidence of that change (for example, no transgene), other than the change itself, which can be as subtle as a single nucleotide substitution. Targeted modifications have been proposed for a variety of applications, including modification of lipid composition in oil seed crops, changes in nutrient utilization, or changes in inflorescence type in cereals. Many additional applications are possible, suggesting that many more species could be subject to modification than has been possible for traditional transgenic products. Targeted modifications could also be used to treat specific genetically induced diseases, an application that might be particularly compelling in agriculturally important animals. However, the regulatory environment around changes in animals is likely to remain more stringent, in part because of concerns about animal welfare.

Pests, Diseases, and Mutualists

Pests and diseases of agricultural plants and animals have plagued human cultures throughout history and remain the single biggest challenge to agricultural production in the U.S. and globally. U.S. Agriculture has benefitted from three major processes: (1) the introduction of most major crops, leaving behind many disease organisms; (2) the ability of many crops to tap novel mutualists, enhancing stress tolerance, and (3) an outstanding, well-funded cooperative research interaction among federal, state, university, and private partnerships that can rapidly mobilize to identify, research, and attack diseases. However, all three are threatened by human travel, biodiversity loss, and funding priority shifts.

Theory of disease progression has been a major focus of research agencies and agricultural university scientists for as long as the agents of disease have been recognized. The identification of the causal agent of the Irish potato famine as *Phytophthora infestans*, a microscopic fungus, not humors, or vapors, or lightning, or even witches, led to the field of Pathology. Advances in basic understanding of disease from microbes to insects continues and is expected to continue into the future.

The emergence of the "enemy release" hypothesis shows how crop and tree disease issues continue to emerge and has major ramifications requiring both care for the transport and sale of products, the impacts of bureaucratic constraints on research, and the importance of collaborative international research. The vast majority of crops and animals used in the U.S. come from wild sources outside of the U.S. borders. When these were introduced, many of the diseases and the enemies of the enemy, critical for biological control, were left behind where the wild populations exist. With time and international travel and trade, slowly but inexorably these diseases continue to "emerge", and disperse to and infect important U.S. hosts. In some cases, the time frame for invasion can be very long, especially when an intermediate vector, such as an insect transmission species, must invade first, followed by the invasion of the actual disease agent, such as a bacterium or fungus. Historical examples include *Phytophthora* diseases of grapes, and current examples include the HuangLongBing (HLB) or "citrus greening" disease or swine influenza (H1N1). A variant is introduction of pests from related host taxa, such as the chestnut blight, *Cryphonectria parasitica*, on the American Chestnut (*Castanea dentata*) found naturally in the Chinese Chestnut, *Castanea mollissima*, which had evolved resistance to the *C. parasitica*. A third variant of the enemy release hypothesis is the emergence of hybrid strains from the introgression of genetic material from two or more original strains that results in one capable of infecting new hosts. An example is work on *Xylella* mulberry scorch diseases (Almeida and Nunney 2015).

Emerging "new" diseases will continue as long as there are crops. Further, as long as crops continue to be transported across borders, diseases will be transferred from a source population to a novel population. The only solution is the identification of potential threats through international cooperation among research agencies and universities, and the collaborative ability to search for and utilize biological control agents. The USDA European Biological Control laboratories located in France, Italy, and Greece is an outstanding example of cooperative efforts to identify and control diseases of important crop plants. Especially, the search for pests of the pests that become valuable control agents requires constant international cooperation. However, this potential could easily be lost if funding for collaborative efforts shifts, or if international collaborations are threatened.

A final concern is the loss of biodiversity associated with global change and with shifting land use patterns. The wild relatives of domesticated plants and animals have evolved resistance mechanisms that could be preserved and tapped by understanding and protecting the original gene pools. Just as importantly, microbial mutualisms provide protections beyond the genetic resources of the species itself. These mutualisms are also threatened by a general loss in wildland biodiversity as microbial symbionts often cross-taxonomic constraints of the individual species or populations.

Opportunities for and obstacles to new management technologies (e.g., in irrigation and water management or fertilizers) and policies

The current management, policies, and institutions in place are not sufficient to adapt to declining water resources (Gold et al.,2013; Morton, 2015). Groundwater policies, for example, vary by state and often lack adequate hydrologic and crop water use data to manage pumping rates (Wohlers et al., 2014). Considering nutrient management, many effective current technologies are not utilized because economic and social barriers impede their adoption (Davidson et al., 2015). The economic risk of applying too few nutrients is high. Providing excess fertilizers can improve yields with a marginal increase in cost, thus providing an economic margin of safety. A lack of obvious visible or tangible local environmental and economic consequences of nutrient losses can make further improvements of nutrient management a difficult sell. In most cases, groundwater pollution emerges downstream in space or in time. In addition, most farmers have significant demands on their time and labor, so that learning and adopting new practices requires strategies that are easily implemented and worth their time. In some cases, adoption of cover crops may be inhibited by government policies and crop insurance programs.

Development of aquaculture/ marine resources

The primary challenge to evaluating the sustainability of aquaculture and marine resources remains the need to continuously evaluate the localized and the aggregated production of aquatic environments and determine the fisheries' harvestability. This is especially difficult in aquatic ecosystems because the primary food resource tends to be organisms higher in the food chain. While some species used for human food are herbivores, most of these tend to be just above the base (primary producers) of the food chain. What we consider the desirable foods are either higher trophic structure (salmon, tuna, trout) or even detritivores (many shellfish).

The U.S. remains a net importer of edible fishery resources, importing more than triple the dollar value of exports. By biomass, domestic landings exceeded exports by nearly 10%, but catch was still below imports by approximately 20%. There is certainly considerable variation by species and by the particular product, but the trends in consumption remain steady to declining (http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus15/index). In the context of food sustainability, U.S. fisheries are one of the more troubled topics-of-concern and in need of further research. Overfishing has been reduced, based on NOAA estimates, but 10-20% of commercial fisheries remain overfished in 2015 in the U.S.

Aquaculture remains a technology for a limited suite of commercial products, (e.g., salmon, oysters, clams, mussels, shrimp, catfish, tilapia) but provides a large fraction of the hatchery populations, contributing to both commercial fisheries and sport fishing. Although research in new technologies and how aquaculture interacts with ocean ecosystems is undertaken, this area has been clearly undervalued in the larger context of food sustainability within the U.S. As the population of the U.S. continues to grow, along with global populations, aquaculture will likely become an increasingly crucial food resource and contribute to the sustainability of fisheries broadly.

Threats to fisheries' sustainability continue to exist, in many cases, mimicking those of other areas of food production. These include pollution, invasive species, and global change, especially climate and direct impacts of elevated CO_2.

Aquaculture, once the greatest concern for pollutants and genetic declines in wild stocks, has become increasingly addressed by industry and regulation. There remain a number of critical issues, especially diseases, medications, and habitat quality. Care in the selection and escape of genetic modifications, whether intentional or simply selection in artificial environments versus the wild ecosystems, remains of concern. As we look toward a 50-year horizon, aquaculture will likely become an essential approach to fisheries' management both as an increasing food source and to reduce over-harvest from demands by U.S. and global consumers.

Pollution remains a critical problem for sustainable fisheries. Movement of nutrients and chemicals from aquaculture will likely be a growing problem as human population continues to grow and demands for aquaculture products continue to escalate. But oceans are not independent of terrestrial environments. Pollution by N and P from runoff has impacted fisheries and threatened fishery sustainability throughout history. Classical studies on places such as Waquoit Bay, Cape Cod, Massachusetts, have demonstrated that nutrient loading from development has dramatic impacts on estuaries, and even out into the open oceans, through wastewater and fertilizer impacts on N and P cycling (e.g., Bowen and Valiela 2004). Chesapeake Bay fisheries and seafood production remains detrimentally affected by development and by animal husbandry up the Potomac River. Efforts to improve the water quality of the Bay continue, often through simple approaches such as ribbon forest restoration.

Pollution, especially runoff, also appears to be a major driver of red tide and other harmful algal and cyanobacterial blooms that can produce neurotoxic shellfish poisoning.

Invasive species

As human populations become increasingly connected in both the amounts and speed of global trade and human movement, invasive species become of equal or greater importance than terrestrial invasions. There are multiple vectors, although improved understanding of invasions has reduced the impacts of some. biofouling of vessels, including recreational vessels, fishing vessels, and commercial shipping, all remain critical contributors to marine invasions. Moreover, imported seafood, ornamentals, bait, aquaculture, and ballast water all remain critical vectors. As Williams et al. (2013) and others have stated, there is a crucial need to address these impacts at the nexus of a multiplex of problems, and not simply focus on each individually.

Climate change has a variety of impacts on the sustainability of fisheries of the U.S. Temperature increases without doubt alter the composition of microbes, flora, and fauna of a particular region. Changes in global temperatures may well alter current global air circulation patterns with dramatic impacts on ocean circulation patterns. At more regional scales, water diversion patterns may result in the loss of critical links in complex food chains. An example is the Delta Smelt, a small native fish in the San Francisco and Sacramento-San Joaquin Delta that is dependent upon freshwater inputs and the freshwater/saltwater interface. With increasing drought coupled with water diversions to agriculture and urban developments, reduced and altered water flows threaten this small fish. Yet, this animal is a key link and indicator in the food chain that integrates the San Francisco Bay with the larger fisheries running off the California coast, including juvenile salmon and steelhead, and the larger species that depend upon these anadromous fishes.

Atmospheric CO_2 inputs affect more than just climate (Albright et al. 2016). Dissolved calcium is required by shellfish, such as oysters, mussels, and corals. Of importance to climate change, the oceans represent the largest sink for absorbing the increasing atmospheric CO_2. Since the 1950s, atmospheric CO_2 has increased from 320 ppm to over 400 ppm. Simultaneously, surface water ocean pH has gone from 8.13 to 8.03, a loss of 0.1 pH unit. As pH units, the measurement unit of alkalinity, are logarithmic, this means a nearly 30% increase in acidity. Decalcification decreases in dissolved carbonate in seawater as pH decreases. This means that the solubility of calcium carbonate increases and dissolution or reduced calcification then occurs. The calcium that builds shells of calcium carbonate for shellfish, such as oysters, mussels, and corals, is preferentially absorbed by the bicarbonate in the water caused by the additional partial pressure of CO_2. The result is increasing calcium carbonate in the water and the loss of shell formation and mortality of corals. These animals are not only important in themselves, but are builders of reefs, critical structural elements to ocean fisheries. This process has occurred before, so we know that this response is real. During the Paleocene-Eocene Thermal maximum, under a high level of CO_2 and a 5°C temperature increase, the pH of the deep ocean dropped and coral and shellfish production appears to have declined. About 300 million years ago, at the end of the Carboniferous, with high CO_2 and high global temperatures, coral reefs nearly disappeared. The impacts on global and U.S. fisheries remain unknown but are potentially highly significant.

5. Increasing efficiency of food systems

Prospects for technology based increases in agricultural production

Telematics allow navigation, prescription application, location, and other data to be transferred easily to and from farm machinery. These systems help farmers improve efficiencies in high-priced equipment.

Soil and crop sensors to monitor plant health, crop water needs, and soil nitrogen levels. These sensors enable on-the-go application of inputs based on real-time field conditions. Sensors help optimize water use and avoid yield loss. Optical-sensing technologies detect crop N levels that can communicate with application systems to apply the correct amount of nitrogen to meet crop needs.

Sensor technology also is available to measure soil features such as soil electrical conductivity, ground elevation, organic matter content, and pH. Another type of sensing system is satellite or aerial imaging to detect crop health, pests, and weeds. Growers can then apply nutrients and pesticides based on a prescription from the remote sensing images.

Biologicals are expected to increase in the future. Pest control and growth enhancements provide more environmentally-friendly and cost-efficient crop inputs. Advanced technologies such as high-throughput screening help to identify beneficial organisms.

Precision agriculture technologies are becoming more robust and more precise, ushering in an era of hyperprecision. The widespread adoption of navigation systems is driving the hyperprecision era and have allowed for precise and variable rate seeding and fertilizer applications. Controlled traffic systems, such as strip till and precise installation of drainage tile, are also possible with precision agriculture.

Automation is taking over operation of equipment, which allow operators to do more jobs with less strain and more accuracy. Some of the features include GPS steering, GPS headlands turning, conventional headlands programmable automation, automatic balers, automation of operator control of combines and forage harvesters, and automation of tractor operator functions like intelligent power management. Autonomous or robotic vehicles could be the next big change in controlled steering technology.

Seed companies are developing corn hybrids with the ability to better use available nitrogen by producing the same amount of corn with less applied nitrogen or improved yield with the same amount of nitrogen.

Radio Frequency IDentification, or RFID, has been widely used in livestock to identify animals. This technology will expand to crops to allow consumers to track individual products from cradle to grave as consumers want to know how farmers grow their food and what inputs they are using to determine environmental impacts.

Biotechnology allows alteration of many different factors involved in a plant's growth under water-restricted and high-heat conditions to find new keys to improving yields under environmental stress.

Infrastructure needs (e.g., transportation systems)

U.S. agriculture relies heavily on a transportation system that includes rivers, rail, and roadways.

Farmers and ranchers need the ability to move products, inputs (fertilizer), and equipment. U.S. transportation as a whole needs drastic upgrades to allow for efficient movement of goods. Agriculture is the largest user of freight transportation in the U.S., claiming 31% of all ton-miles transported in the U.S. in 2007 (Casavant et al., 2010). Much of this freight travels out of the country. During the past 5 years, half of U.S. wheat was exported, along with 36% of the soybean crop and 19% of the corn crop. These exports travel from the inland areas of the U.S. where they are produced to borders and ports by way of a network of trucks, trains, and barges. Trucking is critical for U.S. agriculture. The industry carries 70% of the tonnage of agricultural, food, alcohols, and fertilizers (Casavant et al., 2010). It links farmers, ranchers, manufacturers, and service industries to grain elevators, ethanol plants, processors, feedlots, markets, and ports. The first and last movements in the supply chain from farm to grocery store are by truck. Many agricultural products are perishable and time-sensitive, requiring the efficiency, special handling, or refrigerated services best provided by trucks. Existing bridge capacities requires investment in highways.

Significant and sustained growth in freight demand is expected, and could double by 2035 (Casavant et al., 2010). Investment in the railroad industry, however, is not expected to keep up with demand, especially in agricultural areas. This shortfall of investment could threaten the U.S. competitive position as a low-cost supplier of high- quality grain.

Barges offer a low-cost transportation alternative for moving crops and fertilizer. Barges move more than a third of U.S. corn exports and 17% of soybean exports through the New Orleans region along the Mississippi River (Casavant et al., 2010). The funding to maintain and rehabilitate the existing infrastructure needs to remain a priority.

Issues for food utilization and minimizing waste

In the U.S., 31% of the 195 MMT of the available food supply in 2010 went uneaten. Retail-level losses represented 10% and consumer-level losses 21% of the available food supply (Buzby et al., 2014). Recovery costs, food safety considerations, and other factors would reduce the amount of food that could actually be recovered for human consumption.

Food versus Energy

In terms of total production per unit land area and in number of permanent and migratory farm workers, the U.S. is easily the most productive country globally. However, U.S. agriculture is energy-dependent on foreign imports (40%) relative to other countries. Indeed, one of the primary limits to agricultural production in the U.S. is energy security (i.e., uninterrupted availability at an affordable price). Today, energy expenditures supporting U.S. agricultural productivity (e.g., equipment manufacture and use, fertilizer production) are among the largest expenses. In the coming decades, two additional conditions may further constrain production: (1) availability and affordability of energy used for fertilizer and pesticide production, and (2) a scarcity of land for both energy and food production. And, as most energy use remains tied to fossil fuels, CO_2 and methane production and release from agriculture into the atmosphere exacerbates global warming.

Over the past decade, observed and predicted shifts in the use of prime agricultural lands for biofuel production has raised concerns over their role in unintended land-cover changes (e.g., deforestation) elsewhere leading to no net positive or enhanced net greenhouse gas emissions ("leakage"). Demonstrating further complexity, many utility-scale renewable energy installations that may support, in part, the energy demands of grid-connected farmers are being sited on land that was previously natural or agriculturally productive. Site preparation for such large renewable energy complexes typically includes the removal of all aboveground biomass, soil compaction, road construction, and gravel and/or herbicide application. This siting behavior may expand greenhouse gas emissions through reductions or elimination of ecosystem functioning, not to mention the adverse effects on soil quality that may limit reversion back to agriculture. Energy development in the U.S. is now the leading driver of land-use and land-cover[1] change—augmenting losses from urban and exurban development. This trend poses serious land and energy challenges for U.S. agriculture and inhibits progress toward a more sustainable food system.

Nonetheless, careful consideration of financial incentives away from these extractive approaches could readily reinvigorate both food production and integrative energy and food production strategies. Use of solar or wind power generation along field edges, the built environment portion of farms, the salt-affected portion of lands, and floatovoltaics over reservoirs (that reduce algal productivity and potentially generate thermal transfers) could readily generate electrical energy for on-farm hybrid-powered vehicles and energy-intensive tasks. Every farm generates biological waste and diesel distillations at a range of scales are becoming available that could provide an important fuel source. Newer approaches to collect and utilize the energy from methane (CH_4) to CO_2 conversion at dairy or on-farm scales would also provide a powerful energy source immediately located on farms where the energy demands are high. As CH4 is 38 to 75 times as powerful a greenhouse gas as CO_2, this technological shift could be important both for future food production and for climate remediation.

In summary, the U.S. retains the most important food production system globally. Yesterday's agriculture is a major contributor to fossil fuel burning and global warming. Tomorrow's U.S. agriculture could readily utilize and depend upon on-farm energy sources and become a major solution to global warming.

1. land cover, a type of vegetation on the landscape, for example, crops, suburban housing, or forest.

6. Health Considerations Foodborne diseases

Foodborne diseases remain a major concern in agriculture

In fresh produce, approximately 48 million people get sick from foodborne diseases in the U.S. alone, where nearly 128,000 are hospitalized and 3,000 die annually. The major problem is fresh, raw foods, particularly of animal origin (mostly unpasteurized dairy and shellfish) and secondarily, raw fruits and vegetables. Despite high degree of incidence, the control mechanisms in the U.S. are refrigeration, pasteurization and cooking, and sustaining normal standards of water quality.

Four issues emerge as current and future challenges. These include spatial localization of agricultural activities, mishandling along a complex production chain, antiquated diagnostic tests, and antibiotic resistance. In many areas, animal production (feedlots for cattle, swine, chickens) co-occurs with the production of fresh vegetables. Locating feedlots upstream, or upwind of vegetable and fruit production, remains surprisingly common. Simple care in where differing agricultural production activities occur would easily remedy this problem. Care can also be taken as to timing of fertilization, especially manures, and making certain that high-quality water is used for fresh vegetable and fruit production. The complex and intertwining human and machine handling chain, between the producer and consumer, means that foodborne diseases can erupt at any point. New technologies that reduce human handling might reduce some points of disease agent insertion, but continued monitoring and maintenance, and re-design of equipment with food safety in mind, becomes of even greater importance.

Antibiotic resistance is an increasingly challenging arena for research and development. Foodborne microbes behave just like other pathogens. Antibiotic resistance is an evolutionary response by the microbes. Their resistance mechanisms include both rapid regeneration, thus mutation rates and horizontal gene transfer (Verras et al., 2013). These processes mean that resistance should be expected. For fresh vegetables, the sources could be upstream or upwind of animal production facilities, or even humans. Antibiotic resistance should be anticipated and predicted, and new conceptual approaches are needed.

The regulatory mechanism for detecting and anticipating disease emergence often remains plating and identification. This approach was necessary for the last century, but detection kits, rapid PCR (Polymerase Chain Reaction) approaches, and even rapid large-scale sequencing approaches are becoming less expensive and far more rapid. These approaches should be refined and incorporated nearly everywhere. The key issue for all foodborne disease is largely a mentality of safe food handling and careful preparation.

Overconsumption

In a world where concerns continue focusing on sustainability of food resources, an irony exists in that in many regions, the primary concern is overconsumption and obesity (e.g., CDC 2017). More than 36% of adults have obesity-related issues and the highest rates exist in some of the highest agricultural production regions of the country. A plethora of programs and strategies are available, and new approaches can be found at local, state, and national levels. Probably the most important contribution that our food and nutrition security perspective can contribute is to continue to point to the importance of sustainable, high-quality food production and distribution systems. These are documented throughout our report.

7. Policy Considerations

The national government of the U.S. provides support services, extensive research, and education programs to and on behalf of the agricultural sector. It also has regulatory authority to help ensure that the quality of food, both domestically produced and imported, meets modern health and safety standards. Most of the policies that govern these nationally based activities are administered by the U.S. Department of Agriculture, a cabinet-level ministry. The 50 states (and 6 territories) are also involved in agricultural policy making. State policies tend to be focused on the particular circumstances and prevalent crops in each individual state. Below several overarching policy considerations at the national level, related to food and nutrition security and the subject of on-going discussion and debate are enumerated.

Agricultural Support Policies

There currently exist a broad array of policies that provide direct economic support to agriculture in the U.S. These include policies that result in cash payments to growers and acreage limitations. The original intent of such policies was to stabilize the prices of agriculture output and buffer growers against prices so low that they could no longer afford to engage in agriculture. In recent years as the structure of U.S. agriculture has changed these policies have become less prevalent and their future less certain. Recent studies have shown that farm policies have little or no impact on food consumption patterns and the nutrition of the poor (Glauber, Sumner, and Wilde 2016). While it is often asserted that direct economic support to growers must be continued in order to enhance food consumption and nutrition among the poor, the evidence does not support that contention.

Policies of Direct Income Support and Targeted Programs to Alleviate Poverty and Advance Food Security Among the Poor

It is widely held in the U.S. that hunger, inadequate nutrition, and the absence of food security are problems of the poor. The policies focused on ensuring adequate nutrition and food security for all are, therefore, aimed at ensuring that the poor have adequate food and eat high-quality diets. There are three programs governed by these policies. The primary program is called the Supplemental Nutritional Assistance Program (SNAP). Eligibility to participate in this program is based upon income levels that approximate or are lower than the federally defined poverty level. Beneficiaries receive coupons or the electronic equivalent that average USD$125/month. The coupons can be used to buy foodstuffs but not fast food or alcohol. These latter restrictions are intended to ensure that beneficiaries eat a healthful and high-quality diet. For 2016 some 44.2 million people were enrolled in the program. The number varies with the economy with more enrollees during times of economic downturn.

The Expanded Food and Nutritional Education Program (EFNEP) is a community outreach program that operates through the Land Grant University in each state. The program is based on classes taught by paraprofessionals and the priorities are to emphasize the importance of diet quality, food safety, and food security as well as the management of food resources. The program also emphasizes the importance of physical activity. In 2016 80% of the families that participated in the program were below or near the federal poverty level. The program is also directed at youth, about 5 million of whom participate.

The Special Supplemental Nutrition Program for Women, Infants and Children (WIC) is a federal program that provides grants to states for supplemental food and nutrition education. Program beneficiaries are pregnant or breastfeeding women who have low incomes as defined by the federal poverty level. Non-breast feeding postpartum women are also eligible, as are infants and children who are not over the age of 5. In addition, eligibility requires that participants be at substantial risk nutritionally. This risk must be assessed by qualified health professionals at WIC Clinics or other medical facilities. Nutritional risk may be medically-based – such as anemia or underweight – and / or dietary-based – largely poor diets.

The policies upon which these programs are based tend to be noncontroversial though the levels at which they are funded, benefits and criteria for eligibility are sometimes the subject of legislative debate. Policies are clearly focused on the poor and on women and children who may be chronically undernourished. The programs that are based on overarching policies have educational components and sometimes restrictions that tend to ensure that resulting diets are of high quality. These programs also have educational components that emphasize food resource management. The policies that govern and guide these programs will be important elements in sustaining food and nutrition programs for the future.

Policies Supporting Agricultural Research and Technology Development

In the U.S. much agricultural research is carried out by the Agricultural Research Service in the U.S. Department of Agriculture and at the Land Grant Universities in each of the 50 states, the District of Columbia, and the 6 Territories. Additionally, there is a modest amount of proprietary agricultural research conducted in the private sector. Publically supported agricultural research has served the nation well by lowering the costs of food and fiber and by improving the quality of agricultural produce. In spite of this record, the U.S. invests significantly less in terms of dollars invested per dollar of gross domestic product than other developed countries that are agriculturally important. The level of this investment is an on-going policy issue.

There are studies that show that the internal rate of return on investment in agricultural research was 19% during the last half of the 20th century. During that period the percentage of food costs in the average family budget dropped significantly. Willingness to invest in public agricultural research will be important and as well as the related objective of applying science and technology to agriculture to providing adequate food, nutrition, and food security to future citizens as well as to the trading partners of the U.S.

Policies Facilitating and Enhancing Trade in Agricultural Products

In the absence of a globally catastrophic war or extensive isolation of nation-states from each other, the agricultural economy of the world is likely to become further globalized. The U. S. is an important actor in agricultural trade globally and an important actor in hemispheric trade. Mexico and Canada are among its most important trading partners. Effective policy making is needed to facilitate international trade and enhance the flows of produce, implements, and know-how through trade. It is important to recognize that both the U.S. and its trading partners gain from trade. The issue of whether the U.S. should be fully supportive of international trade in agriculture and treaties that govern such trade is now being debated nationally. Policies that constrain such trade and bar related treaties would certainly threaten the ability of the U.S. to be a significant and effective actor in efforts to improve food availability, nutrition, and food security globally and within the hemisphere.

Policies Related to the Protection and Enhancement of Complementary Resources – Land and Water.

Land and water are two critical inputs to agricultural production processes. Arable land is essentially in fixed supply. Although the supply of arable land in the U.S. is large it is not unlimited and careless management of it could result in increasingly tight constraints on agricultural production. Economic growth frequently leads to agricultural land conversion, often to urban uses. Overly intensive use of agricultural lands can lead to desertification, as in the Middle East, North Africa, and elsewhere. It could be visited upon the southwestern U.S, Both public and private land use management will need to be focused more intensively than it has been in the past if additional arable lands are not to be lost to production in the future.

Water is also a critical input to food production. Irrigated agriculture, which is practiced on roughly 7% of crop and pasture land in the U.S., accounts for approximately 3 % of the value of total agricultural production. Irrigated agriculture is the largest consumptive user of water in the country, accounting for about 80% of total consumptive use. In recent years, irrigated acreage has declined due principally to regional droughts and economic downturns. There are, however, a number of factors that threaten to reduce supplies available to agriculture that must be more carefully managed in the future. Groundwater overdraft is a problem for some regions where effective management is absent. Declining water quality limits supply just as surely as drought. The impacts of climate change are uncertain but require farm water management to become more adaptive than it has been in the past.

The policy problems surrounding land and water are complicated because the legislative and administrative authorities over land use, water rights, and on-farm water management rest with state and local government rather than with the national government. Nevertheless, such fragmentation of policy responsibility may be appropriate since requirements for managing land and water resources more effectively differ from state to state and region to region. National policies can be important in encouraging state action by providing financial support and specifying methods and the specific nature of the required response.

Space does not permit a comprehensive survey of all U.S. policy considerations related to the provision of nutrition, and food security. The five policy realms discussed previously are among the most important, however. Among the others are policies for protection of food quality and for combating foodborne diseases; policies to further promote healthful diets, and policies to promote better management of agriculture at the farm level. All are deserving of detailed consideration, debate, and action in the future.

References

Albright, R., L. Caldiera, J. Hosfelt, et al. 2016. Reversal of ocean acidification enhances net coral reef calcification. Nature 531: doi: 10.1038/nature17155.

Alexander, E.B. 1988. Rates of soil formation: Implications for soil-loss tolerance. Soil Sci., 145: 37-45.

Alexander, R.B. & Smith, R.A., Schwarz, G.E., Boyer, E.W., Nolan, J.V. & Brakebill, J.W. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River basin. Environmental Science and Technology, 42: 822-830

Alexandratos, N. and J. Bruinsma. 2012. World Agriculture Towards 2030/2050: The 2012 Revision. ESA Working paper No. 12-03. Rome, Italy: FAO.

Bowen, J.L., I. Valiela. 2004. Nitrogen loads to estuaries: using loading models to assess the effectiveness of management options to restore estuarine water quality. Estuaries 27: 482-500.

Brown, J.B., L.A. Sprague & J.A. Dupree. 2011. Nutrient sources and transport in the Missouri River basin, with emphasis on the effects of irrigation and reservoirs. J. Amer. Water Res. Assoc. 47: 1030-1065.

Buzby, J.C., H.F. Wells, & J. Hyman. 2014. The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States, EIB-121, U.S. Department of Agriculture, Economic Research Service, February 2014.

Casavant, K., M. Denicoff, E. Jessup, A. Taylor, D. Nibarger, D. Sears, H. Khachatryan, V. McCracken, M. Prater, J. O'Leary, N. Marathon, B. McGregor, & S. Olowolayemo. 2010. Study of Rural Transportation Issues, U.S. Department of Agriculture, Agricultural Marketing Service.

CDC. 2017. Overweight and Obesity. (https://www.cdc.gov/obesity/).

Delgado, J.A., P.M. Groffman, M.A. Nearing, T. Goddard, D. Reicosky, R. Lal, N.R. Kitchen, C.W. Rice, D. Towery, & P. Salon. 2011. Conservation practices to mitigate and adapt to climate change. J. Soil Water Conserv. 66:118A-129A

FAO and ITPS. 2015. Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.

Fuglie, K.O. & A.A. Toole. 2014. The evolving institutional structure of public and private agricultural research. Am.. J. Agr. Econ. 96: 862-883.

Glauber, J.W., D. SmnerN.B. and P.E. Wilde. 2016. Effects of Farm Policy on Food Consumption Patterns and Nutrition of the Poor in the United States. American Enterprise Institute, December. 34 pp.

Goecker, A.D., E. Smith, J.M. Fernández, R. Ali, R. Thelle. 2015. Employment Opportunities for College Graduates in Food, Agriculture, Renewable Natural Resources, and the Environment United States, 2015-2020.

Gopnik, A. 2017. The illiberal imagination. The New Yorker, March 20, 2017, pp. 88-93.

Grandgirard, J, Hoddle, M.S., Petit, J.N., Roderick G.K., and Davies, N. 2008. Engineering an invasion: classical biological control of the glassy-winged sharpshooter, Homalodisca vitripennis, by the egg parasitoid Gonatocerus ashmeadi in Tahiti and Moorea, French Polynesia. Biological Invasions 10: 135-148. DOI 10.1007/s10530-007-9116-y

Karlen, D.L. & C.W Rice. 2015. Soil degradation: Will humankind ever learn? Sustainability 7:12490-12501. doi: 10.3390

Lewis, S.I. & M.A. Maslin. Defining the anthropocene. Nature 519: 171-180.

Lockwood, J.A. 2004. Locust. N.Y.: Basic Books.

McLauchlan, K.K., S.E., W.M. Hobbie. 2006. Conversion from agriculture to grassland builds soil organic matter on decadal timescales. Ecological Applications 16: 143-153.

Montgomery, D. 2007. Soil erosion and agricultural sustainability. Proceedings of the National Academy of Science, 104: 13268-13272

Núñez, M.A. & I.A. Dickie. 2014. Invasive belowground mutualists of woody plants. Biol. Invas. 16: 645-661.

Ogle, S.M., F.J. Breidt, M. Easter, S. Williams, K. Killian & K. Paustian. 2010. Scale and uncertainty in modeled soil organic carbon stock changes for USA croplands using a process-based model. Global Change Biology 16: 810-822.

Oswalt, S.N. & W.B. Smith. 2014. U.S. Forest Resource Facts and Historical Trends, USDA. FS-1035.

Ryther, J.H. 1969. Photosynthesis and fish production in the sea. Science 166: 72-76. (URL: http://www.jstor.org/stable/1727735).

USDA Agricultural Projections to 2024. Office of the Chief Economist, World Agricultural Outlook Board, U.S. Department of Agriculture. Prepared by the Interagency Agricultural Projections Committee. Long-term Projections Report OCE-2015-1, 97 pp.

Verraes, C., S. Van Boxstael, E. Van Meervenne, E. Van Coillie, P. Butaye, B. Catry, B. L. Herman. (2013). Antimicrobial resistance in the food chain: a review. International Journal of Environmental Research and Public Health 10(7): 2643--2669. (http://doi.org/10.3390/ijerph10072643).

Walthall C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, M. Aillery, E.A. Ainsworth, C. Ammann, C.J. Anderson, I. Bartomeus, L.H. Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M. Dabney, J.A. Delgado, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D. Goodrich, S. Hu, R.C. Izaurralde, R.A.C. Jones, S-H. Kim, A.D.B. Leaky, K. Lewers, T.L. Mader, A. McClung, J. Morgan, D.J. Muth, M. Nearing, D.M. Oosterhuis, D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, C. Rice, M. Rivington, E. Rosskopf, W.A. Salas, L.E. Sollenberger, R. Srygley, C. Stöckle, E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright-Morton & L.H. Ziska. 2012. Climate Change and Agriculture in the United States: Effects and Adaptation, USDA Technical Bulletin 1935, Washington, D.C. pp. 186.

Williams, S.L., I.C. Davidson, J.R. Pasari, et al. 2013. Managing multiple vectors for marine invasions in an increasingly connected world. BioScience 63: 952-966.

Box 6

Problems of Effective Public Policy-Making: The Case of U.S. Biofuels Policy

Henry J. Vaux, Professor & Associate Vice President Emeritus, University of California.

The making of effective public policy is not always straightforward and without difficulties. Policies sometimes fail to achieve the desired objectives and sometimes create unwanted and unintended consequences that were not foreseen. There are several common pitfalls in the making of public policy. Among them are: 1) the possibility that policies may end up being based on facts and/or assumptions that are either incorrect or no longer hold; 2) the possibility that policies may fail to embody or acknowledge recognition of all of the important interdependencies present in the broad social, political and biological environments to which they are addressed; and 3) in complex and highly variable environments it is difficult to fashion policies that account for important variations between regions or domains while still making them effective. U.S. policies that promote the production and consumption of biofuels appear to have run afoul of each of these pitfalls.

In the early years of the 21st century energy policy was fueled by two concerns. The high price of crude oil drew continuing attention to the lack of energy security in the U.S. Emissions of carbon dioxide and other greenhouse gases were increasingly visible in the face of concerns over global warming. In response, the Congress passed the Renewable Fuel Standard as part of the Energy Policy Act of 2005. In 2007 the Energy Independence Act amended the Renewable Fuel Standard to mandate the production of 21 billion gallons of advanced biofuels and 15 billion gallons from corn based ethanol, both by 2022. Advanced biofuels include so-called cellulosic biofuels derived from woody, perennial plants as opposed to corn that is used to make ethanol that was the dominate biofuel at the time. The mandate of sharply increasing level so cellulosic and other advanced biofuels was apparently desireable because production and consumption of such fuels was thought to entail lower production of greenhouse gases than comparable quantities of hydrocarbon. By contrast corn-based ethanol fuels contribute at least as much or more greenhouse gases than hydrocarbon fuels. Biofuels in general have the advantage that they come from domestic sources and to the extent that they replace imported hydrocarbons contribute to energy security.

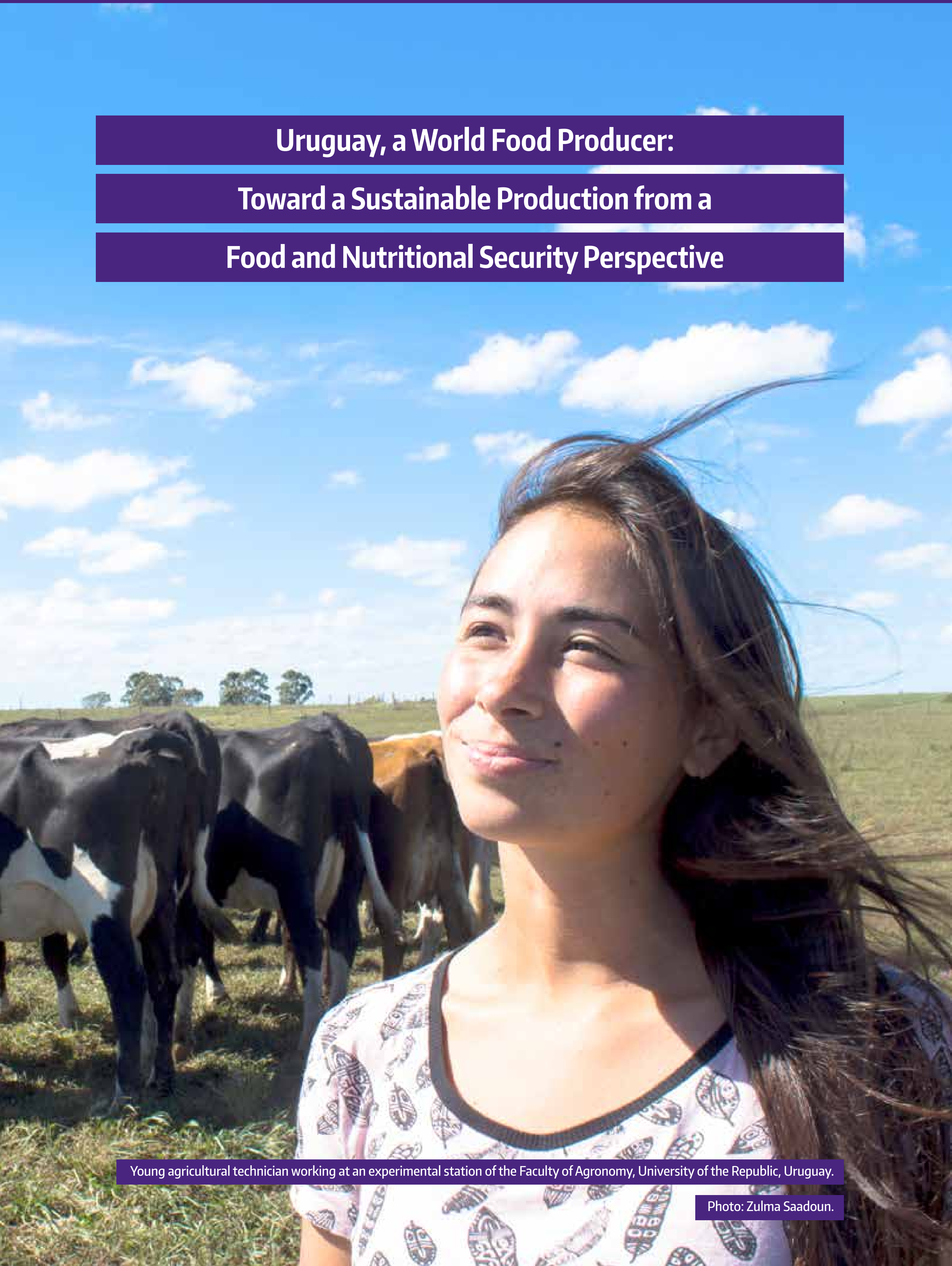
The early policies promoting the production of biofuels were based on two critical observations that no longer hold. First, the price of crude oil was quite high and the price of corn was low. Second, substituting biofuels for hydrocarbons seem the only obvious alternative to garner energy security. Today, today the price of crude oil has fallen significantly and natural gas from fracking has created a significant and now widely produced alternative source of energy. The two critical observations or is assumptions on which the policies of 2005 and 2007 were based no long hold. It is also true that many of the side effects due to the interrelationships between production and consumption of ethanol based biofuels are now much better understood. Thus, for example, the expansion of cultivated agricultural lands (to include lands that were previously marginal) has adverse implications for water quality as the quantities of sediment and fertilizer/pesticide residues that run-off to adjacent water courses is increased. Depending upon the region where biofuels are grown, there may be adverse impacts from increasing demands on already stressed water supplies, including fossil groundwater. Soil erosion may become a bigger problem, again depending on locales. Where existing agricultural land is converted from growing crops to support production of biofuels from other food and feed crops there may be implications for agricultural prices. There may also be adverse impacts on the quantities of food produced to feed the nation and for export.

Cropping circumstances differ by region across the U.S. Some agriculture is irrigated and some is rainfed. Climatic circumstances and suitabilities for agriculture and specific crops are variable. Soils are variable. And, the costs of crop production may differ from place to place. In such variable circumstances it is difficult to fashion policies that are both flexible – to accommodate the variability – and effective. Furthermore, it has not always been recognized that the advent of biofuels serves to strength the linkages between food, water and energy. Each of these is important in its own right but when they are linked together new and important trade-offs are formed. It will rarely be possible to expand supplies of food, water and energy simultaneous. Changes in one will have impacts on the other two. These need to be recognized and accounted for in advance.

It now appears that some combination of all of these circumstances have conspired to defeat the policy mandates on the role and mix of various types of biofuels specified for 2022. The fact that the U.S. has not been able to develop capacity to produce cellulosic biofuels; the absence of the major technological breakthroughs needed to make the 2022 goals achievable; and, the fact that the prescribed standard may be ineffective for reducing greenhouse gas emissions because the ultimate impact of biofuel production depends upon a wide range of land use factors the, availability of water and the fundamental economics has undoubtedly rendered the policy goal unachievable. All of the above factors, including especially the changes of prices and technologies in the energy sector make the future of biofuel markets highly uncertain. In the future such policies need to be both acceptable and flexible to account for changes in energy markets and interrelationships with other resources. Policies also need to be fashioned so that they apply to broad range of differing circumstances yet remain effective.

An ethanol production plant in South Dakota © Shutterstock

Uruguay, a World Food Producer: Toward a Sustainable Production from a Food and Nutritional Security Perspective



Young agricultural technician working at an experimental station of the Faculty of Agronomy, University of the Republic, Uruguay.

Photo: Zulma Saadoun.

Uruguay

[1] María Cristina Cabrera,
[2] Laura Astigarraga, [3] Omar Borsani,
[4] Gianfranca Camussi, [5] Pablo Caputi,
[6] Miguel Carriquiry, [7] Pablo Chilibroste,
[8] Milka Ferrer, [9] Guillermo Galván,
[10] Fernando García Préchac, [11] Lucía Grille,
[12] Carmen Marino Donangelo, [13] Daniel Panario,
[14] Ali Saadoun, [15] Pablo Soca,
[16] Valentín Picasso, [17] Daniel Vázquez,
[18] Fernanda Zaccari

Uruguay, a country with a high rate of human development and availability of natural resources, has the capacity to produce food for its own population and the rest of the world. This gives it a unique opportunity to address the enormous challenge of improving agriculture, making it less vulnerable to external changes, **adding value to chains through a sustainable, sensitive approach to food and nutritional security,** incorporating quality and safety, and promoting equity in the human and social dimensions.

Summary

Located in the Southern Cone, Uruguay is a country with a total area of 176,216 km², and a population of 3,431,555 inhabitants (World Bank, 2015). Its population, living mostly in urban areas (over 95%), has a literacy rate of nearly 99% and a low replacement rate. Uruguay has been classified as a high-income country by the World Bank, and is in the high human- development category according to the index used by the United Nations Development Program (UNDP, 2015). The country has abundant natural resources, arable soils, and available water and natural meadows, which has contributed to its thriving agricultural and livestock industries. Uruguay is a net exporter of agricultural products, with a capacity to produce food for its own population and the rest of the world. It is the world's seventh largest beef exporter (USDA, 2016), while its rice exports account for 2.1% of the rice sold worldwide. It has no significant risk of food and nutrition insecurity due to the abundance and variety of food, as well as the favorable conditions for producing them. However, micronutrient deficiencies coexist with overweight and obesity in young individuals, posing a major challenge for the years to come.

Low-cost production of *commodities* makes the country competitive. However, this specialization also makes it vulnerable to changes in the international market and climate or health events, impacting the population and decreasing the capacity for entrepreneurship and innovation. Food and nutrition security in Uruguay is vulnerable to these changes, which cause the inequities that affect the sectors of the Uruguayan population with the least resources. In recent years, actions have been launched using an integral point of view, to make agricultural systems more sustainable, environmentally-friendly and innovative. This will entail taking into account the added value, quality and safety of food items produced by the country, the social and human component, as well as the knowledge required to implement these changes. Actions are being taken from the new institutional framework to increase highly qualified human capital. Public and private research, development and innovation programs have begun to focus on training human resources capable of innovating and achieving a major impact on value chains. The interdisciplinary approach to problem solving has been encouraged during this new stage and will have a positive impact in the medium term.

Introduction

Using an interdisciplinary approach, this chapter presents the main aspects that determine the Food and Nutrition Security (FNS) status of Uruguay, an agricultural cattle farming country, from its natural resources to food production, including the human component. The academics and specialists participating in this collective study, invited by the Inter-American Network of Academies of Sciences (IANAS) and the Academy of Sciences of Uruguay, provide a critical view of present and future scenarios. This chapter highlights the advances being made as a result of scientific research, and the evolution toward public policies that impact on FNS.

Study Focus

Food production in an agricultural export country faces the challenges posed by changes in markets, quality and safety demands and the care of natural resources such as soil, water and plant cover, in a changing climatic situation. With regard to its own population, the challenge for the country is to streamline food systems, to provide a sufficient quantity of food with nutritional quality and to contribute to the Uruguayan population's food and nutrition. In each aspect, priority is given to a description of the country's opportunities, the obstacles to be overcome and the challenges to be faced in order to achieve sustainable, high-quality food production, as well as nutrition-sensitive value chains that are inclusive at the human and social level.

1. National characteristics

Miguel Carriquiry[1]

1.1 Country area, arable land inventory, environmental heterogeneity of the landscape

Uruguay comprises an area of 176,216 km², with a variety of natural resources that allow the development of agricultural and forestry activities in over 90% of its territory. Tradition and the availability of natural resources are among the main reasons behind the leadership of the agricultural sector as a determinant of economic growth (UNEP, 2015). Over 80% of the territory is devoted to livestock production, while extensive crops and commercial forestry occupy the majority of the remaining area. The establishments dedicated to livestock raising are responsible for more than 75% of the area dedicated to livestock production.

1. Full Professor, Institute of Economics (IECON), Faculty of Economics and Administration, UdelaR.

1.2 Demographic characteristics and future trends

Uruguay has a relatively stable population of 3,286,314 according to the latest official census (INE, 2012), with some estimates placing it at 3,431,555 in 2015 (World Bank, 2015). The majority of the population (over 95%) is urban, while the literacy rate is nearly 99%. Uruguay has been classified as a high-income country by the World Bank, and is in the high human-development category according to the index used by the United Nations Development Program (UNDP, 2015).

Its low replacement rates, emigration of young adults and a relatively high life expectancy mean that Uruguay's population is ageing rapidly. Recent studies (Calvo, 2016) indicate that trends in the age structure, which modify the demographic dependency ratios, pose challenges on various fronts, from health care and the social security system, to labor markets and education. Projections show that, given the limited natural increase in Uruguay's population, the proportion of children will decline to match that of older adults by 2035, and that the latter will exceed the number of children thereafter. These changes will exacerbate certain socioeconomic challenges, such as increased health care and care costs in the context of today's family structure, and labor-market demands, straining the retirement and pension system (Calvo, 2016).

1.3 Proportion of the population suffering from food and nutrition insecurity and the FNS trajectory

According to data from the Food and Nutrition Security Observatory, the proportion of the population under the poverty line and indigence have declined over time, standing at 9.7% and 0.3%, respectively, in 2014. The same source indicates that the fraction of the population at risk of failing to meet the food demands associated with normal physical activity has also fallen. This fraction dropped from 17.5% in 1990 to approximately 10% in 2004, and has since hovered around 8%. Uruguay achieved the Millennium Development Goal of halving the number of people who were food-insecure ahead of time, in 2014.

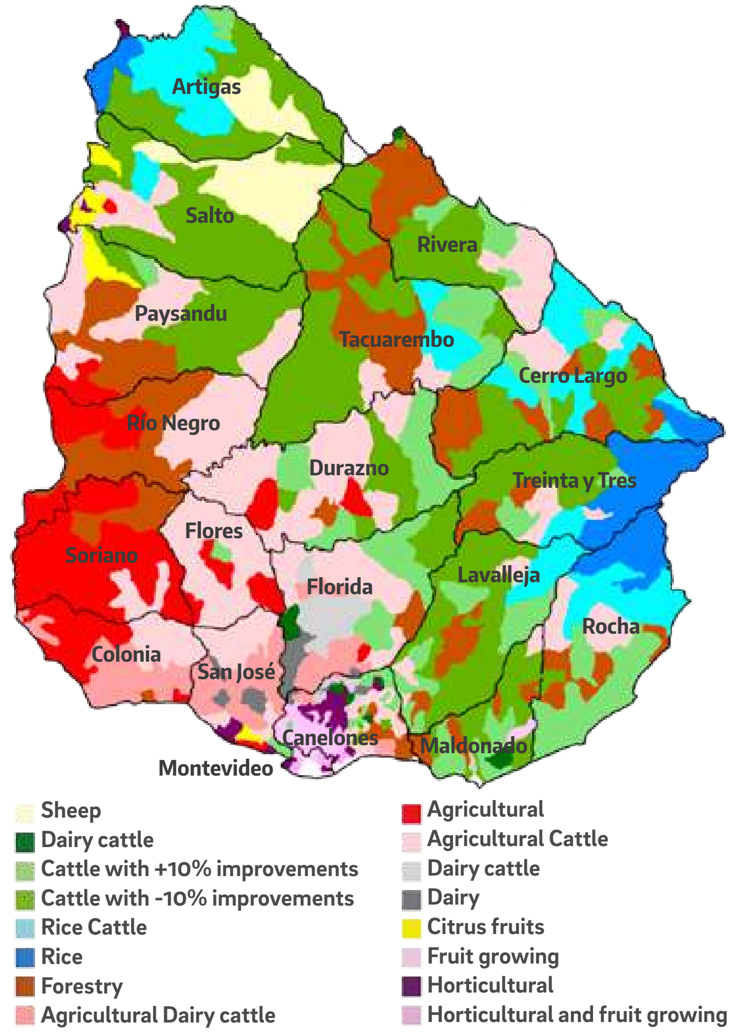
1.4 Agricultural production systems

The Uruguayan agricultural sector is extremely heterogeneous in terms of scale and productive practices, among other dimensions. However, particularly in the extensive agriculture sector, similarities are found with what UNEP (2011) defines as "industrial agriculture", characterized by production practices based on the use of off-farm inputs.

Broadly speaking, most of the agricultural area is used for three activities: extensive agriculture; livestock raising and commercial forestry. The country has seen the rapid transformation of these productive activities. There have also been significant changes in agricultural activity, particularly in terms of the total area dedicated to the mix of different crops and the seasons when these crops are grown. A key aspect of agriculture in Uruguay is the significance of mixed agricultural-livestock production systems in parts of the country where soil is suitable for crop growing. The coexistence of livestock (mainly beef cattle) and crops in crop-pasture rotations is an important aspect of agriculture in Uruguay, whose extension has varied over time. Recent increases in profits from crop production (relative to meat production), and changes in production models and governance have led to a reduction in the inclusion of pastures in rotations and to the displacement of cattle to less productive soils. Some of these changes may be reversing as crop prices decline.

Whereas the area under soybean cultivation was insignificant before 2000, it has become the largest crop in recent years, occupying more than one million hectares. In terms of value, soybean is currently the main export crop, vying with beef for first place in the country's exports. This has also led to a significant change in terms of the seasonality of crop production. In the recent past, the area of winter crops doubled that of summer crops. This ratio has now been reversed due to the rapid expansion of summer crops, particularly soybeans. This reversal has worried a number of observers, since it increases the need for resources, particularly water, during the seasons when droughts or water deficits are more likely. Increases in rainfall variability, as a result of climate change, can increase the risks to the agricultural economy.

Map 1. Map of Uruguay showing political divisions and agricultural production areas



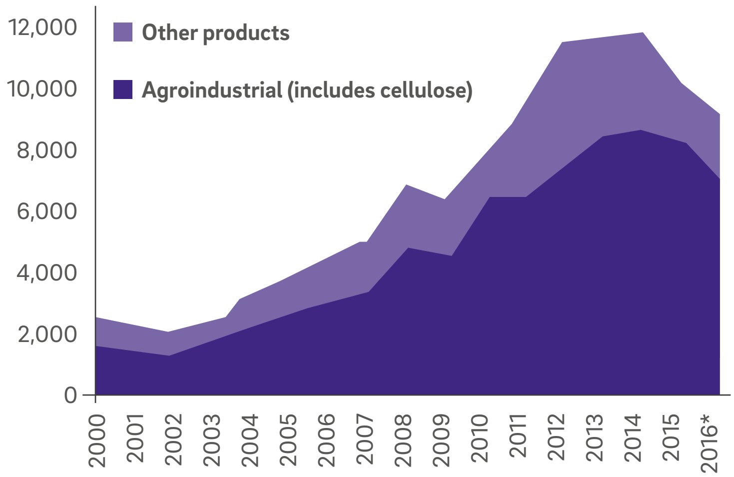
Source: Adapted from MGAP Map.

1.5 Main export/import markets and agricultural products

Agricultural and agroindustrial products account for an increasing share of the country's exports (Paolino and Hill, 2011), currently totaling 80%. Uruguay is mainly an exporter of food products and other agricultural products. The principal export products are beef (chilled and frozen), soybeans, forest products, dairy products (mainly whole milk powder) and rice. **Figure 1** shows the evolution of agricultural exports in recent years.

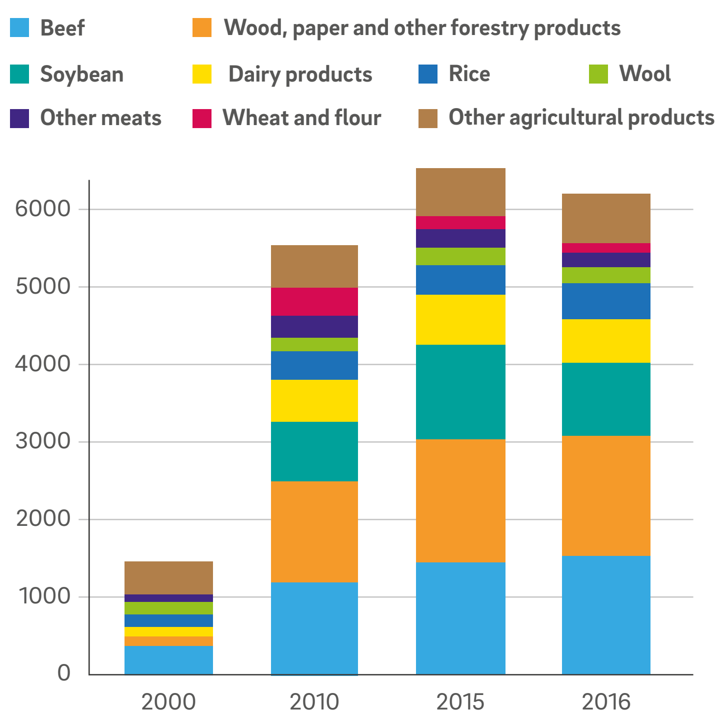
Although soy exports were insignificant or did not exist in 2000, they have become one of the main products sold abroad in recent years (**Figure 2**). Forest-product exports have also expanded, due to strong public incentives to plant commercial forests in the mid-1990s and significant recent investments in pulp-production capacity.

Figure 1. Evolution of exports of goods in millions of dollars



Source: Anuario OPYPA 2016, *Estimated value.

Figure 2. Agricultural and agro-industrial exports in millions of dollars



Source: Prepared by the authors based on data from MGAP and Ministry of Agriculture.

The overseas market is the main destination of several Uruguayan products. To mention just a few, over 90% of rice and soybeans and over 70% of beef production is exported. Although export markets by product, China, NAFTA and the European Union are the main destinations for Uruguayan products in general, and beef in particular. More than 75% of the soybean exported is destined for the Chinese market.

1.6 Potential sources of instability for Food and Nutrition Security

The availability of productive land, climate, agricultural production and low population density are factors that explain why Uruguay faces no significant challenges in terms of FNS. In fact, it is commonly said that Uruguay has the capacity to feed between 27 and 28 million people, a figure that would rise if certain productive practices were improved based on currently available technologies and institutional frameworks (Mondelli and Bervejillo, 2015). As mentioned earlier, Uruguay exports a high proportion of the food and commodities it produces. Despite this abundance in terms of food production at the aggregate level, there are still sectors of the population that face food insecurity, although their numbers have rapidly declined in the recent past.

1.7 Main agricultural challenges

The nature of Uruguay's production systems is a source of both competitiveness and vulnerability. Although its natural resources mean that the country is able to produce crops, particularly livestock products, at low cost, its production systems are vulnerable to climate variability, particularly droughts. Soil erosion and water pollution are among the main environmental challenges facing the agricultural sector and the country as a whole.

Open-air and rainfed production take advantage of the natural availability of land and water. These low-cost production systems expose the sector to risks due to significant rainfall variability both between years and within a single year. This variability is expected to increase in the future as a result of climate change. The changes in crop patterns mentioned previously may be increasing production systems' vulnerability to climate change, which in turn requires different forms of risk management. These include investment in risk and insurance technologies and methods for using the available water (with varying degrees of shortage during the year) more efficiently.

Soil loss, as a result of erosion, has implications for both production and the environment. Erosion and other forms of soil degradation reduce productive potential and increase the need for nutrient aggregation, which results in higher production costs per hectare (ha) and unit-of- output. Moreover, erosion and nutrient runoff result in water pollution, degrading the environment and imposing external costs on society. Loss of water quality is evident in the watersheds and reserves that feed the most populated areas, such as Montevideo, the capital of the country, and the surrounding cities.

2. Institutional framework

María Cristina Cabrera[2]

2.1 National Agricultural Research System

In 2016, the National System of Researchers (SNI) had 1,744 classified researchers, 1,494 of whom were active, 233 associate and 17 emeritus. According to ECLAC (2014), the total number of researchers is only a third of what it should be, in comparison with neighboring countries. Of the total number of active researchers, 9.1% are from the area of humanities, 10.4% from engineering and technology, 11% from agricultural sciences, 12.8% from medical and health sciences, 21% from social sciences and 35.7% from natural and exact sciences. A high percentage of researchers (75%) are attached to the University of the Republic. In the case of agricultural sciences, 25% are drawn from INIA, private universities and other institutions that research agricultural sciences. The total number of classified researchers, as well as those engaged in agricultural sciences, reflects a research capacity that still insufficient for achieving the objectives of a sustainable productive country based on knowledge generation and innovation (ECLAC, 2014).

2.2 Science and Technology Strenghts

The Global Innovation Index, cited by Rubianes (2014) in the ECLAC report and designed by INSEAD and the World Intellectual Property Organization (WIPO), makes it possible to compare countries and their evolution through the use of seven variables: A) Institutional development; B) Human capital and research; C) Infrastructure; D) Market complexity; E) Complexity of businesses; (F) Technology products, and (g) Creative products. According to the 2009 and 2012 annual reports, Uruguay ranks 53rd and 64th worldwide, respectively, and between third and sixth in Latin America. Its greatest strengths are its institutions, infrastructure and creative products. Rubianes (ECLAC, 2014) cites the following aspects as strengths: i) Human capital, which has steadily increased at a reasonable annual rate, mainly as a result of graduate students; ii) infrastructure in nearly all areas, and iii) knowledge production, reflected in the number of Uruguayan publications, also on the rise.

2.3 Universities and research institutes

Science and technology activities related to agriculture are mostly undertaken by the public sector, particularly by higher education and agencies specializing in agriculture, such as the University of the Republic (UdelaR) and the National Institute of Agricultural Research (INIA). Other public organizations, such as the National Seed Institute (INASE), the National Milk Institute (INALE), the National Meat Institute (INAC) and the National Wine Institute (INAVI) contribute to research and human resource training activities in issues related to agriculture, by supporting and participating in them. Private universities, research institutes and other public or private institutions contribute to training and research in various areas of agriculture

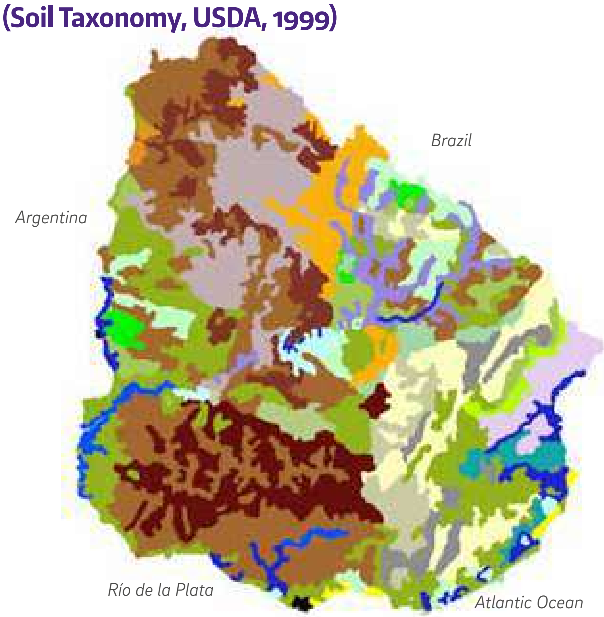
2. Full Professor, GD Nutrition, Faculty of Agronomy. Associate Professor, Physiology & Nutrition, Faculty of Sciences, UdelaR. mcab@fagro.edu.uy

through partnerships with the other actors, primarily in the scientific-university context. This interinstitutionality, in both graduate training and research, has increased in recent years. The relative contribution to investment, research and innovation by the public and private sectors is 70% and 30%, respectively. This proportion is lower than the prevailing rate for the region, meaning that there is a need for the private sector to invest more in research and innovation.

2.4 Scientific collaboration networks inside and outside the country

In 2012, the Uruguayan Agency for International Cooperation (AUCI) announced 114 cooperation initiatives in the Productive Area, 63 of which involve traditional cooperation, 38 regional cooperation and multi-country cooperation, and 12 South-South and triangular cooperation. In traditional cooperation, the largest share of donor funding was used to support science, technology and innovation. In regional and multi-country cooperation, emphasis was placed on partnerships with Mercosur and between Mercosur and Spain and the European Union. The cooperating partners were: Mercosur (FOCEM), Canada (IDRC), UNSG (FAO and IFAD), CIAT, FONTAGRO, IDB, OAS (IICA), CAF and the European Union. In South-South cooperation, Uruguay was a bidder in three, a recipient in one and both in eight initiatives, mostly in the agricultural sector and in science and technology (approximately 65%). The partner countries were Argentina, Brazil, Colombia, Mexico, Nicaragua and Paraguay. In triangular cooperation, only one activity was carried out in the agricultural area, which involved the implementation of a group traceability system for beef in Bolivia. The cooperating partners were Costa Rica, Bolivia and IICA. The main issues were climate change, natural resources and biodiversity, and productive chains and competitiveness. The ANII (National Agency of Research and Innovation) created instruments to promote partnership and coordination between private and public institutes, and concentrating and strengthening research, development and innovation capacities. This was the case of the Sectoral Technology Networks, which synergistically combine the capacities of their members and establish new capacities for the country. Argentinean-Uruguay Scientific Cooperation Programs are implemented in priority areas defined by GMI, the STIC-AmSud Regional Program in the areas

Figure 3. Map of Uruguayan Soils on a scale of 1:10^6, using Soil Taxonomy (Soil Taxonomy, USDA, 1999)



Source: Durán A., Califra A., Molfino J.M., 2001.

of information technology and Eranet-LAC, a project funded within the Seventh Cooperation Framework Program, which consists of a network of the European Union (EU) and the Community of Latin American and Caribbean States (CELAC), in innovation and joint research, one of the areas being biodiversity and bioeconomy. Other Networks are cited in the chapter items.

2.5 Access to and maintenance of databases for monitoring farming systems

Information and databases for the monitoring of agricultural systems are traditional in the country. According to a 2015 FAO report on Priorities for Uruguay in Agriculture and Food Security, the country has a relatively important institutional system linked to the agricultural sector. The main body is the Ministry of Livestock Agriculture and Fisheries (MGAP), which has eight General Directorates: Secretariat, Water Resources (DINARA); Natural Resources (RENARE); Agricultural Resources (DGSA); Livestock Resources (DGSG); Rural (DGDR); Farm (DIGEGRA) and Forestry (DGF) development. It also has three advisory units from the ministerial authority: The Directorate of Agricultural Statistics (DIEA); the Office of Agricultural Programming and Policy (OPYPA) and the International Affairs Unit (IAU). International cooperation is coordinated by the Secretariat for International Cooperation, which is directly answerable to the Minister. Annual reports are submitted on production, export, consumption and other relevant data, which can then be monitored, analyzed and estimated. In their respective Web pages, this information is freely accessible.

2.6 Development of skilled workforce and state of national education systems

In 2016, Uruguay had a Human Development Index (HDI) of 0.793, a high percentage of literate adults (97%) and a public education system, free of charge and freely accessible at every stage: Elementary; middle and high school, university and vocational technical training (UNDP, 2016). A total of 98.7% of children ages 3 to 5 are enrolled at school. Higher education is mostly supported by the University of the Republic with a smaller but growing share of private universities. A total of 3.8% of adult women and 1.9% of adult men have completed tertiary education. However, in order to comply with the Sustainable Development Objectives (SDO) and the 2030 Agenda for sustainable development (UNDP, 2015), it is necessary to consider the shortcomings at the local level, which will have to be reversed in a sustainable development perspective based on knowledge. These are: a higher-than-expected elementary school drop-out rate, a higher-than-expected pupil-teacher ratio, average educational attainment (measured as the average cumulative years of schooling by 2014), and lower-than-expected gross high school enrollment - defined as the total enrollment corresponding to that educational level, regardless of age, and measured as the percentage of the school-age population attending this level from 2008-2014.

3. Ecosystem and Natural Resources

3.1 The Uruguayan soil resource: its use and conservation

Fernando Garcia Préchac[3]

The Uruguayan ecosystem belongs to the Pampa biome. It consists of natural grasslands that occupy 65% of the territory, 10% of native forest and trees on river banks and small areas of mountainous terrain. The topography consists of gently rolling hills, with slopes of between 3% and 6%, and plains whose area varies according to the zones. The average altitude above sea level is 140 meters, with some mountain areas. The highest point is 513 meters above sea level (masl). According to Soil Taxonomy, Molisols and Vertisols predominate (in green and brown in **Figure 3**, the most commonly used type of soil for crops), with significant areas of Alfisols, Ultisols, Inceptisols, Entisols and Histosols.

As for the presence of arable land, 3.5 thousand ha have approximately 75%, 3.1 thousand ha have 50%, 1.9 thousand ha have 25% and 1.4 thousand ha have between 25% and 75% togeth-

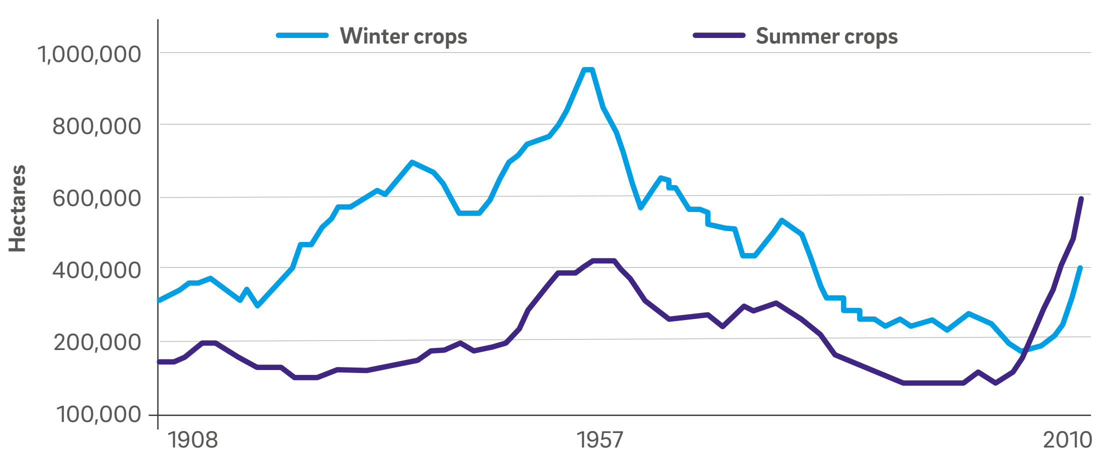
3. Full Professor. Soils and Water Department. Faculty of Agronomy. UdelaR.

er with the topographic conditions that permit rice production (Cayssials and Álvarez, 1983). The rest of the territory consists mainly of fields with less than 25% of cultivable soils (6.9 Mha), mainly dedicated to the production of meat and wool, as well as 0.3 Mha of wetlands and sand dunes.

The cultivated area varied significantly during the 20th and present centuries (**Figure 4**), influenced by market prices and international demand. In the mid-1950s, the size of this area peaked due to wheat production based on a low level of technology and conventional tillage. This led to the first assessment of soil erosion status (Cayssials et al., 1978), indicating that approximately one-third of the country was affected; mainly the area with the best soil. According to more current work (Sganga et al., 2005), this situation has not significantly changed. This stability was due to the reduction of cultivated areas during the second half of the 20th century and the general adoption of crop rotation with pastures planted with grasses and legumes (Crop-Pasture Rotation, CPR). The effect on CPR soil conservation was increased by the widespread adoption of direct sowing in the early 1990s. However, since the beginning of the 21st century, there has been a marked increase in the cultivated area, due to the cultivation of soybean, the grain for which there is the greatest demand on the international market with the highest price per ton (t). Thus, soybean displaced other crops and CPR. Despite the use of direct sowing, the low return of crop residue to the soils, their rapid decomposition due to their low Carbon/Nitrogen ratio, plus the lack of winter cover crops or grain yields in the winters, erosion problems began to be observed that generated a state of general and political alarm, and called for legal regulations governing soil conservation

In 2008, soil management and conservation legislation began to be updated. By 2013, and after a training period for farmers and agronomists, these changes came into full force. Growers must have a plan for responsible soil use and management (PUMR) prepared by a certified agronomist that covers the expected future rotation period. PUMR must demonstrate - using USLE/RUSLE with the EROSION v6.0.20 program (García Préchac et al., 2015) - that the estimated annual erosion rate is below the tolerance value established for the soil used. Each piece of land in the national cadastre has an approximate land survey map at a scale of 1:20,000, whereby the agronomist can obtain soil information for each plan. PUMR is presented "online" and comprises an implementation protocol that can be analyzed and monitored by the official authority (Ministry of Livestock, Agriculture and Fisheries). Those who violate the protocol are fined according to the regulation. At the end of the 2013-2014 agricultural year, nearly 95% (1,438,168 ha) of the farmlands implemented PUMR (**Figure 5**).

Figure 4. Evolution of cultivated areas in Uruguay, with winter and summer crops, from 1908 to 2010 (Saavedra, 2011)



Source: MGAP-DIEA 1. Fortnightly moving averages.

This percentage reached 98% by the end of 2015, which is considered a success in the effort to mitigate soil erosion, as well as its collateral environmental impact.

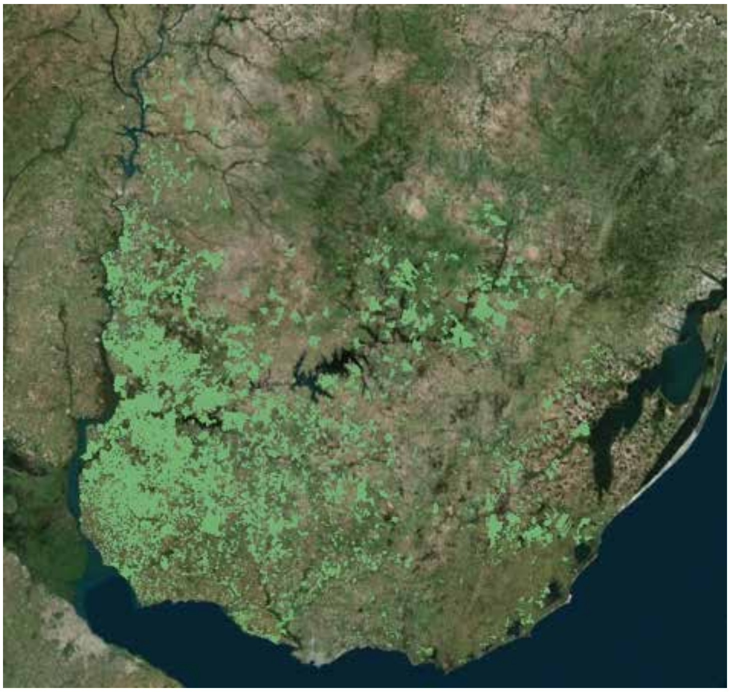
3.2 The water resource. Current status and perspectives

Daniel Panario[4]

Uruguay has more than 10,000 m³ of water per inhabitant per year (Revenga, 2000), both surface and groundwater, which would be more than enough to meet the demands of a larger population. Surface water is uniformly distributed throughout the territory as surface aquifers, most of which are suitable for supplying the scattered rural population.

What happens to water in the various compartments of the environment determines its management. It reaches the rivers from runoff, water tables and, as a universal solvent, in other words, that interaction transforms it when it travels through various settings. This changes life in rivers and reservoirs, determining what remains and what leaves. The three large agro-ecosystems - cattle, agricultural and forestry – behave as follows: **i) Livestock systems.** Although there are intensive livestock systems, such as the dairy industry, most of the territory is occupied by extensive livestock, which usually has a minor impact. However, overgrazing has been observed in most natural pastures. This is the case, in particular, of the concavities of the landscape located in the lowlands, in which the characteristic hard high grasses (scrub) have been eliminated due to fire or animal overload. This has caused these primary channels (concavities) to lodge in the valley, thus producing headwater erosion, significantly accelerating the flow, with the resulting increase in the intensity and frequency of floods and droughts. From the point of view of water quality, total Phosphorus (P) levels in the drainage channels are approximately 25 µg/L (Panario, 2016), since there has been no promotion of a trough system that discourages cattle (12

Figure 5. In light green, farms that submitted the soil use and management plans (SUMP) in 2014



million in 2016) from drinking in the water courses. The phosphorus load of excrement calls for the modification of the legal limit in the current legislation (De León, 2016). These levels are already high enough for dammed waters to be eutrophic, as happens in the Rio Negro dams, to which phosphorus fertilizers and pesticides are added. **ii) Agricultural systems.** Although rainfed agriculture has been a traditional activity since the 19th century, which has gradually damaged the land it occupied, the expansion of soybean cultivation and the technological package that accompanies it have significantly affected water quality in the river courses of agricultural land. Phosphorus is dissolved or bound to the smallest solid particles - those that can only be deposited in reservoirs – meaning that current levels of pollution of the drainage channels cannot be attributed to the agriculture of the past. Irrigation agriculture, mainly deployed in the eastern wetlands of the country, was undertaken through partial drainage, even though they were included in an area protected by the Ramsar Convention. **iii) Forestation.** Afforestation with fast-growing exotic species has

4. Full Professor, Institute of Ecology and Environmental Sciences (IECA), Faculty of Sciences, UdelaR.

expanded significantly since the 1990s as a result of subsidies for these plantations. High forest basins were included in the forest priority areas, despite the fact that forest crops, during years with normal rainfall, reduced watershed yields by approximately 20% (Farley et al., 2005).

In recent years, due to the proliferation of cyanobacteria in the main drinking-water sources, certain preventive measures have been taken. Phosphorus levels have remained unchanged, with an increase in water-treatment costs. Uruguay must draw up a water policy based on the preservation of the ecosystems responsible for the proper functioning of the water cycle, while striking a balance between goods production and the externalities of the productive processes. The greatest challenge for water involves providing sufficient quantity, access and quality to meet society's demands, while allowing ecosystems to maintain the services they provide.

3.3 Environmental sustainability of pastoral meat and milk-production systems: Opportunities for Resilience

Laura Astigarraga[5] y Valentin Picasso[6]

In Uruguay, livestock are reared on natural pasture (Campos Royo Pallarés et al., 2005) and pastures planted with grasses and leguminous mixtures. However, the expansion of soybean production due to direct sowing has reduced the area of pastureland, driving livestock production into marginal land (DIEA, 2011), and providing opportunities for the intensification of livestock systems based on enclosure and grain use. In this context, meat production has increased by over 45% and milk production by over 250% since 1980 (DIEA, 2013), which currently accounts for nearly 77% of the country's GreenHouse Gas (GHG) emissions (MVOTMA, 2015). Uruguay's current and future challenge is to reduce the environmental impact due to agricultural production.

5. Full Professor, Animal Production and Pastures Department, Faculty of Agronomy, UdelaR.

6. Associate Professor, Animal Production and Pastures Department, Faculty of Agronomy, UdelaR; Assistant Professor, University of Wisconsin, USA.

Recent work has studied the environmental impact of Uruguayan beef and dairy systems, based on a case-study analysis of the country's productive systems (Modernel et al., 2013, Lizarralde et al., 2014, Becoña et al., 2014, Picasso et al., 2014). For meat production, Modernel et al. (2013) identified pasture-based systems (natural or planted) and two systems in the finishing phase (pastures or confined plus grains). For milk production, Lizarralde et al. (2014) identified three groups of milk-production establishments – with production processes with low, medium and high efficiency - based on a multivariate analysis of conglomerates. The environmental-impact assessment was undertaken on the basis of a Partial Life Cycle Analysis methodology to study the Carbon Footprint (CF) (IPCC, 2006), the Nitrogen (N) and Phosphorus (P) balance and fossil-energy use, including agricultural activities and agricultural input production.

3.3.1 Environmental impacts of milk production systems

Intensive systems, which produce meat based on confinement and grains, have a lower CF, as borne out by other studies (**Figure 6**). Methane, of enteric origin, was the most important GHG (66%, 58%, and 46% for natural/planted pasture, planted/planted and planted/confined, respectively) together with nitrous oxide due to N excretion and the use of nitrogen fertilizers (30%, 33% and 31%, respectively). However, when analyzing the environmental impact expressed as fossil-energy use or as excess nutrients with respect to what is retained (surplus expressed per kg gained), the systems are arranged in the opposite direction to that presented by the CF analysis. Fossil energy consumption increases with the use of inputs: the planted/confined pasture system requires three times more energy to produce a kilo of live weight gain compared to the natural/planted pasture system. The greater use of energy is due to fuel consumption to produce fodder and grains, owing to fertilizer production and phytosanitary measures. The nutrient surplus (inputs-outputs), expressed in relation to the amount retained (outputs in product) turned out to be double in N and P for pasture planted/confined with respect to natural/planted pasture.

3.3.2 Environmental impacts of meat production systems

Cluster analysis made it possible to identify three groups of farms, with low, medium and high efficiency in the production process, which was reflected in the values of the average CF of each group (**Figure 7**). The low-efficiency group had the highest CF (1.09 kg CO_2 eq/kg MCFP (Milk Corrected by Fat and Protein), explained by low productivity per hectare, low milk production per cow and low rodeo efficiency (VO/stock ratio). Food consumption, of both forage and concentrate, is low (11.0 kg DM/cow), which is explained by reduced forage production and a concentrate supply that does not compensate for the low consumption of forage per cow. The high-efficiency group corresponds to farms with high productivity per hectare (5377 LCGP/ha), high milk production per cow and high rodeo efficiency (VO/stock ratio). These dairy farms are distinguished by high consumption per cow (15.2 kg DM/day) and a high supply of concentrate, presenting a lower contribution of methane (50%) to total emissions when expressed per liter of milk. It was also found that, in mixed pastoral systems, the more efficient the production process, the lower the excess nutrients or fossil-energy use.

In conclusion, in Uruguay the CF varies among production systems, suggesting that there is an enormous potential to reduce GHG emissions. Using forage efficiently by optimizing forage allocation throughout the year is a key mitigation option that can increase beef and dairy productivity and reduce the CF without major investments. At the regional level, for meat-production systems, increased meat productivity and natural resource conservation could be complementary objectives. This approach is being followed in Uruguay and the region, with public policies designed to preserve the natural countryside, achieving a three-fold benefit: the adaptation of pastoral systems to climate variability; the improvement of food security and climate-change mitigation.

Figure 6. Environmental impacts of meat production systems with different feed sources

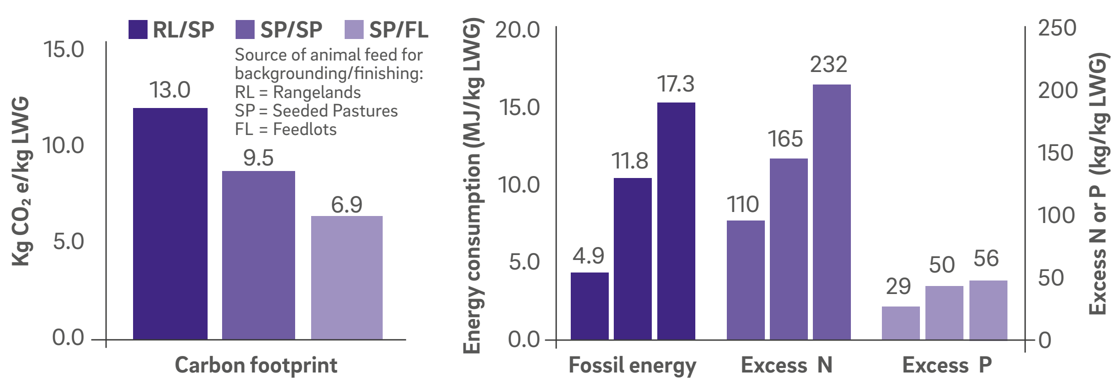
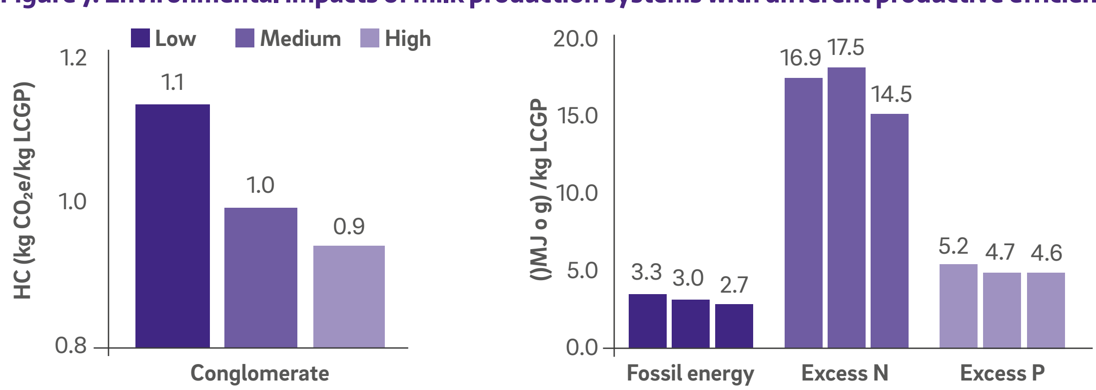


Figure 7. Environmental impacts of milk production systems with different productive efficiency



4. Technology and Innovation in the improvement of agriculture. Opportunities and obstacles

4.1 The Role of biotechnology: The use of biotechnology tools in the development of agricultural products based on local interests

Omar Borsani[7]

It is nearly 15 years since the authorization and subsequent commercial use in Uruguayan agriculture of transgenic maize carrying the *Bacillus turingensis* toxin gene, in a gene construct designed in the laboratory and subsequently incorporated into commercial maize. This marked a watershed in the use of biotechnological tools, especially recombinant DNA technologies for the purpose of improving crop productivity. Since then, new transgenic events have been incorporated into characteristics-of-interest associated with crop management. There are many reasons why this technology has not been adopted to improve characteristics-of-interest in other crops of importance to the country. However, during this period, a number of changes have increased the possibility of developing new improvement strategies through the use of biotechnologies. These include the exponential reduction of the costs of DNA sequencing services over time on the one hand, and the emergence of genetic manipulation technologies that would allow the development of more easily targeted and undeveloped transgenic mutants on the other. This chapter will focus on how these two tools are being used in the country to improve crop quality and productivity and how this will impact the country's agriculture in the near future.

The possibility of sequencing entire genomes of different plant species, at an affordable price by the country's laboratories, means that the genetic information contained in that genome can be accessed, making it possible to identify the characteristics to be improved or transferred. For example, the use of sequencing has made it possible, through associative mapping using SNP (*Single Nucleotide Polymorphisms*), to identify the gene regions associated with grain quality in rice. Thus, on the basis of a mapping population and association with a specific SNP, genes that would be responsible for the starch grain structure among other characteristics, (Bonnecarrere et al., 2014) were identified. Knowing these variants makes it possible to accelerate the improvement processes for these characteristics. At the same time, genome sequencing, as well as the possibility of analyzing complete transcripts of almost any species, has encouraged national researchers to construct genetic maps of fruit species. This is the case of the Uruguayan guava *Acca sellowiana*, a species for which a genetic map is in the process of being constructed (Quezada et al., 2014). On the other hand, genome sequencing and a complete transcriptome of the Tannat berry, an emblematic vine cultivar in the country, is another case where this type of approach significantly increases the appraisal of genetic resource (Da Silva et al., 2013). The information obtained may be used in the medium term for the purpose of improvement or for the identification of new genes with potential biotechnological use. In the same line, breeders working on crops such as barley, wheat and soybeans, among others, are increasingly incorporating the use of genome sequencing tools, both to shorten improvement times and to appraise the germplasm used.

Another tool technology that has begun to be explored in the country is the methodology known as CRIPS/Cas9, which uses the ability of certain proteins to modify DNA in a directed way (Lozano-Juste and Cutler, 2014). This genetic modification will change the way we conceive of the genetic improvement of crops in Uruguay and in the rest of the world. This technology allows specific mutations to be made in a targeted manner, generating mutant individuals in that specific sequence. Some of the country's laboratories are working with this methodology in order to generate specific mutants in proteins-of-interest (National Agricultural Biotechnology Network -Uruguay). In the beginning, the aim was to improve the characteristics associated with tolerance to environmental stress. However, the possibility of improving the quality of certain grains through this type of methodology is presented as a unique opportunity. The future

7. Full Professor, Department of Plant Biology, Faculty of Agronomy, UdelaR.

seems to indicate that improving the quality and productivity of agricultural crops can be achieved on the basis of clearly defined local interests through the use of biotechnology tools that are within reach of the country's capabilities. However, in a country that is still dependent on *commodity* exports, the regulation and global acceptance of these products generated by these new technologies is a challenge that must be addressed. Another challenge will be to gain a deeper understanding of the biochemistry and metabolism of plant cells, which is essential to predicting, with a high degree of certainty, the consequences of the new genetic combinations.

4.2 Prospects for innovation at the farm level

4.2.1 Unlocking the Potential of Traditional and Creole Varieties: The case of the "Pantanoso del Sauce" onion

Guillermo Galván[8]

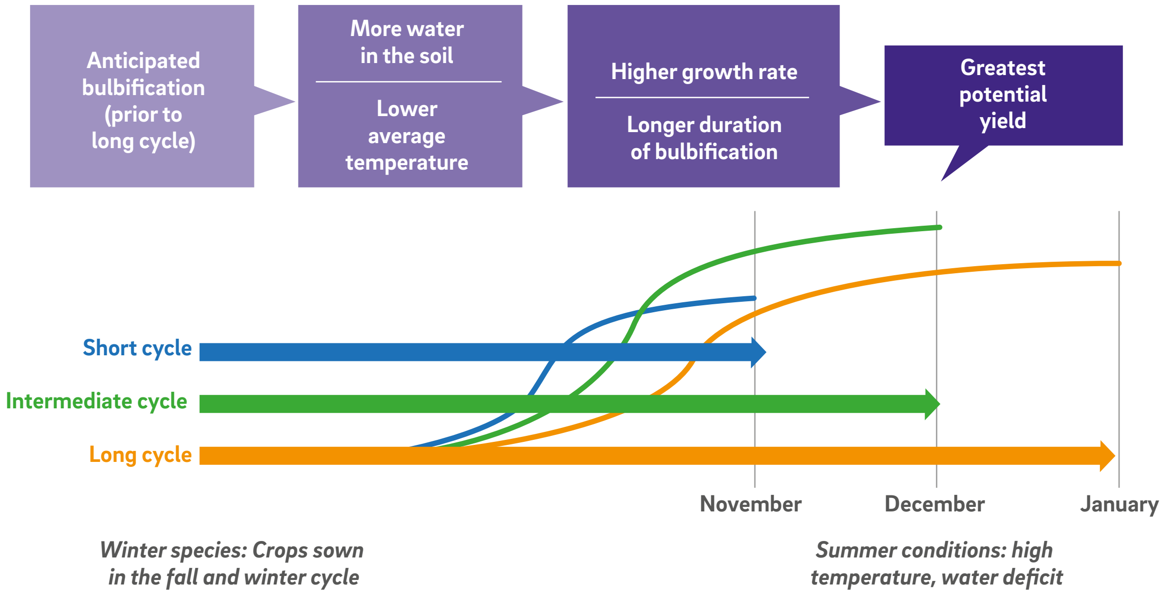
The *Pantanoso del Sauce* onion cultivar is an example of plant genetic improvement that contributes to food sovereignty and security in Uruguay. Local or Creole varieties were introduced into the country by Amerindian and European flows of immigrants (Berreta et al., 2007). This germplasm presents different degrees of adaptation to the local agroecological environment. The adaptation expressed in productivity is the result of a delicate balance between the crop's genetic stock and the environment (Plaisted, 1985). Consequently, seeds maintained by farmers and local breeding have the potential to obtain selections superior to introduced varieties (Pike, 1986). The plants grown today were domesticated in several continents for thousands of years. From the seeds multiplied by farmers and their communities, the development of cultivars[9] expanded in the twentieth century with the application of genetic principles to selection, which made current industrialized food production viable. Despite having been displaced by large industrial agriculture, traditional varieties maintained by farmers persist in association with the logic of family and peasant agricultural production (Frison and Hodgkin, 2016). In many cases, traditional varieties remain economically important and important to food security (McGuire and Sperling, 2016). These varieties constitute a reservoir of genetic diversity for future genetic improvement and generations. Despite the extensive network of institutional germplasm banks, a significant part of the genetic diversity of crops is in the hands of farmers (Jarvis et al. 2008). These traditional varieties offer the necessary diversity for the construction of sustainable production systems in the future (Pautasso et al., 2013). The traditional varieties of onion in Uruguay present diversity at the time of bulbification and harvest, among other characteristics (Galván et al., 1997). Creole intermediate-cycle varieties were extremely interesting, since no similar improved varieties were available (Galván et al., 2005). It was postulated that the intermediate cycle with a harvest in December is the one with the greatest adaptation to conditions in the South of Uruguay (Galván, 1993). In fact, earlier varieties showed lower yield due to lower leaf development at the beginning of bulbification (Galván et al., 2000). At the other extreme, later varieties should achieve higher leaf growth before the beginning of bulbification and consequently higher potential yield, but these later varieties of this winter species are affected by the summer conditions of high temperatures and water deficit (**Figure 8**). High temperatures increase the energy expenditure of leaves, accelerate the entry into senescence of the plant, and shorten the cycle, therefore decreasing the crop's productivity. As a result of a water balance in the surplus soil during the winter, soils typically undergo a progressive drying process in the spring-summer. The water deficit leads to the closure of leaf stomata, which reduces photosynthesis and the crop's growth rate, accelerates senescence and decreases yield.

Based on the intermediate cycle and other favorable characteristics in local varieties of onion, in 1991, a genetic breeding program was launched

8. Associate Professor, Department of Plant Production, Faculty of Agronomy, UdelaR.

9. The term 'cultivar' is used to denote a modern variety, selected by a combination of characteristics, which is clearly distinct from other cultivars, uniform and stable in its attributes when properly propagated. In this text we will retain the term 'variety', which is more commonly used in colloquial language.

Figure 8. Infographic showing the physiological differences associated with cycle differences in onion production in Uruguay



Infographic which determine the greater potentiality of the intermediate cycle. It is important to note the difference between the long cycle, since intermediate and late cycle varieties have the greatest postharvest conservation potential.

that led to the release of the *Pantanos del Sauce* CRS varieties, which occupies more than 60% of the area of the crop in the Southern Region (DIEA-MGAP Surveys, 2009), and "*Canarita CRS*". The potential of the intermediate cycle of the *Pantanoso del Sauce* was evaluated in various production environments. The environment can be defined by technology (plant density, irrigation, fertilization), particularly by soil quality (**Figure 9**). In environments with medium potential (15 to 25 Mg/ha), the *Pantanoso del Sauce's* yield was significantly higher than that of early and late varieties. In high- performance environments (30 to 35 Mg/ha), the long-cycle "*Valcatorce*" variety achieved competitive yields, although in those environments, the intermediate cycle of the *Pantanoso del Sauce* remained higher (**Figure 9**). The dissemination of *Pantanoso del Sauce* is an example of the application of the knowledge generated at the University of the Republic that contributed to food security. In fact, it enabled farmers with limiting technologies and suboptimal productive environments to achieve competitive yields, remain active and contribute to market supply. On the basis of agricultural censuses and production surveys in Uruguay, it is estimated that crop yields have improved positively in recent decades, with increases of 334 kg/ha per year (**Figure 10**). The contribution of the intermediate cycle of the Pantanoso del Sauce is estimated at 20 to 30% of the total, approximately 100 kg/ha per year. Last, a program of certified seed production with family producers was established, which ensured the availability of varieties improved by the University of the Republic and INIA Uruguay. The certification program is a novel experience for horticulture in Uruguay, managed through a public-private partnership that made food sovereignty and food security in Uruguay viable (Peluffo et al., 2016).

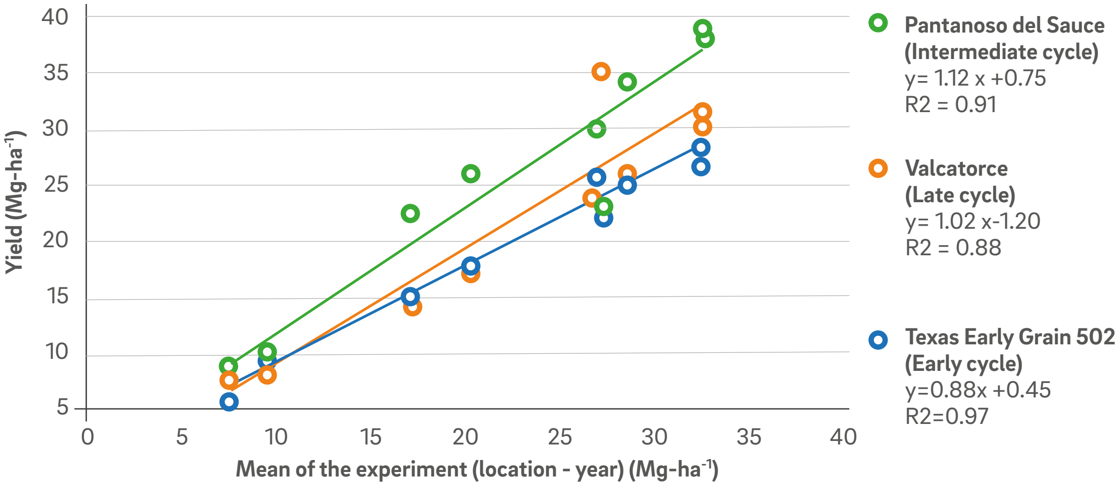
4.2.2 Ensuring milk safety at the farm level

Lucía Grille[10]

Uruguay is one of the main exporters of milk and dairy products in the region, exporting 70% of

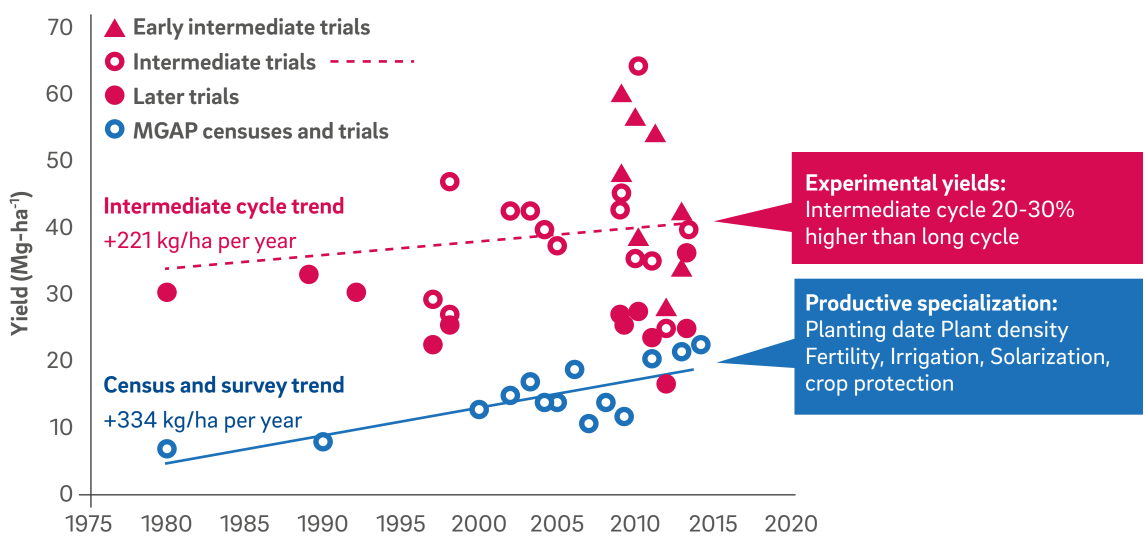
10. Assistant, Department of Science and Technology of Milk, Faculty of Veterinary Medicine, UdelaR.

Figure 9. Comparison of three onion varieties yields



Texas EG 502 (early), Pantanoso del Sauce (intermediate) and Valcatorce (late) yield, as a function of the average yield of each test (locality-year). Localities: (Br) Brunosol of CRS; (Ve) CRS Vertisol; (CG) Canelón Grande; (PS) Pantanosos del Sauce; (Br2) Brunosol 2 from CRS (Galvan et al. 2000).

Figure 10. Evolution of onion yields in experimental trials



Evolution of yields in experimental trials conducted at the Regional Center South and at INIA Las Brujas (red markers), and yields reported by the Agricultural Census and Production Surveys of the Ministry of Agriculture (MGAP) of Uruguay (blue markers).

its production. It primarily exports powdered whole milk (66%), powdered skimmed milk (8.9%), cheeses (18.8%) and butter (6.16%) (INALE, 2016). Most of the milk produced is destined for industrialization. The price of milk is defined by Hygienic-Sanitary quality (HS), evaluated by Bacterial Count (BC) and Somatic Cell Count (SCC). SCC is an indirect indicator of intramammary inflammation (sanitary quality), whereas BC provides information on the hygienic conditions under which the milk was obtained on the farm (hygienic quality). The incorporation of the cold tank in the 1980s (temperatures below 4°C), as well as mandatory pasteurization at the industrial level, are some of the strategies developed to control microbial growth in milk. This has made it possible to control the development of mesophilic microorganisms, but not other bacterial groups, such as thermoresistant, thermoduric and psychotrophic ones, which are difficult to control using these processes (Buehner et al., 2014). The latter also produce thermotolerant enzymes with an enormous potential for damage, affecting the quality of dairy products. That is why some countries (USA, 2004) have incorporated them as indicators of hygienic quality. In Uruguay, the latest HS quality data (January-August 2016) show values of 57,730 Colony-Forming Units (CFU)/ml for BC and 437,610 cells/ml for SCC (Colaveco, 2015). Between 2011 and 2013, a study was undertaken on farms in the NW region of the country, showing BC and SCC values below national and international requirements (Li et al., 2014) and emphasizing the importance of incorporating psychotrophic and thermoduric microorganisms into the control of hygienic quality (Grille, 2016). This demonstrates the permanent progress of milk research in the country, coupled with the maintenance of strict controls even in parameters that are not yet required at the international market level. Since 1995, there has been a National Milk Quality System, created in agreement among producers, industrialists and the state. Since its implementation, it has had a positive impact on the production of quality milk, which has been achieved mainly through economic incentives to the producer and constant updates on the limits of the BC and SCC of milk sent to the plant. In addition to quality, it is important to define when a dairy product is considered safe. By safety, the FAO (2004) means any risk, whether chronic or acute, that can make food harmful for consumer health. Food-safety concerns have focused on microbiological hazards, pesticides, improper use of food additives, chemical contaminants and adulteration. In Uruguay, the requirements for microbiological and physicochemical quality in dairy products are defined in the National Bromatological Regulation (Decree 315/994) (MSP, 1994). At the same time, there has been a National Biological Waste Program (PNRB) in the country since 1978, which controls medicines and environmental contaminants in food of animal origin (Decree 360/003). In dairy products, the following are controlled: bacterial-growth inhibitors, antibiotics (Chloramphenicol, Sulfas, Nitrofurans), anthelmintics, Phenylbutazone, aflatoxins, heavy metals (lead, Pl and Cadmium, Cd), organochlorine pesticides and organophosphates (MGAP, 2009). In order to build a national strategy on safety issues, the Food Safety Coordination and Planning Unit (UCPIA) was also created in the MGAP orbit in 2014. The place currently occupied by safety in core policies demonstrates the evolution of this issue in the country. Consumer demand for safe food with high nutritional quality, as well as natural (non-synthetic) functional foods, has increased in recent years. Since Uruguay has excellent conditions for the production of this type of food (basically pastoral-system), strengthening this production system will allow the production of dairy products with high added value, improving their perception as healthy food. Since safety is a clear attribute of competitiveness in the case of Uruguay, the challenge will focus on generating knowledge for risk analysis, strengthening capacities and training human resources in national needs.

4.2.3 Developing foods of high nutritional value from academia to the poultry farm. Multi-enriched eggs with DHA-Selenium

Ali Saadoun[11]

The development of a multi-enriched egg with DHA-Selenium was the result of a successful alliance between academia (UdelaR, Faculty of Sciences and Agronomy) and the productive sector (national poultry company), within the framework of competitive projects in the Promotion of Agricultural Technologies Fund (FPTA, INIA). Bird feed was used to produce an egg that contained eight times more DHA and twice as much selenium as a common egg. Since egg is a high protein food that is tasty and economical, which, when enriched, makes it possible to deliver DHA and selenium to consumers through a regular diet, this advance provides the opportunity to contribute to the nutritional quality of food, providing micronutrients

11. Full Professor, Animal Production and Pastures Department, Faculty of Agronomy and Physiology & Nutrition. Faculty of Sciences, UdelaR.

of which there is a clear deficiency in the Uruguayan diet (Observatory for Food and Nutrition Security, 2017). This food regains its place in a nutritionally intelligent diet, since the USDA (2016) discontinued the recommendation to limit the daily consumption of cholesterol to 300 mg. The latter has been the main obstacle to the consumption of eggs for half a century. The multi-enriched egg with DHA-selenium, a product of national scientific research, has been present in Uruguayan stores since December 2011 and bears the logos of the institutions that participated in this development.

5. Imporving Food Systems Efficiency and Value

5.1 Status of wheat and prospects for improvement

Daniel Vázquez[12]

Wheat (*Triticum aestivum*) is key to the Uruguayan food culture, to such an extent that it is the main energy source of Uruguayans' diet: 790 kcal per capita (OBSAN, 2017), approximately one-third of the total of a 2,400 kcal diet, and more than 80% of total cereal intake (INE, 2005). The volume of production fluctuated around the volume consumed (around 400,000 t per year) for decades until, during the last ten years, it increased to the point where Uruguay became consolidated as a net exporter, featured on the list of the top 20 exporters on several occasions, with a maximal production of 2 million t in 2011.

Uruguayan wheat's entry into international markets increased the demand for quality. The lack of vertical integration created a system in which the best wheat is not rewarded, causing marketing problems and penalizing prices. As a consequence, since the production peak in 2011, the area-under-cultivation and, consequently, production, has declined year after year, although a high exportable balance has been maintained. The industrialization of wheat means that complex quality requirements are created, and can be summarized in three broad groups. On the one hand, it is crucial to have good-quality physical grain, for which there has traditionally been a demand in Uruguay, without technical or commercial problems. On the other, good baking quality is required. The main limitation of national wheat is the protein content, which must be high, which cannot be achieved with the current production system unless economic incentives for fertilization for this purpose are encouraged. Last, like all food, it must be safe. Annual surveys have shown that, in this respect, the only limitation is the content of mycotoxins caused by fungal infections of the genus *Fusarium*. Given the importance of these infections, the country is at the forefront of research on how to minimize its effect. Nevertheless, in years with adverse climates, it is extremely difficult to obtain wheat without this problem.

5.2 Appraising local vegetables on the basis of their nutritional quality

Fernanda Záccari[13]

Uruguay produces more than 50 vegetables that are commercialized in the country's market, through production systems that promote the application of good agricultural practices. Potato, onion, pumpkin, sweet potato, tomato and carrot are the most important vegetables because of the weight and volume they occupy in the family food basket (OBSAN, 2017). Vegetables are a source of nutrients and antioxidants in the human diet, due to the vitamins, dietary fiber, minerals and essential oils they contain. Potatoes, sweet potatoes and squash, rich in carbohydrates, are also perishable and suffer loss of nutrients. Using tools that combine variety selection, ripeness status during harvesting, storage system and how vegetables are prepared contributes to reducing the loss of food and nutrients (Zaccari et al., 2015). In the Faculty of Agronomy (UdelaR), local cultivars are studied from a nutritional approach with the aim of contributing to food and nutrition security. A study of carrots adapted to local conditions showed that, in addition to being rich in minerals, they have provitamin A

12. Principal Investigator, National Program for Rain-fed Crops, INIA

13. Associate Professor, Postharvest Fruits and Vegetables, Faculty of Agronomy, UdelaR.

contents (6.1 mg of betacarotene/100 g) similar to that of foreign varieties (7.1 mg/100 g), despite their pale color, which are not affected by cooking (Zaccari et al., 2015). At the same time, a study on local pumpkin and sweet-potato varieties shows that they are richer in provitamin A (15 and 33 mg/100 g) in the fourth month (July) of conservation, whereas bioaccessible glucose (0.5-1 and 5-7.7 g/100 g cooked pulp) is maintained for prolonged periods of conservation (six months). The supply of provitamin A and available carbohydrates increases the nutritional interest of pumpkin and sweet potato, staples of the Uruguayan diet. Improving storage conditions to avoid high temperatures (12-14°C and 80% Relative Humidity, RH) reduces loss of quality up two times more than traditional preservation, without temperature and humidity control (Zaccari et al., 2015). Simple culinary practices for consumption *in natura* or with minimal processing are issues to be developed in a nutrition-sensitive approach to agriculture.

5.3 Fruticulture, status and outlook for climate variability

Milka Ferrer[14] y Gianfranca Camussi[15]

Eighty percent of fruit and vine production, concentrated in the southern part of the country, is focused on the domestic market, with 90% of production comprising three types of fruit: apples; peaches and pears. Average total production of the past three years is 630,000 t, which includes the production of citrus fruits, deciduous fruits, vegetables and potatoes. Grape production stands at approximately 90,000 t in 2017 with 5% being consumed as fresh grapes. The average volume of wine is 90 million liters per year (INAVI, 2012). On average, during the same period, 54,000 t of tropical fruits, including banana, and 26,000 t of fruits and vegetables were imported to complement local supply. Estimated fruit consumption in Uruguay is 245 g/day (OBSAN, 2017), below the amount recommended by the World Health Organization (WHO), the optimum being 400 g/day of fruits and vegetables, which is below average consumption in Europe (389.96 g/day) and above that of Chile (168.3 g/day). Wine, consumed in moderation, has been regarded as a food since ancient times, due to its energy contribution, a concept that is now being re-assessed from a health approach. It is an antioxidant due to its phenolic compounds, which protect against diseases related to aging. The beneficial effect of this beverage is associated with sustained consumption not exceeding 250 cc/day, equivalent to the WHO recommendation of a maximum of 30 g/day of alcohol in men and 20 g in women. Wine consumption in Uruguay is 27.5 L year (France, 38.5 L), 1/3 of the recommended limit.

In some years, the variability in production volume and quality of fruits due to the effects of the climate requires the importation of fruits and vegetables. Within the framework of the FAO-sponsored Project "New Policies for Adapting Agriculture to Climate Change-Response to Climate Change and Variability" (Ferrer et al., 2013), the chapter on Fruit Trees and Vines states that, for fruit trees, the insufficiency of low winter temperatures restricts the volumes produced. Longer-term mitigation strategies are proposed, rather than the current technologies available in the country (costly and not 100% effective), based on the use of varieties with low cold requirements. This is mainly possible for peaches, while the varieties internationally available for apples, whose fruit production is of good quality, have medium-to-high cold requirements. The models for probable climate-change scenarios indicate the possibility of an increase in precipitation in spring and summer, average monthly temperature, the number of days with temperatures over 30°C and the more frequent occurrence of extreme events. These predictions will heavily influence the occurrence of pests and diseases. In fruit trees, insects with tropical behavior, such as the fruit fly (Ceratitis capitata Wied) and apple scab (Venturia inaequalis FP), are observed more frequently and earlier during the growing season. Vines have experienced cluster rot (Botrytis spp., Alternaria spp., Aspergilus spp., Penicillum spp.), which affects the quality, safety and useful life of wine, which in turn leads to lossof-yield. There is a need to generate

14. Full Professor, Department of Plant Production, Faculty of Agronomy, UdelaR

15. Associate Professor, Department of Plant Production, Faculty of Agronomy, UdelaR.

products that take into account the environmental impact and consumer health such as: knowing the predisposing conditions of pests and diseases, using cultivation techniques that minimize the use of phytosanitary products, having proper machinery for their application, keeping records of the correct use and dose of permitted phytosanitary products, respecting the waiting times between applications and use, training staff to apply them, incorporating natural biodegradable products, and biological control. In the long term, it is essential to introduce and test disease-resistant varieties, in order to reduce phytosanitary applications. Another result related to climate variability is the need to rethink the current technological package: instead of making irrigation a priority (60% of the irrigated area for fruit trees), attention should focus on the choice of the site to be planted, its topographic location and building good drainage, while irrigation would, in this case, be used to supplement occasional water deficits. The chemical composition of grapes is strongly negatively associated with temperature and positively associated with precipitation, which raises the need for changes in the management of winemaking and alteration in the typicity of the variety.

5.4 Ecological intensification of livestock in Uruguayan native grasslands

Pablo Soca[16]

Livestock systems on native grasslands are the main economic and social activity of agriculture in Uruguay. The native grasslands constitutes 90% of fodder resource and provides ecosystem services such carbon sequestration, reduction of GHG emissions, water regulation and nutrient dynamics. In recent decades, and in order to intensify the production of foods with a human destiny, native grasslands systems have suffered increases in animal stocking rate and the expansion of afforestation and soybeans. Meat production and average weaning rates in the native grasslands were lower than the potential - 70 kg of meat/ha/year versus 200 kg of live weight/ha/year (Do Carmo et al., 2016). Feeding rates, averaging 63% over the past 10 years, could reach 80-85%. These indicators are explained by low energy consumption, which determines a negative energy balance (BEN), poor body condition (CC) at calving, a long period of postpartum anestrus, a low probability of pregnancy and a live weight of calves at weaning (150 kg). Production levels explain livestock with poor economic results, vulnerable to climate and economic changes, and with a limited capacity to compete with agricultural and forestry incomes, compromising the long-term sustainability of livestock. Achieving the greatest amount of animal product-per-unit area, with the lowest cost and economic risk possible, without damaging natural resources, has been the central objective of the line of research on the native grasslands (Do Carmo et al., 2016). Native grasslands are the main productive opportunity to ecologically intensify livestock and guide the increase in production with quality, capture value and improve livestock competitiveness and sustainability. Controlling grazing intensity is the main tool for simultaneously improving the uptake, use and conversion of solar energy to animal products, in order to improve the physical and economic competitiveness of the meat chain (Carriquiry et al., 2012; Do Carmo et al., 2016). Its effect on the energy flow is expressed through the Fodder Supply (FS) (kg DM / kg LW).

This was the basis for the design of experiments to study the effect of changes in the fodder supply and the Genetic Group (GG) of cows on primary productivity, and the use and efficiency of energy use for livestock raising in the native grasslands. Two FS treatments were used: High (HFS) and Low (LFS) treatments (10 vs. 6 kg DM/100 kgLW/day on average, HFS vs. LFS, respectively) as well as cows from two GG (pure: Aberdeen Angus and Hereford and crosses: their respective crosses, F1, Pure (PU) vs. Cross (CR)). A change from LFS to HFS increased the amount of fodder (50%) and fodder production (30%) without modifying the animal load, as well as improving reproductive efficiency, weaning weight and meat production per hectare (Do Carmo et al., 2016). CR cows were productively and reproductively superior (heterosis) to pure cows

16. Full Professor, Animal Production and Pastures Department, Faculty of Agronomy, UdelaR.

(Angus and Hereford), particularly so in restrictive environments (LFS) (Do Carmo et al., 2016). It is possible to double meat production by unit--of-area in Uruguay and contribute to the design of production systems that combine diversity and economic factors. This confirms that there is enormous scope for physically and economically viable intensification for Uruguayan livestock, with no changes in financial resources. This route will be synergistic with the rest of the meat chain since it will encourage the reduction of the production cost per kilo of product, the use of the "denomination of origin" tool and improvements in the sustainability of the productive apparatus. This will allow us to move toward "precision farming" and plan a future where food production is linked to technology.

5.5 Valorizing the pastoral meat chain within a nutrition and health paradigm

María Cristina Cabrera and Ali Saadoun

Foods of animal origin have accompanied humans throughout their evolution and have been associated with the intellectual development of hominids and the differentiation from their ancestors. Nevertheless, some philosophical currents recommend eliminating meat in favor of a strictly plant-based diet. That would ignore the contribution of food of animal origin to human development. Two million years ago, the first humans added game meat, bone marrow and aquatic animals to their diet, and there is convincing scientific evidence that this food innovation caused brain weight growth of 350 g to 1,350 g. The acquisition of cognitive abilities is associated with the main components of the brain, such as docosahexaenoic acid, haem iron, selenium, zinc and vitamin B12. Meat and animal foods are the main source of haem iron, zinc and vitamin B12. Their deficiency in the diet causes serious deficiencies of global importance and are the main cause of anemia incidence in children, adolescents and pregnant women worldwide and in Uruguay (WHO/OPS, 2016; Food and Nutrition Security Observatory, 2017). Since its introduction into America, beef has been a very important food which, in Uruguay, accompanies the local population in several expressions of everyday life. Uruguay produces 1% of the meat consumed worldwide, ranking 23rd in the world's producing countries. It consumes the third largest amount of beef worldwide (58.6 kg per capita) and is the sixth largest beef and sheep-meat exporting country (USDA, 2016). Despite the abundance of this food, there is a proportion of the population that lacks access to it. This is due, on the one hand, to their low purchasing power and the high cost of meat for the domestic market and, on the other, to changes in food patterns and consumer perception of animal well-being.

The importance of lean, good-quality meat in a modern, varied and balanced diet is indisputable because it is a complete food, which not only provides proteins with a high biological value, but also essential micronutrients. Meat is the main source of bioavailable haem iron and zinc iron (Cabrera and Saadoun, 2014) and helps maintains optimal body weight. In children, the contribution of haem iron makes it possible to meet the requirements of optimal cognitive development, impacting learning capacity and future intellectual development. It is a rich source of peptides associated with maintaining muscle mass and delaying aging. Since meat differs in its nutritional composition depending on the type of feed cattle are given, it has been suggested that a pasture-based production system creates meat with better nutritional indicators (lipids, fatty acids, minerals, vitamins) and higher resistance to oxidation (Cabrera and Saadoun, 2014; Trevino et al., 2015). Considering today's consumer, meat from pastoral systems would be better positioned because of its nutritional quality, in addition to other attributes that include environmental and social sustainability, and animal welfare. Within the scientific sphere, and with the aim of recovering consumers who practice a flexitarian diet both within the country and in markets that purchase Uruguayan meat, research has been conducted to describe beef from pastoral systems from a nutritional point of view. The strategic objectives sought are as follows: revalorize the Uruguayan pastoral meat chain within a nutritional value paradigm, and valorize cuts by relating cost to the specific contribution of nutrients, in order to obtain accurate, sustainable nutrition for children, adolescents, expectant mothers and senior citizens. Our study attempts to contribute to the food policies of a country where, although the quantity of food is sufficient for the population, some people, especially children, do not have access to sufficient amounts of meat (WHO/OPS, 2016). Meat from pastoral systems provides the main essential minerals. A 100-gram serving covers 100% of selenium requirements, between 8% and 60% of iron and between 21% and 145% of zinc requirements, considering adults and children. Each cut presents a particular mineral profile, which would allow meat intake to be adapted to specific iron, zinc or selenium needs (Cabrera and Saadoun, 2014). Meat from pastoral systems also contains more creatine (4.308 vs. 3.588 mg/kg) and carnosine (3.877 vs. 3.162 mg/kg) compared to feedlot beef in Uruguay (Cabrera, et al., 2015). These peptides are considered part of the so-called "meat factor": they promote the absorption of non-haem iron from plant foods, increasing the nutritional value of a mixed meal, even it only contains few grams of meat. As for lipids, meat from pastoral systems is richer in linolenic acid (C18:2n3), DHA and CLA, and has less palmitic acid (C16:0), an atherogenic fatty acid, compared to that from cattle fed on concentrate (Saadoun and Cabrera, 2015). Moreover, meat from pastoral systems has high levels of β-carotene and α-tocopherol, which explains the antioxidant capacity of this meat, despite its higher profile in unsaturated fatty acids (Saadoun and Cabrera, 2015). These studies provide information for precision nutrition and the rational use of an expensive food, as well as for the evaluation of pastoral production systems. If we regard meat as a sustainable way to fight anemia and micronutrient deficiencies, the challenge for the next years will be to expand detailed knowledge of the nutritional composition of the meat, considering breeds, type of pasture and type of cut as well as the changes brought about by technological processes.

5.6 The case of the Uruguayan dairy industry

Pablo Chilibroste[17]

In response to the changes in the conditions of competition with other agricultural activities and the increase in land prices (DIEA, 2011), the Uruguayan dairy industry has steadily increased its productivity. In recent decades, the Uruguayan dairy sector has grown at a rate of 5% per year (DIEA, 2009). This sustained pace of growth has accelerated in the last six years with growth rates of 7% per year (INALE, 2016). This growth has mainly been based on productivity increases (liters per hectare), as the dairy area has decreased by 10% during this period (DIEA, 2009). Productivity per cow is the factor that accounts for a greater proportion of growth (>60%), while the increase in animal load explains 25-30% of the sectors productivity increase. This strategy for intensifying milk production in Uruguay has been based on a significant increase in the use of concentrates and fodder reserves (DIEA, 2009), while the direct harvest of fodder by livestock has remained largely unchanged (Chilibroste et al., 2011).

This model of Uruguayan dairy intensification has been extremely demanding with respect to the levels of investment required for feeding processes (Mixer, feeding beaches), milking capacity, infrastructure (road, corrals, irrigation), effluent management and livestock management. Estimates made in the Conaprole cost project (Artagavéytia sp.) show that in the last three fiscal years, between 50 and 75% of capital income from dairy farms has been re-invested in assets (infrastructure and animals). The intensification process has also led to major changes in the area of human resources, significantly increasing the demands of qualified human capital and the levels of complexity in the organization of work. Difficulties in accessing and subsequently retaining skilled labor are one of the first constraints experienced by milk producers on sustaining future growth and/or introducing innovations in systems (ANII Innovation Survey, 2013). The problem of training human capital affects the entire dairy chain (as it does other agri-food chains). In general terms, the intensification process has resulted in production systems with higher productivity levels, improved economic performance, better levels of conversion efficiency (liters of milk produced/kg DM consumed), higher unit production costs, investment, increasing levels of complexity and greater pressure on natural resources.

17. Professor, Animal Production and Pastures Department, Faculty of Agronomy, UdelaR.

The most intensive production systems remain extremely competitive at the international level, with Uruguay achieving the lowest international milk-production costs (IFCN, 2013). The low cost of production of Uruguayan systems is explained by the fact that fodder (direct harvest plus reserves) continues to account for a relatively high share of animal feed (Chilibroste et al., 2011). Redesigning systems requires changes in feeding strategy, animal management and pasture. Evaluating how response variables are affected by modifying these aspects is a matter of concern for the dairy industry. The analysis of the problem must include the fact that Uruguay is a net exporting country (more than 60% of the milk produced), meaning that aspects related to the quantity and type of solids produced, animal health and welfare, waste management (in the milking hall and feeding beaches) and controlling production costs are central to the competitiveness of production systems and the dairy chain as a whole.

It is necessary to lay the foundations and produce the necessary tools to study the efficiency pillars – broad, integrated aspects - of production systems, and generate knowledge about the main components that make the system competitive. The problem is complex and the research undertaken has tended to focus mainly on improving food to maximize production. There has been a predominance of reductionist approaches in the absence of an integral vision of the problem and, in general, without integrating actors from the primary sector of the dairy industry. Information has not reached the productive sector in time, or rather, has been used to provide guidelines that do not make it possible to predict the behavior of the production system as a result of strategic decisions. In response to these demands, over the past two years, Sectorial Innovation Networks have been created in conjunction with academia and the productive sector to provide solid answers based on scientific information from larger-scale experiments, commercially obtained and experimental data, working in a network with professionals who provide commercial services. The proposal implies a methodological change in the type of partnership between actors in the sector to jointly undertake functions in research and outreach.

6. Health Considerations

Carmen Marino Donangelo[18]

6.1 Foodborne diseases

Food safety is a global public health concern since the incidence of foodborne diseases is increasing in many countries, particularly in industrialized countries (WHO, 2015). Although recent changes in primary food production and technological processing, preparation and preservation have generally resulted in better control of the most common food and waterborne diseases - such as typhoid fever, tuberculosis and brucellosis - new practices in farm and agricultural production and the increased time required in the food distribution chain have led to the emergence of new foodborne pathogens such as *Escherichia coli* O157, *Campylobacter jejuni*, *Salmonella enteritidis*, *Listeria* and *Vibrio cholera*. These changes have also increased the risk of food exposure to antibiotic-resistant pathogens, such as *Salmonella typhimurium* DT 104, different noroviruses and rotavirus, agents that cause transmissible encephalopathies (prions) and chemical residues and contaminants originating from the environment and/or agricultural and industrial practices (mycotoxins, persistent organic pollutants, heavy metals). In addition, modern lifestyles are increasingly dependent on the availability of convenience foods, which may contain ingredients from various parts of the world and involve more time between preparation and consumption, which contributes to increasing the risk of foodborne disease.

Food safety is a key aspect of food security since all food available for consumption should be safe. At the international level, WHO and FAO have established global food-safety standards through the Food Codex Commission to harmonize the food-safety legislation of various countries for the whole world and facilitate international trade (WHO/FAO/CODEX).

Uruguay has national regulations to control the safety and quality of food and food products (National Bromatological Regulation, 1994) and to ensure plant biodiversity and biosafety (Decree,

18. Full Professor, School of Nutrition, Clinical Hospital, UdelaR.

2008). The actions related to compliance with these regulations are undertaken by the Ministries of Public Health (MSP) and Livestock, Agriculture and Fisheries (MGAP), the National Meat Institute (INAC), the Uruguayan Technological Laboratory (LATU), Municipalities and other state institutions. There is coordination and integration among the actions of the various institutions, especially with regard to monitoring and compliance with international standards (FAO, 2011).

Ensuring food safety is a high priority for Uruguay, both for national public health goals and for food exports. Indeed, the incidence of foodborne diseases is extremely low in the country, with less than 400 cases per year, 30% of which involve salmonella (WHO/OPS, 2016, MSP, 2016). Prior to 1994, *S. typhimurium* was the serotype most frequently isolated in outbreaks of salmonellosis; from 1997 to 2004, *Salmonella enteritidis* was the most prevalent serotype, but as of 2005 there has been a dramatic reduction in the number of cases related to both serotypes (Betancor et al., 2010). The World Organization for Animal Health has certified Uruguay as a country free of foot-and-mouth disease with vaccination and free from bovine spongiform encephalopathy (International Organization of Epizootics).

Regarding the presence of pesticide residues in food in Uruguay, a report from the Municipality of Montevideo corresponding to the analysis of 831 samples of fruits and vegetables, including fresh, frozen and juice samples, indicated that 2% of the samples had concentrations above the *Maximum Residual Limit* (MRL) established by CODEX (IMM, 2012). These results are in line with the European Union' 2013 report on pesticide residues in food imported into Europe from different countries, where 1.4% of the samples from Uruguay are above the CODEX MRL, a much lower percentage than that of other countries in South America.

6.2 Chronic non-infectious diseases related to food consumption and dietary habits

The health and well-being of populations depend on the complex interaction among socioeconomic, environmental and lifestyle factors, among which food intake and nutrition play an important role. In most countries, overweight, especially when associated with low physical activity, increases the risk of Chronic Noncommunicable Diseases (NCD) such as obesity, metabolic syndrome, cardiovascular disease, type 2 diabetes and certain types of cancer. Smoking, stress and alcohol abuse are also important factors involved. These diseases are generally characterized by an excessive intake of macronutrients or an insufficient supply of micronutrients. Therefore, overconsumption of food often coexists with vitamin and mineral deficiency, and the low intake of bioactive components of healthy food protectors (WHO, 2015). Non-Communicable Diseases (NCD represent the main cause of morbidity and mortality in Uruguay (WHO/OPS, 2016). In 2014, the total mortality rate (per 100,000 population, adjusted for age) was 402.5 for NCD, 38.6 for infectious diseases and 57.4 for other causes. Key information to the general health of the Uruguayan population is that life expectancy in 2016 was 77.5 years (73.9 years for men and 80.9 for women). Two national surveys conducted in 2006 and 2013 by the Ministry of Public Health evaluated the prevalence of major risk factors (metabolic, behavioral, lifestyle) associated with NCD in the urban adult population in Uruguay. In the 2013 survey, younger individuals (≥15 years) were also included. The most recent data (2013) indicated that the prevalence of overweight (Body Mass Index, BMI ≥25 kg/m² and <30 kg/m²) was 42.1% in males and 32.7% in females, while the prevalence of obesity (BMI ≥30 kg/m²) was 26.0% in men and 29.2% in women. The combined prevalence of overweight and obesity was greater at a higher age range regardless of gender: 78.1% in the 55-64 year range compared to 38.5% in the 15-24 year range. The combined prevalence of overweight and obesity in adults increased by 8.1% from 2006 to 2013.

A recent survey (MSP/PPENT, 2016) indicated that the prevalence of hypertension in adults was 40.4% in men and 33.1% in women. The prevalence of hypertension by combining genders was higher in the higher age range, 62.8% in the 55-64 year range of compared with 8.7% in the 15-24 year range. In adult population, the prevalence of hypertension increased 6.0% from 2006 to 2013. In the same survey, high blood cholesterol (≥200 mg/dL) was observed in 22.1%

of adult men and in 20.9% of adult women. This prevalence increased with the age range, from 8.6% in the 15-24 year range to 35.0% in the 55-64 year age range. Similarly, the prevalence of high levels of fasting blood glucose/diabetes was higher in the 25-64 year (11.1%) than in the 15-24 year (2.0%) range. Considering behavioral and lifestyle factors, the prevalence of daily smoking in 2013 was slightly lower in adult women (25.4%) than in adult men (32.5%), and even lower (16.7%) in younger individuals (ages 15-24). On the other hand, the prevalence of habitual alcohol consumption was 37.4% and 64.2% among adult women and men, respectively, with higher prevalences in the younger age groups (48.8% and 40.2% in men and women, respectively, ages15-24 years). Low physical activity was present in 18.5% and 24.5% of men and women, respectively, with no variations by age range. The addition of salt to prepared meals was observed in 21.6% of adults (25-64 years) and in 32.4% of younger individuals (15-24 years). Insufficient daily consumption of fruits and vegetables (less than five servings per day) was present in 92.2% of men and 89.1% of women, with no significant differences by gender or age. The prevalence of three or more concurrent risk factors (metabolic and behavioral) was 47.2% and 39.9% in adults (25-64 years) and 12.6% and 17.5% in the youngest age group (15-24 years) in men and women, respectively.

In these national surveys, information has been obtained, albeit limited, on the nutritional status and dietary habits of the Uruguayan population. However, no attempt has been made to establish associations between nutritional/food information and the presence of risk factors for CNCD.

In a different national survey conducted in urban and rural Uruguay, household expenditures were assessed in different areas, including expenditure on the purchase of food and beverages (Bove and Cerruti, 2008). The information made it possible to estimate average values of daily apparent consumption of food and beverages, stratified by household income levels. Given that aspects such as food waste and intrafamilial distribution within the household were not considered, the results obtained represent per-capita averages of apparent consumption of food and beverages in the population rather than consumption at the individual level.

Considering the results as a whole, it was estimated that approximately 50% of energy consumption from food and beverages comes from the combination of baked goods, refined cereals, fats and oils, 13% from meats - especially red meats - 9% from milk and dairy products, 8% from fruits and vegetables, and 12% from sugar and sugary drinks. In general, typical foods consumed in the country (processed grilled and fried meats, dairy products, breads and pastries, potato chips) promote exposure through the diet to animal protein, simple sugars and starch, saturated fat and trans-fatty acids.

In urban households, the highest values for average per-capita consumption were observed for milk and dairy products (360 g/day); breads, pastries and refined cereals (260 g/day); sugary beverages (138 g/day); and meats, cold cuts and sausages (123 g/day). Very low consumptions were observed for fish (8 g/day) and legumes (5 g/day). On the other hand, consumption of yerba mate (25 g/day) was higher than that of coffee (2 g/day). Indeed 80% or more of the population consume maté (an infusion prepared from the leaves of the Ilex paraguayensis plant), averaging about half a liter per person per day (MSP/PPENT, 2016).

Average per-capita consumption was higher in rural than urban households for milk and dairy products (530 g/day); breads, pastries and refined cereals (313 g/day); (35 g/day), but similar for fruits and vegetables (220 g/day), legumes (6 g/day), fish (5 g/day), fats and oils (38 g/day) and alcoholic beverages (45 g/day).

Household income level was a very important factor that affected the populations per-capita consumption of food and beverages. Households in the highest-income quintile had lower intakes of refined grains, higher consumption of fruits/vegetables and fish, and more frequently selected lean meat cuts compared to households in the lowest-income quintile. Total consumption of energy, sugary desserts and beverages, and alcoholic beverages was also higher in households in the highest-income quintile. Moreover, these households had higher consumption of foods with high total fat and cholesterol. In contrast, households in the lowest income quintile had the lowest consumption of dairy products and lean meats.

Regardless of the household income level, average apparent consumption of food and beverages by the Uruguayan population seems to cover the nutritional requirements of protein and certain micronutrients such as niacin, riboflavin, folate and vitamin B12, yet appears to be insufficient in terms of fiber, vitamin C, vitamin A, vitamin E, potassium and calcium.

6.3 Nutrition and child development

Optimal growth and development from conception to early childhood are well-recognized necessary conditions for ensuring health and well-being from the earliest years of life to adulthood. Interactions between genes and adverse environmental factors such as under- or overnutrition during the early stages of embryonic and fetal development may predispose to chronic degenerative diseases in the later stages of the life cycle (Barker, 1990). Information on dietary intake and nutritional status during pregnancy, lactation and early childhood is therefore crucial to public health.

A recent survey in Uruguay (ENDIS, 2015) was the first to simultaneously assess the nutritional status, health conditions and development of children under 4 nationwide. Information on the income level and educational attainment of families, child-raising practices and total number of persons per household were also examined.

As a general result, it was observed that overcrowding was present in 25% of households, especially those below the poverty line (44.5%), and that the father figure was absent for 20% of children. Pregnancies were unplanned in approximately 50% of cases. Smoking and alcohol consumption were present in 16.7% and 11.4% of pregnant women, respectively, particularly in adolescent mothers and those with lower educational attainment. Less than half the women (39%) received prenatal iron and folic-acid supplements during pregnancy. The prevalence of low birth weight (<2,500 g) was 7.7% while the prevalence of prematurity was 10.7%, with no differences due to maternal age or geographical location.

Stunted growth (height-for-age Z score ≤2) was present in 4.5-5.0% of children, mainly in households below the poverty line (6.7%). Overweight was found in 9.6% and 11.3% of children under 2 and between 2 and 4 years, respectively. Obesity was present in 1.9% and 2.1%, respectively, in the aforementioned age groups. The prevalence of reported anemia was 9%, especially high in children of households below the poverty line (13.1%). In a previous survey of children under 2 in public and private health services, there was a higher prevalence of clinically diagnosed anemia (31%) and stunted growth (10.9%), yet a lower prevalence of overweight and obesity combined (9.5%) (Bove and Cerruti, 2011).

Food insecurity assessed in the ENDIS survey (ENDIS, 2015) through the ELCSA scale (FAO, 2012) indicated that 4.3% of children live in severely food-insecure households, and that 8.9% live in households with moderate food insecurity. In general, children's food intake was low in fruits, vegetables and fish, and included excessive amounts of snacks and sweets. In more than 50% of households, salt was added to foods for children under one year. About 20% of children did not consume water when thirsty, and instead drank processed juices or beverages, particularly in lower-income households.

7. Policies that contribute to food and nutrition security

María Cristina Cabrera

7.1 Comparative advantages in agriculture: competitive yet vulnerable

Uruguay has comparative advantages in agriculture, with a food-production capacity for 30 million people. However, due to the productive specialization of the Uruguayan economy, based on the production and export of primary products with low added value, the country has a risk of vulnerability. The United Nations Common Country Analysis (CCA) warns of the risk of this economic model, which is vulnerable to alterations in world markets, weakens sustained growth and generates negative conditioning in the population¿s economic expectation levels of investment and technological innovation, as well as a propensity to migrate among people of high educational attainment, all key factors for sustaining long-term growth. Comparative advantages are an opportunity to invest in added value and transformation with innovation, strengthening existing agroindustrial chains and creating knowledge-intensive activities. The ultimate goal, according to FAO, is to use environmentally sustainable natural resources, reduce regional disparities in per-capita income levels and develop nutrition-sensitive agriculture.

7.2 Policies that promote technological innovation through skilled human capital

The specific public policies Uruguay launched in 2005 created a new institutional framework for innovation (Ministerial Cabinet of Innovation and ANII) to promote an "innovative Uruguay". Within this framework, innovation is promoted by strengthening and orienting strategic areas, such as the agricultural and agroindustrial sector, through value chains, and generating instruments to strengthen human capital (National System of Researchers, Scholarship Programs, Tertiary Technical Training and National Graduate Programs). Innovation is stimulated through specific R&D&I programs, clusters, innovation consortia, poles and technology parks, innovation in companies and various programs linked to the productive sector, with public funding from UdelaR and ANII. There are a number of aims: training of highly skilled human resources; strengthening of consolidated researchers who contribute to the efficiency and competitiveness of productive resources, with less deterioration of natural resources, more social inclusion, and effective linkage with all aspects of the business and productive environment.

7.3 Policies that promote the consumption of healthy foods

With regard to Food and Nutrition Security policies, actions have been more recent and intended to palliate serious situations arising from the poverty and extreme poverty recognized as existing in the country (ENDIS, 2015). Although the educational attainment of the Uruguayan population is satisfactory, their knowledge, attitudes and eating habits are deficient, meaning that nutritional education programs for the entire population should urgently be undertaken to achieve a healthy diet. In recent years, fruit and vegetable consumption promotion programs have been carried out, with the participation of several institutions -INIA, Rural Montevideo, Mercado Modelo, MGAP (2010-2012) and healthy snacks for school cafeterias (MSP, 2014). Moreover, as a result of inter-agency actions, Food Based Food Guidelines (GABA, 2005; 2016) have been published. In 2013, Health Law 19.140 was promoted at Education Centers, which seeks to contribute to the prevention of overweight and obesity, high blood pressure and chronic noncommunicable diseases linked to poor eating habits and a sedentary lifestyle. It was established that salt shakers would not be available in school cafeterias, as a way to discourage salt consumption. MSP and MIDES, through Uruguay Grows with You and the INDA Food Institute, are working to design strategies to promote healthy habits, since 30% of the food consumed in the country is ultraprocessed, which has led to high obesity and overweight rates. High prices of food such as fruits, vegetables, meats and fish make it difficult to include them in the daily family diet (Barboza, 2007). The challenge is to create public policies for food education and standards for the regulation of ultraprocessed products, as well as labeling that reflects not only the composition of prepared foods (which already exists), but also provides information about the characteristics of the food. Another challenge is to be able to influence prices to achieve greater access to quality food.

7.4 International trade in Uruguayan meat: an interesting case for economic development with equity

Pablo Caputi[19]

Uruguay produces between 550 and 600 thousand t epc of beef per year that are not absorbed by domestic consumption, generating 400 thousand t epc for the international market.

The Markets. The main destination of Uruguayan meat is Europe, the U.S., Russia, China, Israel and Mercosur. Brazil and Argentina are specific markets, while Chile, a net importer, is able to purchase large volumes. Europe was the first natural destination for the continent linked to the industrialization of meat in Uruguay in the 19th century (Liebig Company) until its retraction after World War II. Today there is a regular flow linked

19. Manager, Knowledge Manager, INAC.

to quotas or tariff quotas (from the exporting country or importing bloc), such as the Hilton Quota (6,300 t of valuable cuts) and a very interesting alternative, the so-called quota 481 (or HQB, High Quality Beef). This quota has several strategic advantages: no tariff is paid; nearly all cuts are placed and business is conducted with pre-defined prices. Israel, a consistently solid market, imports 25 to 30 thousand t epc. The two destinations (Europe and Israel) account for 25% of the total amount exported.

The U.S. was an interesting market until the foot-and-mouth disease crisis (2000/2001) and once again in 2004, when it changed its safety policy and allowed Uruguay to export deboned and matured meat. Russia subsequently emerged as a key buyer because of its enormous economic power. The Uruguayan industry showed great flexibility in interpreting movements in markets, redirecting the product to the market that paid most. In recent years, China has emerged in the world beef market, as a strong buyer of all species. It is Uruguay's main importer, accounting for over 45% of the total volume in 2016. The main markets (China, the U.S., Europe, Israel) import 80% of the total. The other 20% is placed in the rest of the world, with no tariff preferences and major logistical disadvantages of localization in comparison with competing countries (such as Australia and New Zealand in the Asian markets). Uruguay has created a strategy of penetration of the country, supported by a rich, relatively complex institutionality that suits the needs of this trade.

The insertion strategy. The organization responsible for setting agricultural policies in Uruguay is the Ministry of Livestock Agriculture and Fisheries (MGAP). For the specific case of meat, MGAP has access to the advice and executive capacity of the National Meat Institute (INAC). This body is a public non-state person, with a mixed Board of Directors: three cattle-rancher delegates, three industrialist delegates, two delegates from the Executive Branch (the president is appointed by the MGAP). In addition to this Board of Directors, INAC has a specialized body of technicians responsible for the main aspects related to the business: Internal Commercial Control (particularly in exports); Information and Economic Analysis, Marketing in both the domestic and international markets and, more recently, the so-called knowledge function, which seeks to accelerate innovation processes in the chain.

Access to the world's markets requires fine-tuning the country's political and commercial priorities, for which coordination with the Foreign Ministry is essential. Thanks to this joint action among MGAP, the Foreign Ministry and INAC, all the world's markets (with the exception of Japan's, which is about to open) have been opened for deboned and mature beef. The so-called "aphasic circuit" ceased to be a non-tariff barrier, thanks to the action of Uruguay, which leads this process.

The biggest constraint for Uruguay is the lack of trade liberalization agreements. It has been estimated that for beef alone, approximately $200 million USD are paid in tariffs, which shows the scale of the problem. Advances in health aspects must be accompanied by advances in the field of international trade, to prevent a weakening of the country's current position.

The future road. Uruguay has 100% of its cattle identified electronically, in a system controlled by MGAP (National Livestock Identification System, SNIG). It is linked to another system of industrial traceability that controls 100% of the meat produced, which in turn is run by the INAC (Electronic Information System of the Meat Industry, SEIIC). It also adapts to demand by creating animal welfare programs and protocols. All this shows the confidence global consumers can have in Uruguayan meat, as a result of the following: natural production, mostly on natural pastures, open air, with an abundance of water and shade, with a law prohibiting the use of hormones and antibiotics as growth promoters. For this reason, the slogan for meat marketing is "We pack nature, we sell trust". However, these marketing supports do not suffice: today's consumer wants more. That is why efforts are being made to improve the sustainability of the entire process, by measuring and demonstrating the fact that Uruguayan meat is indeed sustainable. There are therefore several projects underway. It also attempts to attack specific consumer niches, emphasizing the nutritional aspects of the country's meats that have specific profiles due to their strong pastoral content. Cattle are derived from good British stock (Angus, Hereford), a strength that can be leveraged. Last, all the information incorporated into the chain must be summarized in order to be a useful by-product to sell in the future. The challenge and the opportunity are to sell a meat product with added value, and the engineering and the know how that enabled it to be obtained. Perhaps this is the largest contribution livestock can provide to Uruguay in its path toward sustainable and equitable economic development.

8. Final Considerations

Uruguay has increased its agricultural production over the past 30 years based on productivity increases, yet at the cost of losing part of its resources (soils, water quality), issues that the country will prioritize on its agenda over the next few years.

The abundance of food in the country, and in the region as a whole, fails to reach part of the population, which displays significant nutritional deficiencies, reflecting unequal access to food, either as a result of prices or distance. Other factors with an impact on the population are changes in dietary patterns. The prevalence of protein-energy and micronutrient deficiencies is similar to that of overweight and obesity in young individuals, meaning that specific policies are required to reverse the current food and nutritional security situation.

In order to reduce the risks and vulnerability of Uruguayan agriculture and its impact on Food and Nutrition Security (FNS), policies should be adopted to improve the competitiveness and integration of value chains, as well as to improve food safety and quality. It will therefore be necessary to establish policies for land management, planning and management of natural resources and biodiversity, as well as for the diversification of agricultural and agroindustrial production, which will increase added value and make it nutrition-sensitive. At the same time, local rural-development policies that contribute to FNS should also be promoted.

References

Barker, D.J. (1990). The fetal and infant origins of adult disease. British Medical Journal, 301 (6761): 1111.

Becoña, G.; Astigárraga, L.; Picasso, V. (2014). Greenhouse gas emissions of beef cow–calf grazing systems in Uruguay. Sustainable Agriculture Research, 3 (2):89-105.

Berretta A., Condón F., Rivas M. (2007). Segundo informe país sobre el estado de los recursos fitogenéticos para la alimentación y la agricultura. https://goo.gl/sHZkts

Betancor, L.; Pereira, M.; Martínez, A.; et al. (2010). Prevalence of Salmonella enterica in poultry and eggs in Uruguay during an epidemic due to Salmonella enterica serovar enteritidis, J. Clin Microbiol, 48 (7): 2413-2423.

Bonnecarrère; V.; Garaycochea S.; Fernández S.; Rosas J.; Quero G.; Pérez de Vida F.; Blanco P.; Gutiérrez L. (2014). Genome-wide association mapping in rice for yield and grain quality. Plant and Animal Genome Conference, San Diego, CA, USA.

Bove, M.I. y Cerruti, F. (2011). Encuesta nacional sobre estado nutricional, prácticas de alimentación y anemia en niños menores de dos años, usuarios de servicios de salud de los subsectores público y privado del Uruguay. Montevideo: UNICEF, MSP, MIDES, RUANDI.

Bove, M.I. and Cerruti, F. (2008). Los alimentos y las bebidas en los hogares. Encuesta Nacional de Gastos e Ingresos 2005-2006. Instituto Nacional de Estadística. 2008

Buehner, K.; Anand. S.; García, A. (2014). Prevalence of thermoduric bacteria and spores on 10 Midwest dairy farms, Journal of Dairy Science, 97: 6777-6784.

Cabrera, M.C. and Saadoun, A. (2014). An overview of the nutritional value of beef and lamb meat from South America. Meat Science 98, 435-444.

Cabrera, M.C.; Terevinto, A.; Zaccari, F. y Saadoun, A. (2015). Creatina, carnosina y anserina en el músculo Longissimus dorsi de novillos Aberdeen Angus alimentados a pasto versus concentrado. XXIV Congreso de la Asociación Latinoamericana de Producción Animal (ALPA). 9-13 noviembre. Puerto Varas, Chile.

Carriquiry, M.; Espasandin, A.C.; Astessiano, A.L.; Casal, A.; Claramunt, M.; Do Carmo, M.; Genro, C.; Gutiérrez, V.; Laporta, J.; Meikle, A.; Pérez-Clariget, R.; Scarlato, S.; Trujillo, A.I.; Viñoles, C.; Soca, P. (2012). La cría vacuna sobre campo nativo: un enfoque de investigación jerárquico para mejorar su productividad y sostenibilidad. Veterinaria (Montevideo), 48(Supl. 1): 41-48.

Cayssials, R. y Álvarez, C. (1983). Interpretación agronómica de la Carta de Reconocimiento de Suelos del Uruguay. Dirección de Suelos y Fertilizantes-MGAP, Boletín Técnico No. 9, Montevideo, p. 29.

Cayssials, R.; Liesegang, J.; Piñeyrúa, J. (1978). Panorama de la erosión y conservación de suelos en Uruguay. Dirección de Suelos y Fertilizantes-MGAP, Boletín Técnico No. 4.

Chilibroste, P.; Soca, P.; Mattiauda, D.A. (2011). Balance entre oferta y demanda de nutrientes en sistemas pastoriles de producción de leche: potencial de intervención al inicio de la lactancia. In: XV Congreso Latinoamericano de Buiatría, XXXIX Jornadas Uruguayas de Buiatría. Eds. Centro Médico Veterinario de Paysandú–SUB. Paysandú, Uruguay. 8-10 Junio 2011. pp. 91-97. ISSN 1688-6674.

Cooperativa Laboratorio Veterinario de Colonia (Colaveco) (2015). Estadísticas de Calidad de leche de tanque. Available at: https://goo.gl/iwsyCb Retrieved: December 2016.

Da Silva, C.; Zamperin, G.; Ferrarini, A.; Minio; A.; Dal Molin, A.; Venturini, L.; Delledonne, M. (2013). The high polyphenol content of grapevine cultivar Tannat berries is conferred primarily by genes that are not shared with the reference genome. Plant Cell, 25(12): 4777-4788.

De León, L. (2016). Abordaje de la temática de la calidad de agua por la DINAMA. En: Mesa: Calidad de Agua: Una Visión Multidisciplinaria. Libro de Resúmenes III Jornadas Interdisciplinarias en Biodiversidad y Ecología (JIBE) 'Desafíos Socio-Ambientales para el Uruguay del Futuro' 28 de noviembre al 2 de diciembre. Rocha, Uruguay: Centro Universitario Regional del Este; 2016: 129. https://goo.gl/VZTiLN

DIEA (2009). La producción lechera en Uruguay. Anuario Estadístico Agropecuario 2009. MGAP, p. 79.

DIEA (2011). Anuario Estadístico Agropecuario 2011. MGAP, p. 246.

DIEA (2013). Anuario estadístico agropecuario 2013. MGAP, p. 246.

DIEA-MGAP (2009). Encuesta frutícola de hoja caduca: 1994, 1996 a 2009. Available at www.mgap.gub.uy

Do Carmo, M.; Claramunt, M.; Carriquiry, M.; Soca, P. (2016). Animal energetics in extensive grazing systems: rationality and results of research models to improve energy efficiency of beef cow-calf grazing Campos systems. J. Anim Sci., 94(S6):84-92.

Durán, A.; Califra, A.; Molfino, J.H. (2002). Mapa de suelos del Uruguay y memoria explicativa, con leyenda basada en la clasificación de suelos de EEUU, Taxonomía de Suelos. Facultad de Agronomía-UdelaR..

ENDIS (2015). Encuesta nacional de salud, nutrición y desarrollo infantil.

EU (2015). European Union on pesticide residues in foods. EFSA Journal 13(3):4038..

EU (2004). Regulation (EC) N° 853/of the European Parliament and of the Council of 29 April 2004. Laying down specific hygiene rules for food of animal origin. Official Journal of the European Union 47: L226/22-L226/82.

FAO (2004). El Control de los Alimentos en el Uruguay. Segundo Foro Mundial FAO/OMS de Autoridades de Reglamentación sobre inocuidad de los Alimentos. Bangkok, Tailandia.

FAO (2011). Marco de Programación País para la cooperación de la FAO en Uruguay 2011-2015.

FAO (2012). Escala Latinoamericana y Caribeña de Seguridad Alimentaria, ELCSA. Available at: http://www.fao.org/3/a-i3065s.pdf

Farley, K.A.; Jobbágy, E.G.; Jackson, R.B. (2005). Effects of afforestation on water yield: a global synthesis with implications for policy. Global Change Biology, 11(10):1565-1576. doi: 10.1111/j.1365-2486.2005.01011.x

Ferrer, M.; Camussi, G.; Fourment, M.; Varela, V.; Pereyra, G. (2013). MGAP-FAO. Sensibilidad y capacidad adaptativa de la viticultura y la fruticultura frente al cambio climático. Volumen VI de Clima de cambios: nuevos desafíos de adaptación en Uruguay, p. 60.

Frison, E. and Hodgkin, T. (2016). Strategic opportunities to strengthen community based approaches to seed agrobiodiversity. In: The Future of Food: Seeds of Resilience. A Compendium of

Perspectives on Agricultural Biodiversity from Around the World. p. 29.

Galván et al. (2000). La adaptación productiva del germoplasma local de cebolla y morrón y su utilización en el desarrollo de cultivares. Informe Final del Proyecto CSIC I+D. Universidad de la República. p. 18.

Galván, G.; González, H.; Vilaró, F. (2005). Estado actual de la investigación en poblaciones locales de hortalizas en Uruguay y su utilización en el mejoramiento. Agrociencia, 9(1-2):115-122.

Galván, G. (1993). Poblaciones locales de cebolla. En: Capra et al. (Editores). Cultivo de cebolla en la región Sur. INIA Boletín de Divulgación, 29:19-20.

Galván, G.; González, H.; Sollier, S. (1997). Productive adaptation of onion (Allium cepa L.) landraces used for postharvest storage. Acta Horticulturae, 433:165-170.

García Préchac, F.; Hill, M.; Clérici, C. (2015). EROSION versión 6.0.20, Programa de computación para el uso de la USLE/RUSLE en Uruguay y la Región Sur de la Cuenca del Plata. Operating version in Windows. Available at: www.fagro.edu.uy Dpto. de Suelo y Aguas, Manejo y Conservación.

Grille, L. (2016). Caracterización estacional de la calidad de la leche de tanque en predios de la región litoral norte del Uruguay. Efecto del tiempo de almacenamiento y tamaño del rodeo sobre la calidad higiénico-sanitaria. Master thesis in Animal Production. Facultad de Veterinaria, Universidad de la República.

IMM (2012). Informe sobre control de residuos de plaguicidas en frutas y hortalizas. Available at: https://goo.gl/bUiarU

INALE (2016). Información del Uruguay, exportaciones, productos y destinos. Available at: https://goo.gl/rvBCcU

INAVI (2012). Estadísticas de vino y viñedos. Disponible en: www.inavi.com.uy

IPCC (2006). Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. In: H. S. Eggleston, L. Buendía, K. Miwa, T. Ngara, y K. Tanabe (Editors). Japan: (Hayama: IGES).

Jarvis, D.I., et al. (2008). A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming communities. Proceedings of the National Academy of Sciences, 105:5326-5331.

Lizarralde, C.; Picasso, V.; Rotz, A.; Cadenazzi, M.; Astigárraga, L. (2014). Practices to reduce milk carbon footprint on grazing dairy farms in southern Uruguay: Case studies. Sustainable Agriculture Research, 3(2).

Lozano-Juste J. & Cutler S.R. (2014). Plant genome engineering in full bloom. Trends Plant Sci, 19(5):284-287. doi: 10.1016/j.tplants.2014.02.014

McGuire, S. and Sperling, L. (2016). Seed systems smallholder farmers' use. Food Security, 8(1): 179-195.

MGAP (2009). Manual de Calidad del Programa Nacional de Residuos Biológicos. Departamento de Sanidad Animal. Departamento Control Sanitario de Lácteos. Available at: https://goo.gl/RBnnTW Consultado: diciembre 2016.

Modernel, P.; Astigárraga, L.; Picasso, V. (2013). Global versus local environmental impacts of grazing and confined beef production systems. Environmental Research Letters, 8(3).

Mondelli, M., y Bervejillo, J. (2015). "Desempeño, desafíos y oportunidades del sector." Capítulo: El Desarrollo Agropecuario y Agroindustrial de INDA. (2017). Observatorio de Seguridad Alimentaria y Nutricional (OBSAN). Indicadores. Consumo y utilización biológica de nutrientes.

MSP (1994). Reglamento Bromatológico Nacional. Decreto N° 315/994 del 05/07/1994. 2ª ed. Montevideo, IMPO.

MSP (2016). GABA, Guía alimentaria para la población uruguaya, p. 104.

MSP (2016). División Epidemiología. DIGESA.

MSP/PPENT (2016). 2a Encuesta Nacional de Factores de Riesgo de Enfermedades no Transmisibles.

MVOTMA (2015). Primer Informe Bienal de Actualización de Uruguay GEI . Montevideo. Available at: https://goo.gl/KZ94nn

OBSAN (2017). Observatorio de Seguridad Alimentaria y Nutricional. Indicadores. Consumo y utilización biológica de nutrientes. Available at: http://obsan-inda.mtss.gub.uy/indicador/?id=101 Retrieved: February 6 2017.

OMS/OPS (2016). Organización Mundial de la Salud y Organización Panamericana de la Salud. Salud en las Américas. Uruguay. Available at: https://goo.gl/weU9xX

Panario, D. (2016). Efectos del Cambio Global sobre la Calidad del Agua. Una Visión desde las Geociencias. In: Mesa: Calidad de Agua: Una Visión Multidisciplinaria. Libro de Resúmenes III Jornadas Interdisciplinarias en Biodiversidad y Ecología (JIBE) 'Desafíos Socio-Ambientales para el Uruguay del Futuro' 28 de noviembre al 2 de diciembre. Rocha, Uruguay: Centro Universitario Regional del Este; 2016:129. Available at: http://www.cure.edu.uy/sites/default/files/Libro de resumenes III JIBE.pdf

Paolino, C. y Hill, M. (2011). "Perfiles de especialización agro/agroindustrial y eficiencia en el uso de los recursos naturales: Uruguay frente a otros países de América Latina". Anuario OPYPA 2011, 223-238, MGAP.

Pautasso, M., Aistara, G., Barnaud, A. et al. (2013). Seed exchange networks for agrobiodiversity conservation. A review. Agronomy for Sustainable Development, 33(1):151-175.

Peluffo, S.; González-Idiarte, H.; Galván, G.A.; Hirczak, A. (2016). Production of certified onion seeds in Uruguay: an experience of public-private articulation. Acta Horticulturae, 1143:15-22.

Picasso, V.; Modernel, P.; Becoña, G.; Salvo, L.; Gutiérrez, L.; Astigárraga L. (2014). Sustainability of meat production beyond carbon footprint: a synthesis of case studies from grazing systems in Uruguay. Meat Science, 98:346-354.

Pike, L. 1986. Onion breeding. In: Bassett, D. (Editor). Breeding Vegetable Crops. CT, USA: AVI. pp. 367-395.

Plaisted, R.L. 1985. Population breeding applied to improvement of unadapted Solanum cultivated species. In: Present and Future Strategies for Potato Breeding and Improvement. Lima, Peru, International Potato Center. pp. 143-162.

PNUD (2016). Informe Regional sobre Desarrollo Humano para América Latina y el Caribe. Progreso multidimensional: bienestar más allá del ingreso. Available at: https://goo.gl/EbKb16

Quezada, M.; Pastina, M.; Ravest, G.; Silva, P.; Vignale, B.; Cabrera, D.; Hinrichsen, P.; García, A.; Pritsch, C. (2014). A first genetic map of Acca sellowiana based on ISSR, AFLP and SSR markers. Scientia Horticulturae, 169:138-146.

Revenga, C. (2000). Will There Be Enough Water? Mock, G. (Editor). World Resources Institute; 2000. Available at: http://www.earthtrends.wri.org Retrieved: December 12 2016.

Royo Pallarés, O.; Berretta, E.J.; Maraschin, G.E. (2005). The South American Campos ecosystem. In: J.M. Suttie, G. Reynolds, and C. Batello (Editors). Grasslands of the World. (pp. 171-219). Rome, Italy: FAO.

Saadoun, A. y Cabrera, M.C. (2015). Calidad nutricional de la carne bovina y ovina de sistemas pastoriles: desde Uruguay para el mundo. En: La ganadería en América Latina y el Caribe: alternativas para la producción competitiva, sustentable e incluyente de alimentos de origen animal. Capítulo XV. Rafael Núñez Domínguez et al. (Editores). COLPOS, UACh, ALPA, FAO, IICA. pp. 623-641.

Saavedra, C. (2011). Un siglo de agricultura. Rev. del Plan Agropecuario No. 137, p: 46-49.

Sganga, J.C., Víctora, C.D. y Cayssials, R. (2005). Plan de acción nacional de lucha contra la desertificación y la sequía. ROU, DINARA-MOTVMA, RENARE-MGAP, Proy. GM2/020/CCD, p. 168.

Terevinto, A.; Cabrera,. M.C.; Saadoun, A. (2015). Influence of feeding system on lipids and proteins oxidation, and antioxidant enzymes activities of meat from Aberdeen Angus steers. Journal of Food and Nutrition Research, 3(9):581-586.

WHO/FAO/CODEX. International Food Standards.

Zaccari, F.; Cabrera, M.C.; Ramos, A,; Saadoun, A. (2015). In vitro bioaccessibility of β-carotene, Ca, Mg and Zn in landrace carrots (Daucus carota, L.). Food Chemistry, 166(1):365-371.

Zaccari, F., Galeazzi D., Rahi V. (2015). Efecto del tiempo de almacenamiento en condiciones controladas de temperatura sobre atributos físicos y químicos de zapallos "tipo kabutia" (Cucurbita maxima x Cucurbita moschata). Revista Iberoamericana de Tecnología Poscosecha.

Acknowledgments

Thanks are due to **Zulma Saadoun** for her help with copyediting and editing and the cover photograph.

Box 7

Food Security with Conservation of the Environment: The Case of Pastoral Farming in Uruguay

Laura Astigarraga, Faculty of Agronomy and Interdisciplinary Center for Response to Climate Change and Variability, Universidad de la República, Uruguay, and Valentín Picasso, Agronomy Department, University of Wisconsin - Madison, United States of America.

Livestock production is growing worldwide due to increased demand for animal protein. Meat production has increased in the last three decades almost 40% in the world and milk production more than 50%, with South America being one of the regions that led this growth. At the same time, concern about the environmental impacts of livestock is growing for industry, policy makers, and society in general. FAO estimated that the global livestock sector contributes 14.5% of anthropogenic greenhouse gases, and therefore presents challenges for climate change mitigation (Gerber et al., 2013). Also, other local-scale environmental impacts, such as water pollution and loss of biodiversity, question the role of livestock for sustainable food production. The great challenge for producers, researchers, and public policy makers is how to combine food security and environmental conservation. "Environmental competitiveness" is a new rule of the game, which adds to the preferences of consumers in terms of product quality and animal welfare.

Sustainable agricultural production requires a balance between social, economic and environmental goals. Agricultural holdings will not be sustainable if natural resources are degraded in the pursuit of increased economic income, nor will they be sustainable if economic and environmental pressures render the economic benefit of agricultural holdings unfeasible. This perspective requires high standards in product quality and responsibility and care of the environment. The environmental sustainability of food production is a much broader concept than carbon footprint, including other dimensions such as: reducing soil erosion, not locally contaminating water, conserving natural biodiversity, minimizing or avoiding the use of biocides which affect human health, use fossil energy efficiently, be resilient and flexible to respond to climatic or economic variability (Astigarraga and Ingrand, 2011; Picasso et al., 2014; Llanos et al., 2013).

Pastoralist cattle systems, as in the case of Uruguay, allow to combine food production and environmental sustainability. In pastoral systems, using forage efficiently by optimizing forage allocation throughout the year is a key mitigation option that can increase meat and milk productivity by reducing the carbon footprint per unit of product, without major investments (Becoña et al., 2014, Lizarralde et al., 2014). This improvement has the potential to simultaneously increase productivity, reduce greenhouse gas emissions, and minimize other environmental impacts such as excess nutrients, fossil energy use, and biodiversity loss (Modernel et al., 2013; 2014). In addition, the production of meat based on a natural field with a pasture management that optimizes the forage allocation, achieves high production levels (Carriquiry et al., 2012) while providing multiple ecosystem services (Modernel et al., 2017).

Uruguay has increased its meat production by more than 45% and milk production by more than 250% since 1980 (DIEA, 2013). Both the pastoral production of meat and milk benefit from the image "Uruguay country natural" which is a public good, an added value associated with good sanitation, good innocuity, good commercial control, good livestock practices, good manufacturing practices, backed for a product traceability. In this context, the country's brand image as a natural food producer is an asset that has allowed to support a successful export policy to the markets with greater purchasing power. Pastoral farming systems, managing grazing and feeding efficiently, are an example of integration between food security and conservation of the environment.

References

Astigarraga L., Ingrand S. 2011. Production flexibility in extensive beef farming systems. Ecology and Society 16(1): 7.

Becoña, G.; Astigarraga, L.; Picasso, V. D. 2014. Greenhouse gas emissions of beef cow–calf grazing systems in Uruguay. Sustainable Agriculture Research, v.3 (2), p. 89–105

Carriquiry, M., Espasandin, A. C., Astessiano, A. L., Casal, A., Claramunt, M., Do Carmo, M., ... Soca, P. 2012. La cría vacuna sobre campo nativo: Un enfoque de investigación jerárquico para mejorar su productividad y sostenibilidad. Veterinaria (Montevideo) 48(Supl. I), 41-48.

DIEA (MGAP) 2013. Anuario estadístico agropecuario 2013.

Gerber, P. J.; Steinfeld, H.; Henderson, B.; Mottet, A.; Opio, C.; Dijkman, J.; Falcucci, A.; Tempio, G. 2013. Tackling climate change through livestock — A global assessment of emissions and mitigation opportunities. Rome, FAO, 115.

Lizarralde, C.; Picasso, V.; Rotz, A.; Cadenazzi, M.; Astigarraga, L. 2014. Practices to Reduce Milk Carbon Footprint on Grazing Dairy Farms in Southern Uruguay: Case Studies. Sustainable Agriculture Research, v. 3 (2)

Llanos, E.; Astigarraga, L.; Jacques, R.; Picasso, V. 2013. Eficiencia energética en sistemas lecheros del Uruguay. Agrociencia Uruguay, v. 17 (2), p. 99–109

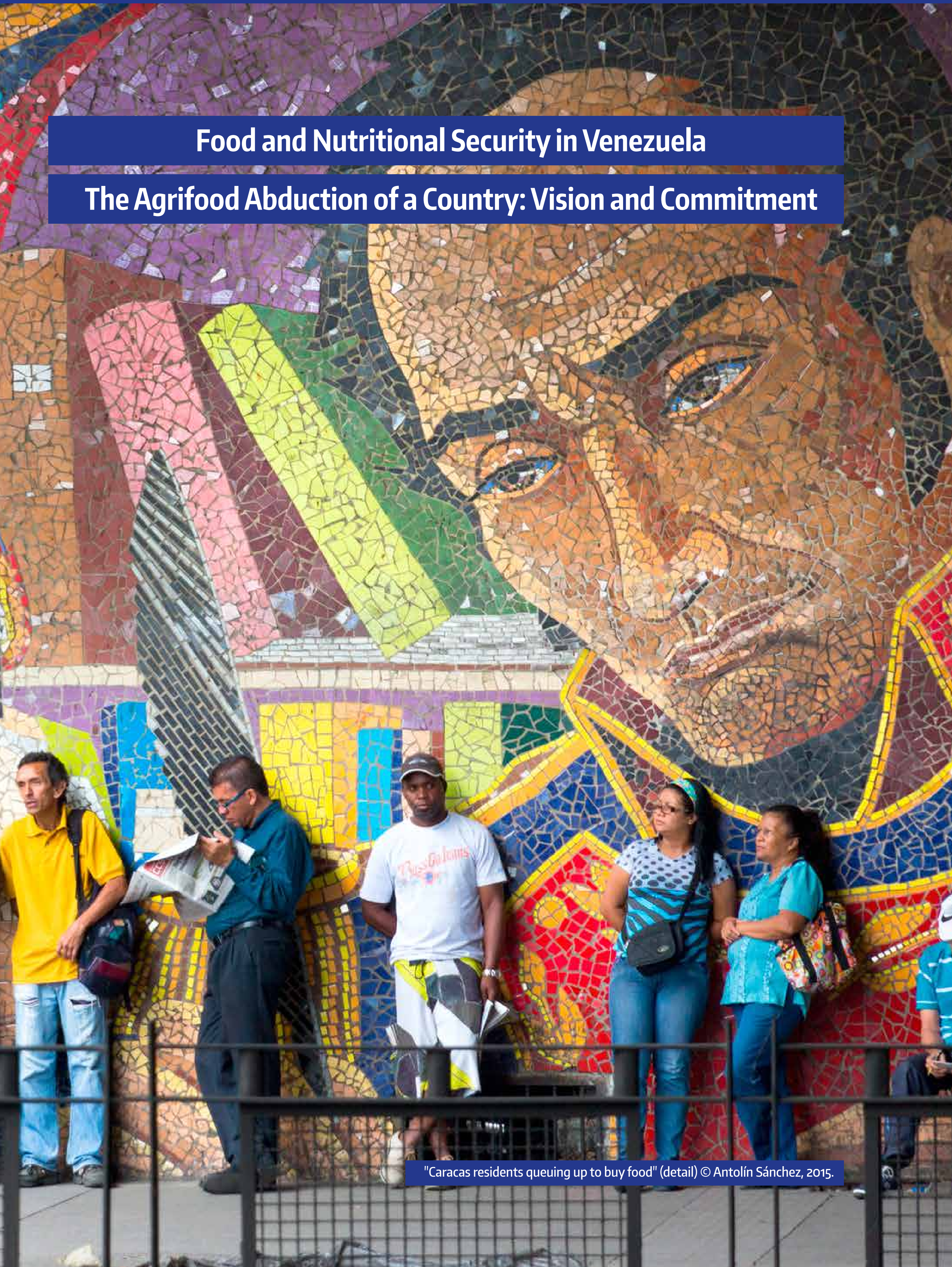
Modernel, P.; Astigarraga, L.; Picasso, V. 2013. Global versus local environmental impacts of grazing and confined beef production systems. Environmental Research Letters, v. 8 (3)

Modernel, P. W. Rossing, M. Corbeels, S. Dogliotti, V. Picasso, P. Tittonel. 2016. Land use change and ecosystem service provision in Pampas and Campos grasslands of southern South America. Environmental Research Letters 11 (2016) 113002.

Picasso V, Modernel P., Becoña G., Salvo L., Gutiérrez L., Astigarraga L. 2014. Sustainability of meat production beyond carbon footprint: a synthesis of case studies from grazing systems in Uruguay. Meat Science, v. 98, p. 346–35.

Food and Nutritional Security in Venezuela

The Agrifood Abduction of a Country: Vision and Commitment



"Caracas residents queuing up to buy food" (detail) © Antolín Sánchez, 2015.

Venezuela

[1] María S. Tapia, [2] Marelia Puche, [3] Alejandro Pieters, [4] Juan Fernando Marrero, [5] Santiago Clavijo, [6] Alejandro Gutiérrez, [7] Carlos Machado-Allison, [8] Susana Raffalli, [9] Marianella Herrera, [10] Maritza Landaeta de Jiménez, [11] José Félix Oletta, [12] Juan Comerma, [13] Óscar Silva, [14] Marta Barrios, [15] Aída Ortiz, [16] Eladys Córcega, [17] Enio Soto, [18] Livia Pinto, [19] Daniel Vargas, [20] Víctor García, [21] Juan Carlos Rey, [22] Juan Carlos Aciego, [23] Naghely Mendoza, [24] Gerardo Fernández López [25] Francisco Bisbal

Solving the enormous flaws in food and nutritional security in **Venezuela** is an uneluctable commitment. **Sustainable food production and less dependence on imports can only be ensured through knowledge.** The opportunity is for the Academies, the scientific community, producers and companies, and for a State that guarantees political and economic freedoms.

Summary

Venezuela is an oil state with price control and currency exchange policies and high inflation, where production and manufacturing are affected by expropriations, confiscations and invasions; with government, military and political control over food production, importation, distribution and marketing. The state is the sole supplier of certain staple foods, since it nationalized input and seed distribution. Falling oil prices and dependence on imports weakened agricultural production, which, coupled with the lack of imports, produced shortages and scarcity (>50%) at critical levels of certain items and regulated foods that are the main contributors of energy and nutrients. Food inflation was 315% in 2015; and is expected to at least double in 2017. This is compounded by the lack of investment in infrastructure, restrictions on access to foreign exchange for inputs, seeds, machinery, equipment and spare parts; pricing below production costs, and legal uncertainty over property and personal insecurity. Agribusiness, agricultural research and talent training have all been affected. Food programs are a universal subsidy that does not target the most vulnerable population. The state has implemented the rationed distribution of regulated foods that create long lines at outlets. It created Local Supply and Production Committees (CLAP) to selectively distribute food. Average energy consumption is below requirements (with 94.1% adequacy). A reduction in acute child malnutrition was reported from 1990 to 2013; in 2016, unofficial organizations disclosed worsening malnutrition, to humanitarian dimensions in the poor parishes studied. The population's diet is monotonous and unhealthy, with problems of availability/access. According to the 2016 Venezuelan Survey on Living Conditions, 81.8% of households are poor, 51.5% live in extreme poverty, many eat two or fewer meals a day and 74.3% reported uncontrolled weight loss (8.7-9 kg in 2016). Nevertheless, the Venezuelan agricultural/livestock sector has comparative advantages in many areas. Changes in macroeconomic and microeconomic policies could boost these areas, build competitiveness, strengthen value chains, substitute imports/ increase exports and revert the negative food trade balance in order to ensure the food and nutrition security, which is currently severely compromised, of the Venezuelan population.

Introduction

Discussing the current status of Food and Nutrition Security (FNS), and the challenges and future of Venezuela is a complex task since official statistics are outdated, inaccessible, unreliable or nonexistent, and official reports are preliminary and sometimes contain figures that do not coincide. The authors were forced to use a variety of sources: national and international official figures; non-governmental institutions, academic publications, expert opinions, etc.

I. National characteristics

a. Physical area, inventory of farmland, landscapes and environmental heterogeneity

Venezuela has an area of 916.445 km² divided into 23 states, a Capital District, 235 islands and 71 islets and keys in the Caribbean Sea that make up the Federal Dependencies (INE, 2016) and an extremely varied geology, comprising seven large physical-geographical systems: Escudo Guayanés; the Deltic Plain of the Orinoco River; Los Llanos; the Andes; the Coriano System; the Paraguaná Peninsula and the Yaracuy; Barquisimeto and Carora Depressions; the Maracaibo Lake Depression and the Coastal Range (MARN, 2005). The agricultural area (2011 figures) accounts for 24% of the country; while 84.71% of the farmland is pasture, 12.2% arable land and 3% used for permanent crops (FAOSTAT, 2017).

b. Demographic characteristics and future trends

According to the 2011 census, the population of Venezuela was 27,227,930. The projection for 2050 is an upward trend, with 31,028,637 inhabitants in 2016, and 40,500,721 by 2050. By 2011, 88.8% of the population was urban. The interannual GDP growth rate (third quarter of 2015) stood at -7.1 and in 2015, the inflation rate was 180.9 (UNICEF, 2015), the latest data published by the Central Bank of Venezuela (BCV).

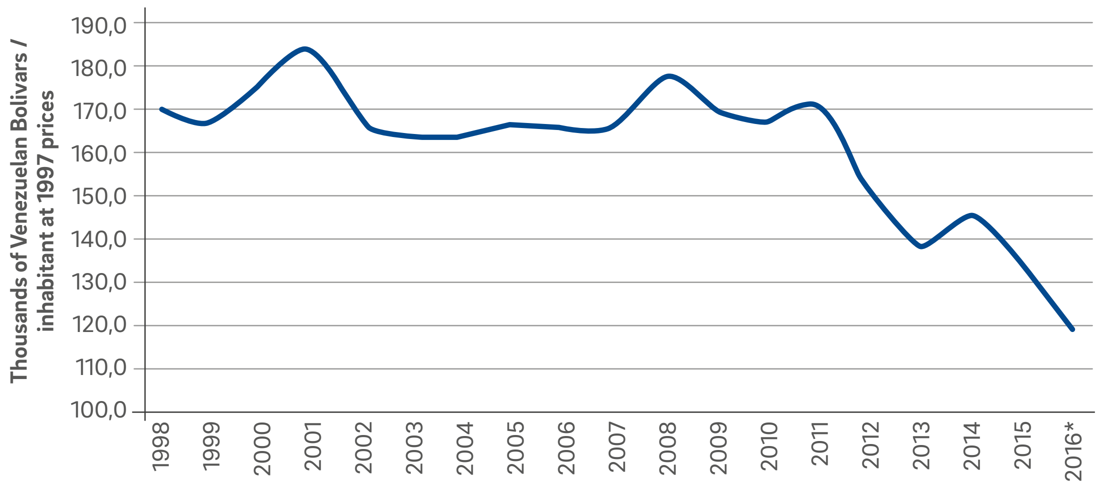
c. Fraction of the population with food and nutrition insecurity. Trajectory

Forecasting FNS involves considering the country-specific conditions prevailing in early 2017, such as difficulties in accessing food -even basic products at regulated prices affected by shortages, high prices of unregulated products -a small food basket with imported or black market prices exceeds the subsidized price by 900-1,000% (up to nine minimum wages), whereas an expanded food basket is equivalent to 20.1 minimum salaries. Moreover, the state controls the importation, distribution and sale of subsidized foods, which undercuts the usual places of food purchase; and consolidates the black market and food smuggling.

In 2016, caloric consumption decreased due to the shortage of staple foods. A food inflation rate expected to double the general inflation rate and a decrease of Gross Domestic Product Per Capita (GDPPC) estimated at 11.2 make it possible to predict a decline in consumption and an increase in the malnutrition and food insecurity of the poorest households. A reduction in caloric intake has been estimated for the average inhabitant of 7% to 10% (higher in poorer areas), while the

[1] **María S. Tapia,** Faculty of Sciences, Institute of Food Science and Technology, Central University of Venezuela (UCV), mtapiaucv@gmail.com [2] **Marelia Puche,** Faculty of Agronomy, Institute of Agricultural Engeneering, UCV, marelia.puche@gmail.com [3] **Alejandro Pieters,** Center of Ecology, Venezuelan Institute of Scientific Research (IVIC), alejandro.pieters@gmail.com [4] **Juan Fernando Marrero,** Faculty of Agronomy, Institute of Agricultural Economics UCV, Observatory of the Right to Food in Latin America and the Caribbean, fernandomarrero63@yahoo.es [5] **Santiago Clavijo,** Department of Agricultural Zoology, Faculty of Economy UCV, sclavijo@gmail.com [6] **Alejandro Gutiérrez,** FACES-Center for Agrifood Research (CIAAL) University of Los Andes, National Academy of Economic Sciences, alegutie53@gmail.com [7] **Carlos Machado-Allison,** Instituto de Estudios Superiores de Administración (IESA). Agribusiness Program. National Academy of Physical, Mathematical, and Natural Sciences, carlos.machado@iesa.edu.ve [8] **Susana Raffalli,** Caritas de Venezuela, susana.raffalli@gmail.com [9] **Marianella Herrera,** Center for Development Studies-CENDES. UCV and Bengoa Foundation for Food and Nutrition, manyma@gmail.com [10] **Maritza Landaeta de Jiménez,** Bengoa Foundation for Food and Nutrition, mlandaetajimenez@gmail.com [11] **José Félix Oletta,** Medicine Faculty, Vargas School of Medicine, UCV, jofeole2@outlook.com [12] **Juan Comerma,** National Institute of Agricultural Research and Institute of Edaphology, Faculty of Agronomy, UCV, comermasteffensen@gmail.com [13] **Óscar Silva,**

Figure 1. Venezuela: Gross value of agricultural production per inhabitant (VBPAGPC) 1998-2016



Source: MPPAT (Ministry for Agricultural Production and Land), INE (National Institute of Statistics), Authors' calculations. (*) 2016 values are estimates and subject to review (Gutiérrez, 2016).

caloric intake for the average inhabitant will be at a level of critical sufficiency (Gutiérrez, 2017), below the 100% set by the National Institute of Nutrition (NIN, 2001). The BCV estimates an 18.6% drop in GDP in 2017 (http://lta.reuters.com/article/idLTAL1N1FA0RD). This is categorized by Schejtman criteria (1994) as a level of critical sufficiency.

Although agrifood security and sovereignty are state objectives, there has been a drop in domestic food production and the imports used by the state to guarantee availability. **Figure 1** shows the evolution of the Gross Value of Agricultural Production/Inhabitant (GVAPI) from 1998 to 2016.

The Average Annual Growth Rate (AAGR) was -1.5% of GVAPI (1998-2014), -0.8 (1998-2003), 1.8% (2003 to 2008) and -4.7% (2008-2014), reflecting a decline in incentives for profitability, subsidies and financing that had a positive effect during the oil boom (2003 to 2008). Between 2008 and 2014, the decline in the production of major agricultural crops was exacerbated. There was only positive AAGR for banana production/capita: 3.3%. The rest of the items analyzed showed a negative AAGR: rice (-1.3%); corn (-8.4%); oil palm (-0.9%); cassava (-0.9%); cocoa (2.3%); sugar cane (-9.0%); poultry (-0.9%); cattle (-3.2%); eggs (-0.6%) and swine (-1.6%) (Gutiérrez, 2016).

Institute of Agronomy, Faculty of Agronomy, UCV, oscarsilvae@gmail.com [14] **Marta Barrios,** Institute of Agronomy, Faculty of Agronomy, UCV, martabarrios3@gmail.com [15] **Aída Ortiz,** Institute of Agronomy, Faculty of Agronomy, UCV, aidaortizd@gmail.com [16] **Eladys Córcega,** Institute of Agronomy, Faculty of Agronomy, UCV, eladys7@gmail.com [17] **Enio Soto,** National Institute of Agricultural Research and Institute of Agronomy, Faculty of Agronomy, UCV, eniosoto@yahoo.com [18] **Livia Pinto,** Institute of Animal Production, Faculty of Agronomy, UCV, liviapintosantini@gmail.com [19] **Daniel Vargas,** Institute of Animal Production, Faculty of Agronomy, UCV, danivagu2000@gmail.com [20] **Víctor García,** Institute of Agricultural Engineering, Faculty of Agronomy, UCV, victorgarcia02@gmail.com [21] **Juan Carlos Rey,** National Institute of Agricultural Research and Institute of Edaphology, Faculty of Agronomy, UCV, jcreyb@hotmail.com [22] **Juan Carlos Aciego,** National Institute of Agricultural Research and Institute of Edaphology, Faculty of Agronomy, UCV, juanaciego@gmail.com [23] **Naghely Mendoza,** Institute of Agricultural Engineering, Faculty of Agronomy, UCV, naghely.mendoza@gmail.com [24] **Gerardo Fernández López,** Department of Process Control and Department of Electronics and Circuits, Universidad Simón Bolívar, gfernandez@usb.ve [25] **Francisco Bisbal,** Ministry for Ecosocialism and Waters, fbisbal60@gmail.com

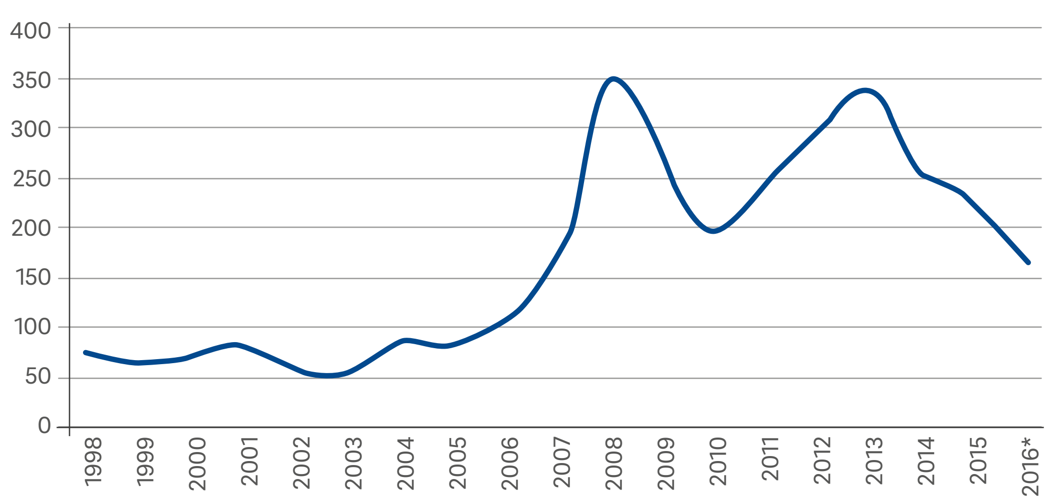
Statistics show that Per Capita Agricultural Imports (PCAI) increased during the oil boom. The decline in oil prices and macroeconomic policies produced a shortage of foreign exchange and falling domestic food production could not be compensated by imports. It is estimated that total/capita imports fell by 66.5% (from 2012-2016). Imports (PCAI) experienced an interannual reduction in 2016 with respect to 2015 -24.5%- and a 44.2% reduction between 2012 and 2016 (**Figure 2**).

The agroindustry has experienced critical situations due to political uncertainty, difficulty of access to foreign exchange and non-compliance with suppliers and payment in foreign currency, price controls, difficulty of access to machinery and spare parts, power failures, labor disputes and disruptions of the food chains (due to intense government intervention in prices, foreign exchange, transportation and distribution systems). A key sector has also been involved: the outlets. There are 113,859 private food outlets and 7,245 government outlets; for example, in the municipality of Libertador de la Gran Caracas, there is a private final point- of-sale for every 1,458 consumers and a public one for every 388,780. Price regulation also prevents profitable operations in one or more links in the chain. The situation is exacerbated by the decline in sales, supply and demand problems due to shortages of inputs and raw materials and the installation of a powerful network of resellers of regulated products at prices up to 1000 times higher, whose origin is in public and private chains, supermarkets (67%), independent supermarkets (13%), small and medium suppliers and warehouses (13%) and butchers and bakers (7%). The theft of trucks loaded with food is another contributor to the irregular market.

Table 1. Scarcity rate reported by the official source, the Central Bank of Venezuela (BCV, undated), and the polling firm Datanálisis (2015)

Year	Central Bank of Venezuela (a)	Datanalisis (b)	Difference (a-b)
2012	14.23%	15.2 %	-0.97%
2013	20.73%	37.2%	-16.47%
2014	28.1%	59%	-30.9
2015		58.4%	

Figure 2. Venezuela: Agricultural imports per inhabitant (USD/inhabitant)



Source: INE (National Institute of Statistics), Authors' calculations. (*) 2015 and 2016 values are estimates and subject to review. (Gutiérrez, 2016).

Box 1. Child nutrition status in Venezuela, according to non-official organizations

- In 2015, the Antímano Integral Nutrition Care Center (CANIA) recorded a 47.7% malnutrition rate (low weight) among 2,872 children, and 1.9% with severe nutrition (CANIA, 2016).
- Nutritional deficit (low weight) increased between 2013 and 2015, and the number of overweight children decreased. In June 2016: 12% of children with a nutritional deficit in urban centers, 19% in periurban centers and 27% in slum areas. The prevalence of low birth weight increased from 2.9% to 3.4% between 2011 and 2013 and the percentage of premature births rose, revealing severe nutritional problems among pregnant women coupled with a lack of access to care programs (Bengoa Foundation, 2016).
- At the Domingo Luciani Public Hospital in Caracas, in June 2016, 100% of infants hospitalized in the pediatric unit shown some degree of malnutrition. Until June 2016, 31 children suffered from moderate to severe malnutrition (58% of these children were infants ages 0 to 2).
- Between 2013 and 2015, the J.M de Los Ríos Hospital, a national reference standard and the pilot site of the National Institute of Nutrition, treated an average of 30 children with severe malnutrition a year. By the end of 2016, this figure had doubled (Soto de Sanabria, 2016).
- Out of 830 anthropometric records of children under five in sentinel sites in four states, levels of acute malnutrition (emaciation) among children below five (< -2 Z-SCORE) stood at 8.9% in January and 11.4% in April, 2017 (Caritas de Venezuela, 2017).

Table 2. Child malnutrition in Venezuela

Index	2009	2011	2013
Acute Malnutrition Children <5 years Weight/Height Index	3.2 (UNICEF) 4.1 (WHO)	2.9 INN	3.4 INN
Chronic Malnutrition Children <5 years Height/Age Index	9.5 (UNICEF) 13.4 (WHO)	NA	NA

OMS (WHO). Nutrition Growth Database: www.who.int/nutgrowthdb/jme_master2013.xlsx
UNICEF Basic Indicators. Venezuela: https://www.unicef.org/venezuela/spanish/overview_13275.htm
MINPPAL (Ministry of Food) - INN (National Institute of Nutrition). Nutritional Profile of Venezuela 2013-2014
INN Technical sheet: Anthropometric nutritional evaluation among children under five years of age, based on international criteria. Caracas, Venezuela: Government of Venezuela, Ministry of Health, INN, 2012

Table 1 shows the index of shortages according to the BCV, whose publication has been delayed. In response, other sources, either academics or specialized consultants, have addressed the challenge of obtaining information. The data obtained from these sources contrast significantly with official figures. A total of 20.1 minimum wages are required to cover the basic food basket. Moreover, ENCOVI, the Survey of Venezuelans' Living Conditions, conducted by three major universities and the Bengoa Foundation for Food and Nutrition, reports that 93% of Venezuelans, most of whom are in the poorest income quintile, perceive that their income is insufficient to buy food, thereby violating the dimension of access to food in the concept of food security. As for child malnutrition, the Food and Nutrition Surveillance System (SISVAN) has not published data since 2007 (INN-SISVAN, 2008), when chronic malnutrition was reported in 10% of children <15 years. The fact that 10 years have elapsed without SISVAN data is a serious omission.

According to the official figures included in the 2013-2014 Country Profile by the Ministry of Popular Power for Food (MINPPAL) and INN (MINPPAL- INN, 2014), a decrease in child malnutrition (<5 years) was recorded. According to the World Health Organization (WHO) (1994), this meant that Venezuela was a country with low malnutrition. However, the figure shows an increase in acute malnutrition from 2009 to 2013 (**Figure 3**). In any case, these figures may be underestimated due to the official use of cutoffs that have not been adjusted to the latest WHO standards, adopted by all countries since 2006, which is the only international benchmark for assessing growth in childhood. Estimates of malnutrition in Venezuela continue to follow NCHS/OMS 2000 standards (http://www.who.int/childgrowth/standards/tr_summary/es/), which tend to underestimate the number of children with global acute malnutrition before 36 months of age. Children evaluated and classified with moderate malnutrition according to the WHO international standards in force (children with a Weight/Height Index between -2 DS and-3 DS with respect to the reference of normal weight) are not classified as malnourished in the country's health evaluations according to the standards used by the Venezuelan State. For a child under two years with acute malnutrition to be visible in the State's public health accounts, he or she must show much greater severity of nutritional damage (-3 SD deficit for moderate malnutrition and severe malnutrition from -4 SD for Weight/Size Index rather than -3 DS, which is the value considered by WHO international standards in force as the cutoff for severe malnutrion that places children in great risk of dying (Caritas de Venezuela, 2017). However, according to UNICEF (2013), in 2011 in Venezuela, there were 458,000 children with chronic malnutrition, making it the fourth country with lowest child malnutrition in Latin America and the Caribbean. UNICEF and WHO data are in turn based on the INN (**Table 2**). Detailed information is not available by state. The gap in official data existing since 2013 has been filled with data from other organizations (**Box 1**). Caritas Venezuela (2017) provides the most recent data at the subnational level for four states in the country in poor parishes that operate as "sentinel sites", with 11.4% of acute malnutrition (emaciation) in children <5 years. The data are not representative of the country or of specific states, but if they were, the trend suggested by the information from Caritas' sentinel sites would mean a tripling of acute malnutrition and a doubling of growth retardation at a rate of deterioration of humanitarian dimensions. With this rate of deterioration (near 1 percentage point per month), there are expected to be 60,000 new cases of acutely malnourished children every year among the poorest. An increase has also been reported in the rate of chronic malnutrition (stunting), the most severely affected age group being children <2 years in which the prevalence of chronic malnutrition is 38.5% compared with 19.3% in the group ages 2 to 5. Emerging acute malnutrition, which has continuously increased since 2007, is most significant in the group aged <2 years. The simultaneous increase in chronic malnutrition suggests that from a nutritional point of view, Venezuela is witnessing the development of a nutritional emergency which is slow and selective in vulnerable groups in the country, with an exacerbation in the past 2 years demonstrated by the thresholds of net nutritional damage achieved by the speed of the deterioration with which the country reached that point.

According to MINPPAL-INN (2014), since 2007, Venezuela has exceeded 2,720 calories per capita, noting that according to FAO criteria, this would make it a country with adequate food sufficiency and food security policies. According to MINPPAL-INN, in 2013, this indicator rose to 3,108 calories/person/day (**Figure 4**). However, according to the experts, it is unlikely for Caloric Availability for Human Consumption (CAHC) to increase precisely in the years when agricultural production and agrofood imports per inhabitant (**Figures 1 and 2**) decreased.

d. Agricultural and industrial modes of production, plantation systems and peasant agriculture

The area and production of the main agricultural items for 2015 are summarized in **Table 3**. The harvested area was 1.7 million hectares, its main items comprising production of 15.3 million Mg (Mega-grams). Highest volumes correspond to sugar cane, fruits and cereals, which occupy the largest surface, maize being the main crop. Regarding animal production, there were 497'219,975 heads of cattle, and 2,807 million liters of milk, and 2,906 million eggs were produced. Aquaculture production reported a total of 254.901 Mg (MPPAT, 2015). Venezuelan agricultural systems are diverse, ranging from family and semi-commercial agriculture to various types of plantations (**Tables 4 and 5**).

Table 3. Main categories of agricultural and fishing products in Venezuela, 2015

Vegetable production					
Category	**Main items**	**Production (Mg)**	**Area harvested (ha)**	**Percentage of production (%)**	**Percentage of area harvested (%)**
Sugar cane		5,075,878	101,324	33.2	5.9
Fruit	Plantain, pineapple, banana, orange, watermelon, papaya, melon, avocado, mango, grape, lemon	3,679,413	239,737	24.1	13.9
Cereals	Corn, rice, sorghum	2,742,787	725,174	17.9	42.0
Vegetables	Carrot, onion, tomato, cabbage, pepper, lettuce, cauliflower, beetroot, eggplant, garlic, green beans, cucumber, sweet pepper, zucchini	1,717,475	96,909	11.2	5.6
Roots and Tubers	Potato, cassava, ocumo, yam, celery, sweet potato, mapuey	1,309,690	93,677	8.6	5.4
Textiles and oil seeds	Palm oil, coconut, sesame, sunflower, soy, peanut	664,519	177,524	4.3	10.3
Coffee and Cacao		71,117	249,249	0.5	14.4
Legumes	Kidney bean, black bean, pigeon pea, pea	24,130	34,005	0.2	2.0
All principal categories		15,285,009	1,717,599	100	99.4
Country total			**1,728,601**		**100.0**

Livestock Production	
Poultry (heads)	491,999,000
Swine (heads)	2,677,914
Cattle (heads)	1,904,716
Goats (heads)	391,105
Sheep (heads)	247,240
Total (heads)	**497,219,975**
Dairy (thousands of liters)	2,807,475
Eggs for consumption (thousands of units)	2,906,491

Aquaculture Production	
Maritime (Mg)	176,493
River (Mg)	48,703
Aquaculture (Mg)	29,705
Total (Mg)	**254,901**

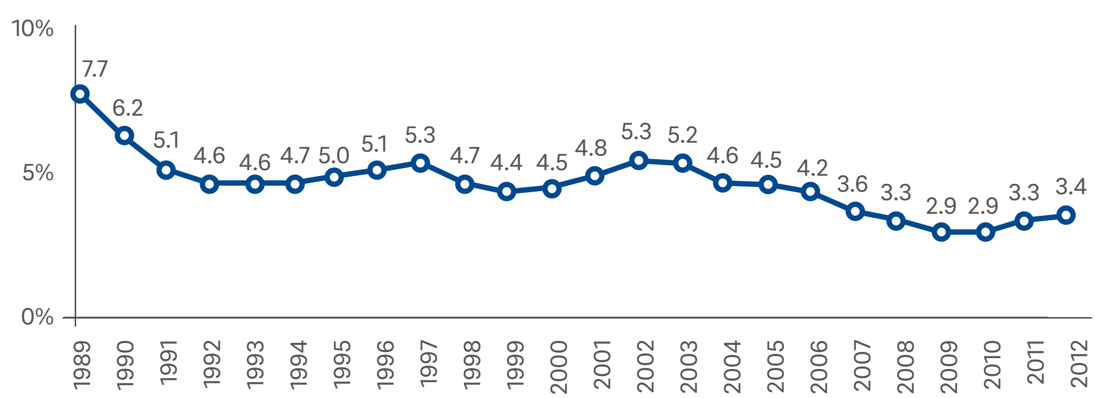
Source: Author's calculations obtained from preliminary figures with estimates for December (MPPAT, 2015).

e. Is the country self-sufficient in agriculture?

In the country's recent history, it has not been self-sufficient in agriculture. In the BCV reports, 'agriculture' was eliminated as a major sector in the breakdown of the Gross Domestic Product (GDP). The latest official figures (2013) report an annual GDP value of 62.233 million bolivars (BCV, 2017). That same year, according to FAO, agricultural GDP was $13,313,295, representing 1.36% of GDP at the official rate of the time (6.3Bs/$) (FAOSTAT, 2017). That official rate corresponds to an overvalued exchange rate to which few have access, and there is an enormous difference from the parallel market.

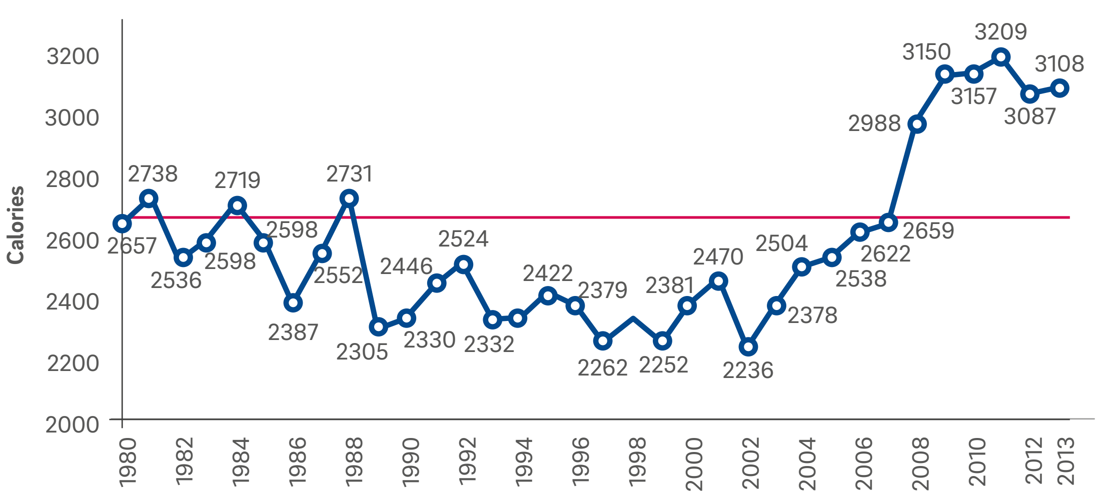
According to the Confederation of Agricultural Producers (FEDEAGRO) (HYPERLINK "http://www.fedeagro.org/detalle3.asp?id=2721"), of the twelve items monitored by the Federation, whose contribution to the value of Plant Agricultural Production exceeds 70%, eleven showed significant decreases in 2015, in many cases reaching record lows in the evaluation period (2015-2008): corn -58.5%, rice -37.3%, sorghum -80.5%, sugar cane -31.3%, sunflower -80%, orange 31% (in 2015-2014, it was -17%), coffee -71.2%, potato -74.3%, onion -52.5%, tomato -18.7%, paprika -40.9% and sesame 103.3%. According to the Federation, in most cases, the drop in production was the result of shortages of agricultural supplies (seeds, fertilizers, agrochemicals), problems of access to foreign exchange to meet domestic demand and commitments to external machinery, equipment, spare parts and tire and battery suppliers. Problems with sunflower and sorghum led farmers to opt for sesame, which had no problems with seeds and a more attractive price. Its production (38,400 t) therefore increased by 41.7% during 2014.The drought made it impossible to achieve the goals of cultivated acreage included in government and private-sector plans. Other factors included rural insecurity and the deterioration of the machinery and agricultural implements. Foreign exchange constraints meant

Figure 3. Child malnutrition (<5 years) in Venezuela, 1990-2013



Source: MINPPAL-INN, 2014.

Figure 4. National Energy Availability, 1980-2013 (Includes food and alcoholic drinks)



Source: INE. HBA, 1980-2013.

Table 4. General characteristics of the main plant production systems in Venezuela

System	General characteristics
Sugar cane	Grown using a high-tech system for the sugar industry, and on a small scale for unrefined sugar production.
Annual mechanized and high-tech crops	Comprises corn (white and yellow), rice, sesame, sunflower and soy. Located in Central and Western plains and Eastern savannahs.
Vegetable and fruit production systems	Located in the foothills of the Andean mountains and the coastal mountain range. Comprises perennial and semi-perennial fruits, principally banana and plantain and citrus, and to a lesser degree pineapple, mango, avocado, papaya and guava. In Andean states vegetables are the main categories, and in Zulia, Falcón, Lara, Guárico and Aragua low-altitude vegetables are grown such as tomato, pepper and onion, in addition to short-cycle fruit such as melon and watermelon.
Legumes	The principal varieties are black and kidney beans, the former with a slightly more technified system.
Roots and tubers	Systems with varying degrees of technification in the case of cassava, highly technified systems for potato, and small scale systems for multiple subsistence crops such as ocumo, yam and sweet potato.
Coffee and cocoa	Grown on a small scale with state support.

Information and estimates by the authors (Faculty of Agronomy, Central University of Venezuela).

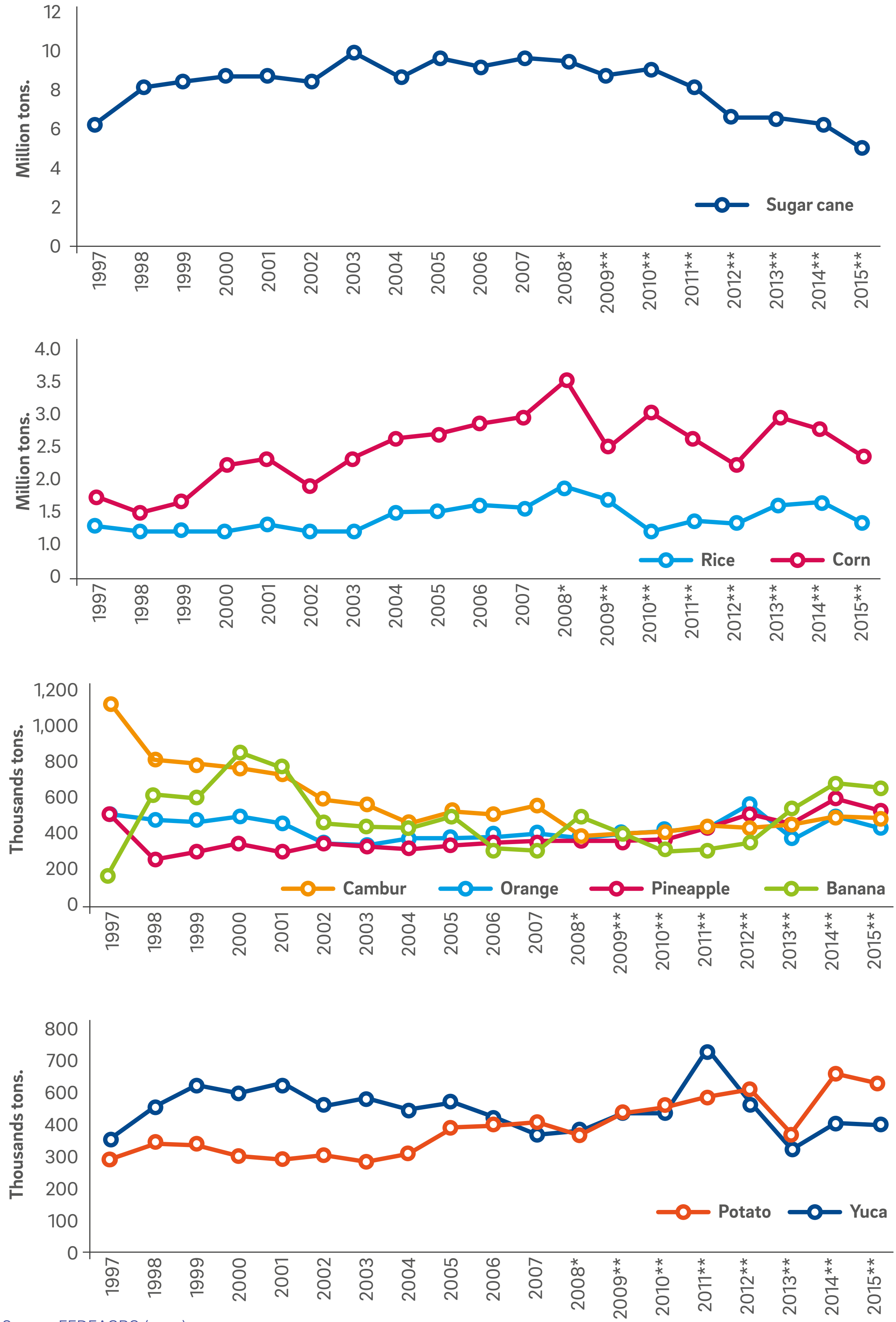
Table 5. General characteristics of the main livestock production systems in Venezuela

System	General characteristics
Beef cattle farming	Predominantly extensive systems located in the Central, Eastern and Western plains.
Specialized dairy production	This represents a low percentage, with semi-intensive systems located in Andean states: Mérida and Táchira.
Dual-purpose livestock farming	Heterogeneous, predominantly dairy or beef production depending on prices, with extensive and semi-intensive systems, manual milking and poor hygienic conditions. Production of llanero cheese in certain production units, using non-pasteurized milk and poor sanitary conditions (Soto-Belloso, 2004; Padilla et al., 2007)
Sheep and goats	Managed marginally with extensive systems (Lara, Falcón and Zulia), with great potential, and currently some semi-intensive systems in the goat sector.
Poultry production systems	Highly technified, intensive and organized in collaboration with the agro-industry and abattoirs. Heavily dependent on imported raw materials. They produce lightweight hen breeds for eggs for consumption, heavyweight hens to obtain fertile eggs and for the chicken fattening industry. Located close to urban centers and sea ports.
Swine	A similar technical level and location to poultry. A number of farms have recently been transferred to other geographical locations (such as Cojedes and Guárico), due to pressures caused by contaminated bodies of freshwater and the proximity to cities.

Information and estimates by the authors (Faculty of Agronomy, Central University of Venezuela).

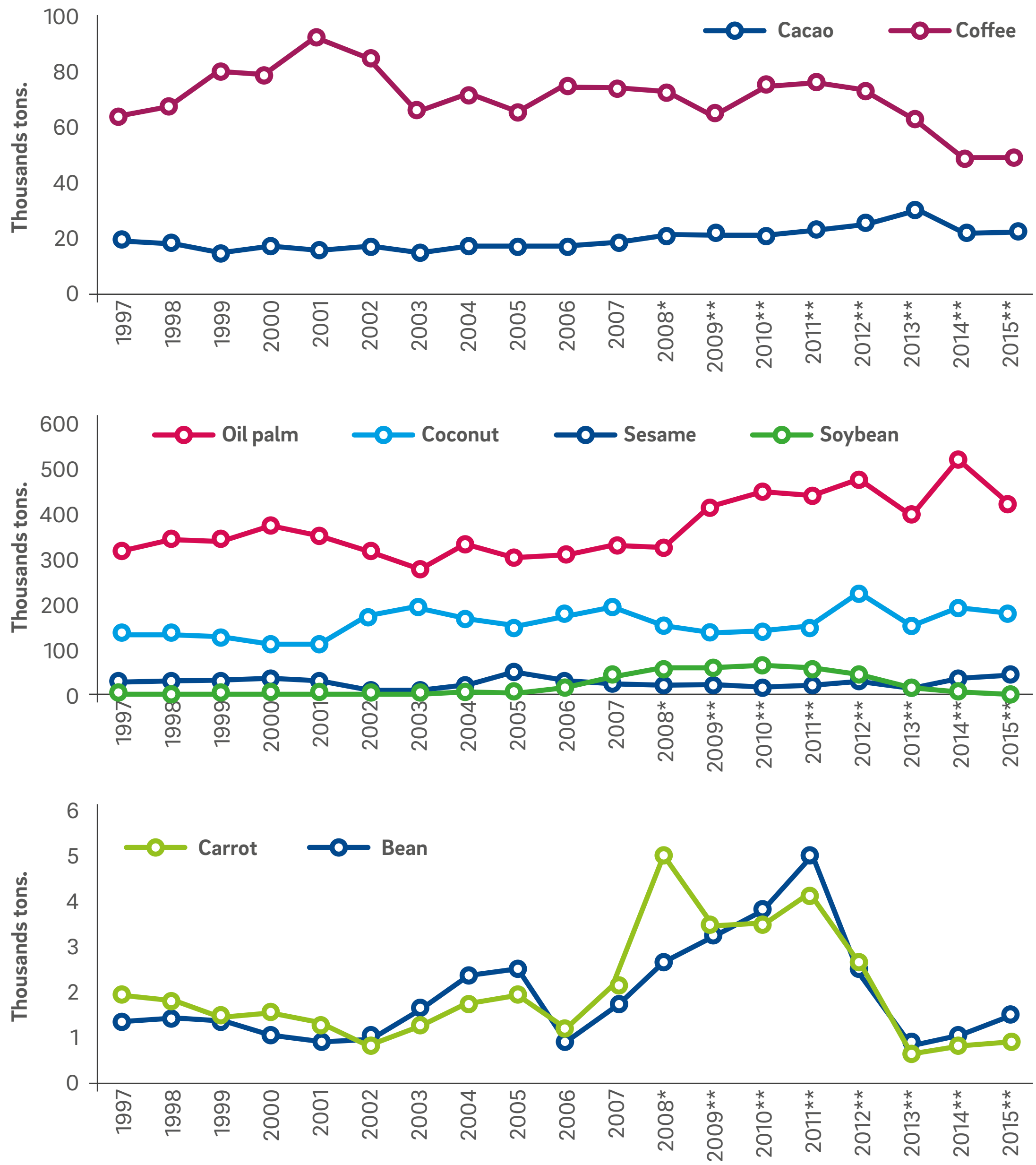
that new, more effective agrochemical and new equipment/machinery did not enter the country. The increase in production costs reduced the area financed by private banks. With the percentage established by the Agricultural Portfolio and the volume of loans granted in 2014, a much smaller crop area was financed in 2015 and again in 2016; these figures warrant a review. **Figures 5 to 11** show the production of major plant items since 1997 to 2015. Only a few areas show recent slight increases (oil palm, potatoes, musaceas, and pineapple). **Table 6** summarizes the situation and obstacles in some of the major crops. In 2016, the Ministry of Urban Agriculture was created to contribute to the supply of certain horticultural items in cities. Their viability is compromised by the shortage of water, seeds and seedlings.

Figures 5 to 8. Production of principal crops in Venezuela in the period 1997-2015



Source: FEDEAGRO (2017).

Figures 9 to 11. Production of principal crops in Venezuela in the period 1997-2015



Source: FEDEAGRO (2017).

f. Main crops and export/import markets

Agrifood exports represent a very small fraction. Regarding livestock exports, since Venezuela is not free of Foot and Mouth Disease (FMD), it cannot export cattle, swine, sheep or goat meat (OIE, 2017). In the 1990s it managed to increase and diversify its agricultural exports to Colombia, the US and Europe, but barely exceeded $680 million USD in 1998. Since then, figures have steadily declined, amounting to less than $40 million USD in recent years. With appropriate policies, Venezuela would be able to export rice, tropical fruits and agroindustrial derivatives, cacao and its derivatives, coffee, fishery and agroindustrial products.

g. Potential sources of food and nutrition insecurity

Productive, business and academic sectors linked to agriculture agree on the main factors contributing to food insecurity in Venezuela: legal uncertainty (goods and people); pricing policies that fail to cover production costs; exchange control; price control; agricultural import policy with an overvalued exchange rate that has caused distortions and corruption; misinterpretation of the Land Law, which has led to invasions, and the recovery and seizure of productive surfaces, the expropriation or compulsory purchase of farming industries, cold chains, silos and depots, transport fleets, supermarket chains, food and input distribution and supply networks; lack of investment and the deterioration of roads, infrastructure and agricultural services. Climate variability and climate change introduce a significant element of uncertainty, with threats such as droughts and floods that affect crops, livestock and the incidence of pests and diseases.

h. Main agricultural challenges

In the midst of a situation of falling oil prices and scarcity, agricultural development should be strengthened due to its productive potential; projections will depend on solving structural problems. Concrete proposals have been made (**Box 2**) in terms of legislation, state policies, technology and research, capacity building, supplies, and so on.

II. Institutional framework

a. National Agricultural Research System

National basic and applied agricultural research systems, made up of national universities, public research centers and private foundations, are located in most of the country's states with different agroecological conditions for domestic agriculture. Official sites include the former

Table 6. Status of main agricultural crops in Venezuela

Crop	Evolution of production, 1997 to 2015	Self-supply in 2015 (%)*	Obstacles
Corn	Increase in production between 1997 and 2008. Since then, there has been a decrease in area sown and production.	32	Price policy. Difficulties to import hybrid seeds and delays in delivery (98% of national production uses hybrid seeds). Adverse climatic situations. Land expropriation. Theft of crops.
Rice	Increase in production between 1997 and 2008. Decrease until 2010.	67	Failure in receiving subsidies. Price policy. Shortage of inputs (only 30% of those required). Processing plants paralyzed by lack of raw materials.
Soy	Slight increase in production between 2005 and 2010, followed by a steady decrease ever since.		High percentage of loss of land sown, principally due to seed problems. Financing. Decrease in international prices.
Sugar cane	Very little variation in production between 1997 and 2002. Steady decrease since then.	31	Price of sugar not in line with production costs. Excessive imports. Lack of technological investment. Expropriation of land, sugar processing plants and research centers.
Coffee	Increases between 1997 and 2001, and few variations with a downward trend until 2015. The two last years are the lowest in the historical series.	25	Price policy, inadequate production and commercialization. Inflation. Lack of organization in sector. Insufficient plant protection checks. Old plantations with low productivity. Abandoned nurseries. Smuggling to Colombia. Corruption in resource use. Purchase of low-quality seeds. Lack of inputs and labor. High interest rates from private banks. Unfavorable climatic conditions. Disincorporation of land to use it for other purposes. Lack of raw materials for processing plants.
Cocoa	Stagnant production.		Low yields. Lack of programs to improve, recover and renovate plantations.

Source: Information and estimates by the authors (Faculty of Agronomy, Central University of Venezuela).

Box 2. Proposals from the productive, business and academic sectors to overcome the crisis in the Venezuelan agricultural sector

Legislation	• Guarantee property and security rights for goods and persons in the rural sector, applying the procedures established by the Land Law and enabling a direct, frank and open dialogue with farmers in the areas concerned. • Rules for the establishment of internal prices that stimulate agricultural development and consider the production cost structures of the various items.
State Policies	• Adjustments of the exchange rate policy through a unification of the exchange rate process to an economically viable rate, which would ensure competitiveness for national production. • Balanced fiscal and monetary policy, to ensure the public resources necessary for the agricultural sector. • Re-orient the state's role as an economic agent, by limiting controls and direct intervention, and promoting agreements with private agents and regulations for stimulation and promotion. • Strategy to improve competitiveness of agricultural chains based on agricultural products for which the country probably has comparative advantages. • Nationwide plant and animal health campaigns to eradicate and/or control plagues and diseases that have spread throughout the country. • Create adequate instruments to assess the situation of food consumption in all its components, and use the results to redirect and define policies. • Develop programs to invest in production chains. • Review policy on transgenic crops and foods, to resolve the current inconsistencies, since the import of transgenic food is permitted and the use of genetically modified seeds is banned in Venezuelan agriculture. • Design short-, medium- and long-term agricultural plans. Substitute agricultural imports for key foods: white and yellow corn, rice, sugar, tropical oils, beef, milk and chicken. Encourage agricultural exports of crops with comparative and competitive advantages, such as coffee, cacao and their derivatives, fish and seafood, and tropical fruit and vegetables. • Plan for national self-sufficiency in edible fats and oils, by developing 300,000 hectares of sunflower in the western plains and a million hectares of soybean in the west, center and east of the country. • Policies for financing and partnerships with other countries, and to invest in productive infrastructure, renovate infrastructure, machinery, equipment and roads, strengthen producer organizations, technological upgrades and simplify public administration. • Long-term financing to consolidate estates and permanent categories.
Technology, research, training	• Design programs for scientific and technological development integrated into the production dynamics. Staffing and training to use Information and Communication Technologies (ICTs) for precision agriculture. • Improve herd genetics and preserve existing "Creole" genetic resources (Criollo Limonero (Tropical Bos Taurus), Carora, Creole Goat, Creole Swine, poultry strains). • Strengthen the small ruminant sector. • Improve networks to measure climate, soil, hydrology and water quality and integrate them into systems to support decision-making.

Information and estimates by the authors (Faculty of Agronomy, Central University of Venezuela).

National Agricultural Research Fund (FONAIAP) of the Ministry of Agriculture, transformed into the National Agricultural Research Institute (INIA), transferred to the Ministry of People's Power for Science and Technology in 2000, and the Ministry of Popular Power for Agriculture and Lands (MPPAT) in 2007. A regulatory framework enshrined in the Constitution defines the National System of Science, Technology and Innovation, a Law on Science, Technology and Innovation (LOCTI) and a governing body, the Ministry of Science , Technology and Innovation. Calls for project applications at Programa de Estímulo a la Innovación e Investigación (PEII) permit financing. Nevertheless, the national capacity for scientific and technological development is limited by the lack of coordination between the actors and organizations responsible, a research budget deficit at universities and official institutes, obsolescence and the physical deterioration of laboratories and programs providing services to farmers, growing emigration of professionals and a decrease in scientific production and patents. The National Academy of Physical, Mathematical and Natural Sciences (HYPERLINK "http://acfiman.org/site/pronunciamientos/en-apoyo-y-resguardo-a-la-ciencia-en-venezuela/") issued a statement for the support and protection of science in Venezuela in response to the attempted mediatization by the State, protesting the fact that these serious problems are no concern of the relevant ministries. Since government programs with abundant resources during the oil boom (Mission: Science, Alma Mater, Ribas, etc.) were isolated from the formal research structure, they have been unsuccessful.

i. Is there a need to increase research skills?
Research capacities require ongoing thematic and instrumental updating. Venezuela has seen the deterioration of scientific equipment and infrastructure coupled with a high drain of human talent with fourth-level training. Researchers in agricultural sciences accredited in PEII accounted for 23% of all knowledge areas in 2012, falling to 11% in 2015. Further effort is required to reposition the talent that has left due to migration or retirement, and to develop new areas of knowledge that demand highly trained staff.

ii. Areas with local strengths
The country has had group and individual strengths in areas that combine technical, social and economic aspects related to agriculture and food security: Breeding (animal and plant), Agricultural Pest Control, Soil Science, Animal and Plant Taxonomy, Agricultural and Agroindustrial Engineering, Agricultural Product Processing and Rural Development, Biotechnology, Food Technology, Nutrition and Dietetics, and emigration and retirement have undermined these strengths.

iii. Scientific collaboration networks inside and outside the country
Venezuelan researchers have consolidated national/international relations in the agrifood sector. Institutional interest in these partnerships is limited and often responds to individual initiatives or those of scientific societies linked to the food sector. There is a lack of real, institutional support for the consolidation of stable networks to facilitate cooperation between individuals and organizations. From 1998 to 2007, Venezuela participated in the FONTAGRO consortia, which it only led twice, and was among the member countries that benefitted least. Numerous interagency agreements and government commitments to multilateral bodies have been implemented precariously and without the proper dissemination.

iv. Access to and maintenance of databases for monitoring farming systems
There are very few programs to monitor Venezuelan agricultural systems. Historical records have been undervalued. There is distortion and a lack of information from primary public sources (Central Bank of Venezuela, National Institute of Statistics, Ministry of Agriculture and Lands, Ministry of Food), while both public and private sources are difficult to validate. An example of this is climate records, vital information for agricultural activity, which are outdated, incomplete and in some cases difficult to access. For the food industry, the only official source of information are the Proceedings and Accounts of the Ministries of Agriculture and Lands and Food, which have no updated bulletins. At universities, information is scarce despite efforts such as those of the Center for Agrifood Research (CIAAL) of the University of the Andes, and the Center for Agricultural Information at the Agronomy Faculty of the Central University of Venezuela (CIAGRO). There are private initiatives, companies that collect and analyze data (Datanálisis, Econometric, INNOVAVEN), foundations (Bengoa Foundation, Polar Foundation) and trade associations (Center of Documentation and Analysis for Workers, Venezuelan Teachers' Federation-CENDA, Confederation of Associations of Agricultural Producers (FEDEAGRO and IPAFI) and National Federation of Livestock Producers (FEDENAGA), Venezuelan Chamber of the Food Industry (CAVIDEA), although some of their databases are of limited access or not free.

b. Universities and Research Institutes

Table 7 presents the national universities, research centers (public or private) and private foundations that support research in FNS. The Center for Development Studies (CENDES, UCV) offers a Professional Development Course in Public Food and Nutrition Policies to train experts in public health policies focusing on Social Nutrition. The Agrifood Research Center at the University of Los Andes (CIAAL) conducts research, and offers postgraduate training and specialized studies in the area of agrofood, with a focus on economic and social aspects, information systems on Venezuelan Food System and analysis methodologies. The Bengoa Foundation for Food and Nutrition Research makes important contributions in the area, as seen in other sections of this chapter. The Agricultural Research Foundation (DANAC) -of the Polar Company Foundation- is dedicated to improving food systems in partnership with producers, trade associations and public and private institutions. The Foundation for the Development of Physical, Mathematical and Natural Sciences (FUDECI) is devoted to environmental conservation in the Amazon State through the promotion of sustainable agricultural development, technology transfer or social interest, Sustainable Agricultural Systems, the promotion of livestock raising for family farms, the characterization of indigenous roots and tubers, and gastronomy based on the natural resources of the Amazon. At national universities, there is research on energy generation from wind and hydrogen, with student groups in the areas of robotics and mechatronics to develop electric and autonomous vehicles (such as solar cars). The Universities of Carabobo, Simón Bolívar and Zulia are working on fuel cells and the use of drones with the potential for the exploration, monitoring and control of floods and forest fires, and the prevention of extreme environmental events. Research funding is provided by the National Fund for Science, Technology and Innovation (FONACIT) with contributions from the government and private companies in the frame of LOCTI, which makes the government responsible for deciding what is to be financed with these contributions. In the past, contributions could be agreed on between companies and research centers. According to the Ministry of Popular Power for University Education, Science and Technology, in its Book of Opportunities for Study 2016 (revised),

Table 7. Some national universities, official research institutes, private foundations and NGOs that support research on food and nutritional security in Venezuela

National universities:

- Central University of Venezuela (UCV) and its Faculties of Agronomy, Veterinary Sciences (FCV), Agro Sciences, Environmental Sciences, Sciences and others.
- Simón Bolívar University (USB)
- University of the Andes (ULA)
- University of Zulia (LUZ)
- University of the Orient (UDO)
- Lisandro Alvarado Central-Occidental University (UCLA)
- Rómulo Gallegos University(UNERG)
- Ezequiel Zamora University of the Plains (UNELLEZ)
- Francisco de Miranda Experimental University (UNEFM)
- National Experimental University of Táchira (UNET)
- Experimental University of the Southern Lake (UNESUR)
- National Polytechnic University (UNEXPO) (*)

Research Institutes:

- Institute of Food Sciences and Technology (Faculty of Sciences, UCV)
- Institute of Chemistry and Technology (Faculty of Agronomy, UCV)
- Center for Development Studies (CENDES, UCV)
- Center for Agricultural Research (CIAAL), Faculty of Economic and Social Sciences (FACES, University of the Andes)

Research centers in the public sector:

- National Institute of Agricultural Research (INIA) (Ministry of Agriculture and Land) (*)
- Foundation for Advanced Studies (IDEA) (Ministry of University Education, Science and Technology) (*)
- Venezuelan Institute for Scientific Research (IVIC) (Ministry of University Education, Science and Technology)
- State Research Center for Experimental Agricultural Production (CIEPE) (Ministry of University Education, Science and Technology)
- National Institute of Nutrition (INN) (Ministry of Food)

Private organizations and non-governmental foundations or organizations:

- Bengoa Foundation. Food and Nutrition
- DANAC Foundation for Agricultural Research (Polar Company Foundation)
- National Rice Foundation. Guárico Portuguesa (Fundarroz)
- Fundacaña (Sugar Foundation for Development, Productivity and Research)
- Foundation for the Development of Physical, Mathematical and Natural Sciences (FUDECI)

(*) With Postgraduate programs (Masters' Degree, Specialization and Doctorate): Rural Development, Animal Production, Environmental Engineering, Genetics, Agricultural Zoology (Faculty of Agronomy, UCV); Veterinary Medicine (FCV, UCV), Food Science and Technology (Faculty of Science, UCV); Development Studies, Environmental Studies, Professional Development Course on Public Policies in Food and Nutrition (CENDES, UCV); Food and Nutrition Science (USB).

opportunities are available at various autonomous universities, experimental universities and regional polytechnic universities offering a selection of short and long degree courses, and national training programs in various areas of knowledge directly related to FNS, such as Agricultural and Marine Sciences, Agronomy, Agriculture and Farms; Foods; Environment; Forestry; Fisheries and Ocean Science; Veterinary and Health Sciences and Nutrition and Dietetics.

1. Scientific development and infrastructure
Infrastructure for both public and private research has aged rapidly and lacks maintenance, undermining its operation, as evidenced in universities with agricultural degree courses and the National Institute for Agricultural Research (INIA). Laboratories and projects operate precariously, their operational capabilities limited by the lack of equipment, instruments, reagents and vehicles to support fieldwork. National postgraduate programs have seen a drop in enrolment and scholarship programs. Scientific and technological development has slowed significantly. Permanent currency devaluations and exchange controls (since January 2003) have affected scientific and technological exchanges as well as the purchase of equipment, parts and spare parts.

2. Inter- and transdisciplinary research capacities Model development, assimilation of technological innovations
The individual disciplinary approach has prevailed over inter/transdisciplinary research. However, agricultural research has been conducted in various disciplines. Traditionally quick assimilation of technological innovations, supported by an economy able to purchase them abroad and adopt them has decreased as a result of the shortage of foreign exchange and the dismantling of technical assistance programs, particularly those offered by the public sector. Some private organizations such as livestock producers' associations –including the National Association for Agricultural Cultivators (ANCA) and the Association of Rural Producers in Portuguesa State (ASOPORTUGUESA) - have partially taken on this task, with limitations.

c. Development of qualified labor groups. Status of national education systems

Good development areas have been weakened by the emigration or retirement of researchers, shortage of funding, policy renewal and training of talents, lack of auxiliary staff and the obsolescence of structures, equipment and support instruments. The former National Council of Scientific and Technological Research (CONICIT) began a promising line of work in 1995, called Agendas for Research, Innovation and Strategic Partnerships: a set of policies aimed at the creation of innovation networks in multiple areas, promoting new avenues of collaboration among researchers, entrepreneurs, citizens, unions, politicians, etc., to agree on the specific needs of certain sectors or areas, formulated as projects: Agendas for Cacao, Rice, Sesame, Animal Feed, Seed and Grain, and the National Agricultural Information System. Subsequent evaluations document the abandonment of its original proposals and a return to traditional academic research (Peña-Cedillo & Flores-Urbáez, 2006). National education systems are affected by financial problems, insufficient budgets (national public universities have had the same budget since 2008) and a recurring practice of additional credits, which prevents proper planning.

d. Relative contributions of the public and private sectors

The national agrifood industry was at a disadvantage in a strong oil economy that encouraged imports that were cheaper than domestic commodities/products. Since 1999, state interventionism has intensified, discouraging private sector investment in the agrifood system and making the state nearly fully responsible for funding research and talent development. Some items that are very competitive due to international supply have received attention from the private sector because of their role in feeding the Venezuelan population, as in the case of the most popular cereals (rice, maize and sorghum) and the unsuccessful attempts to incorporate soy into agricultural systems. The genetic improvement of these items has primarily been due to those contributions. A comparative analysis of contributions from the public and private sectors in the aforementioned areas over the past 10 years shows that four of the 15 new rice varieties were developed by INIA (26%). Translating this reality into the market for domestic seed production, 67% of the seed sown came from private sources, of which the DANAC Foundation was responsible for close to 47%. One of the crops for which the largest number of new cultivars has been developed is maize, since the sector involves the participation of national and transnational companies seeking eligible cultivars, particularly hybrids. Since 2004, 86 white and yellow maize hybrids have been released, only six of which were developed by the public sector (7%). Soy is a sector dominated by private enterprise, which basically implements introductions from other programs, particularly from Brazil. The development of new soybean cultivars has been intermittent. National programs have not produced new developments in over 10 years. The only institution that engages in crossbreeding and obtains soybean cultivars is the DANAC Foundation, which has recently attracted the interest of the Lisandro Alvarado Central Western University (UCLA). Over the past 10 years, five varieties have been released, only one of which is the result of national breeding programs. In recent years, the state has failed to work successfully on sorghum. Seven varieties of grain forage and two kinds of sorghum forage exist, all produced by the private sector. Accordingly, over the past 10 years, the private sector has led the contribution of genetic materials produced nationally while the presence of seeds from abroad increases annually, encouraged by government controlled imports at a preferential exchange rate, making it difficult for private Venezuelan companies to operate. Unless this situation is reversed, the contribution of the public sector (INIA and universities) will be increasingly marginalized as a result of the drastic decline in the contribution of government resources for breeding programs, the growing insecurity affecting individuals and work teams, and the talent drain. Traditional sectors such as coffee, cacao, roots and tubers, sesame seeds, cattle and the capture of marine species have progressively been abandoned. Private efforts to produce coffee and cocoa have been affected by government controls over prices and marketing channels.

e. Future outlook

The future of the agrifood industry depends on the provision of three guarantees: legal certainty; social security, and personal safety. Those involved in the primary link must be guaranteed adequate living conditions compared to the rest of the chain or other economic activities. The government should consider environmental protection, the restoration of degraded natural areas and be aware of adaptation and mitigation actions for climate change. Last, the main goal for people and their development will not be possible without education, health and decent work in an environmentally protected, socially secure environment. There should also be a collective awareness that the everyday exercise of citizenship involves the defense of their rights and the fulfillment of their duties.

III. Characteristics of Resources and Ecosystems

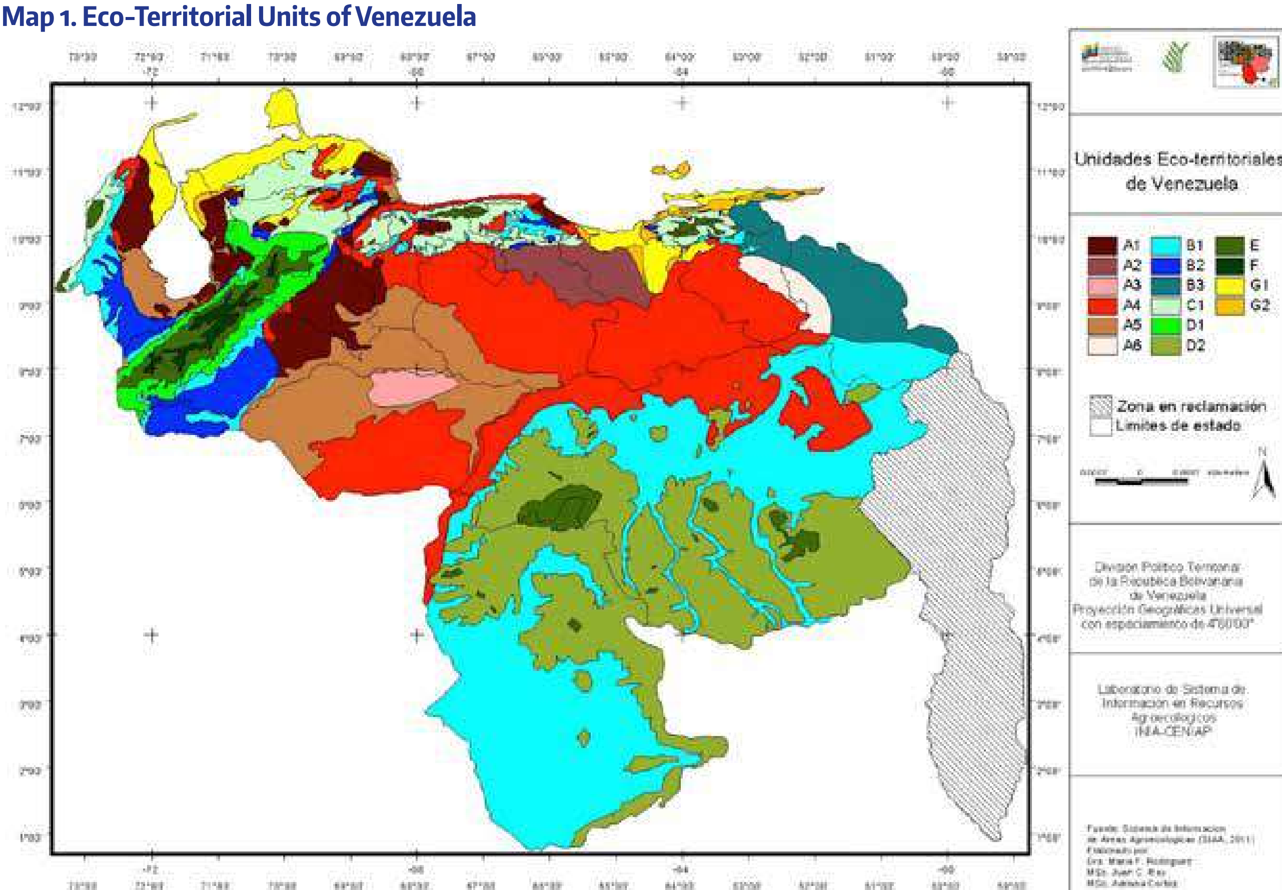
Its geographical location means that Venezuela has a tropical climate with bimodal patterns of solar radiation and temperature and minor fluctuations in these variables throughout the year. Altitude, cloud cover and geographic location are the most important factors determining its climate variations, meaning that temperatures range from 28°C in low-lying areas to below 0°C in the Andean highlands. Temperatures fluctuate by approximately 10°C in most of the country and to a lesser extent in coastal areas, islands and regions with high cloud levels. The various precipitation patterns (quantity and distribution), together with evaporative demand and the texture and depth of the soil, determine water availability and constitute the main climate and soil variables for agriculture, since they define the length and quality of the crops' growing season. Thus, there are places with humid periods lasting between 11 and 12 months (South of Venezuela, South of Lake

Maracaibo, Sierra de Perija, the Orinoco Delta, parts of the Andean piedmont and Barlovento), and areas where the absence of a humid period prevents rainfed agriculture (Goajira, Paraguaná and places in the Lara-Falcón Depression, coastal strip and islands). In the rest of the country, the length of the humid period varies from 3 to 10 months. The variations described here result in a wide variety of agroecosystems in terms of climate, with the possibility of producing multiple crops. This raises the need for crop selection and management systems to make optimal use of the range of climates and minimize climate-related risks. It is essential to undertake crop zoning to plant species according to the growing season and perform mechanized work at the most appropriate times. The **Map 1** shows the country's main ecoregions and their current use (INIA, 2016).

a. Water resources and challenges in the next fifty years

Venezuela has abundant water resources in seven river systems and 16 hydrographic regions. However, the North of Orinoco, where the population is concentrated, faces problems of water availability. The country has over 100 dams built for various purposes: supplying drinking water, water for industrial use and irrigation, flood control, recreation and hydroelectric power generation (González and Matos, 2012). In 2014, a total of 745.300 ha were irrigated (2.9% of the agricultural area) and 910,000 ha drained (INDER, undated). Challenges for water resource use include the following: the application of measures to solve problems of eutrophication; silting (dams filled with sediment derived from erosion); pollution; decreased water flow and conflicts over water use, as well as enhancing

Map 1. Eco-Territorial Units of Venezuela



Source: INIA, 2016.

Map 1. Eco-Territorial Units of Venezuela

Ecoregion			Use
A	Sub-humid low tropical zones, altitude below 500 masl, annual rainfall between 700 and 1,800 mm and four to eight humid months.	**A1:** flat areas, soils with good to moderate drainage, good natural fertility and risk of physical deterioration through compaction and surface sealing.	Annual mechanized crops, sugar cane, orchards, woods, vegetables and semi-intensive cattle farming.
		A2: areas with undulating topography, soils with average natural fertility and risk of erosion.	Annual mechanized crops, vegetables and semi-intensive and extensive cattle farming.
		A3: flat areas, soils with good natural fertility and drainage, in intricate physiographic patterns, determined by local topographic variations, comprising banks, shoals and estuaries.	Subsistence and semi-commercial agriculture, in addition to fishing and aquaculture, semi-intensive and extensive cattle farming, and semi-intensive buffalo farming.
		A4: flat areas, soils with low to very low natural fertility and a tendency to excessive drainage.	Extensive and semi-intensive cattle farming, annual mechanized crops, forest plantations, orchards, vegetables, subsistence and semi-commercial agriculture.
		A5: flat or very flat areas, with problems of seasonal flooding with little to no drainage capacity.	Extensive cattle farming, semi-intensive buffalo farming, subsistence and semi-commercial agriculture, fishing and aquaculture. Rice.
		A6: flat areas with flooding problems and acidification risk, when drained artificially.	Extensive cattle farming, semi-intensive buffalo farming, subsistence and semi-commercial agriculture, fishing and aquaculture.
B	Sub-humid sub-tropic zones, altitude below 500 masl, annual rainfall above 1,800 mm and nine or more humid months.	**B1:** areas with varied topography and soils with low to very low natural fertility.	Tropical rainforest with little intervention or protection, indigenous subsistence farming, plantations, extensive and semi-intensive livestock farming.
		B2: areas with predominantly flat topography, and soils with moderate to good natural fertility.	Forest reserves, plantations, semi-intensive cattle farming, semi-commercial subsistence agriculture.
		B3: areas with frequent or almost permanent flooding, caused by tide flows and overflowing rivers.	Environmental protection, tropical plantations, roots and tubers, indigenous plots of land.
C	Premontane sub-humid sub-tropic zones, altitude between 500 and 1,500 masl, annual rainfall between 700 and 1,600 mm and four to eight humid months.	**C1:** areas with varied topography of valleys and hillsides. In flat zones there is principally good drainage and good natural fertility, and in the zones with the steepest slopes there is an erosion risk.	Vegetables, orchards, sugar cane, pineapple and coconut, annual mechanized crops, semi-intensive cattle farming and poultry.
D	Premontane humid tropic zones, altitude between 500 and 1,500 masl, annual rainfall of 1,600 mm and over for nine months of the year.	**D1:** areas whose main limit is erosion and soil acidity, in addition to several more fertile zones.	Coffee, bananas, cocoa and pineapple, legumes, semi-commercial roots and tubers, vegetables, roots and tubers, intensive dairy and feed cattle farming.
		D2: very humid areas, with a predominance of very ancient geological material, severely limited fertility and a risk of biological degradation when used for agricultural purposes.	Tropical rainforest with little intervention or protection, indigenous family farming.
E	Humid and cold zones in the low-montane and montane levels, altitude between 1,500 and 3,000 masl, and almost year-round rainfall.	**E:** areas vulnerable to erosion with a risk of contamination of bodies of water, in addition to ecological fragility due to the risk of biodiversity being affected by endemic species.	Vegetables, roots and tubers, orchards, intensive dairy farming.
F	Very cold high mountain zones, altitude above 3,000 masl. .	**F:** areas highly vulnerable to erosion with a risk of contamination of bodies of water and loss of biodiversity, with endemic moor species.	Vegetables.
G	Dry sub-tropical zones, altitude below 500 masl, with annual rainfall under 700 mm and less than four months of wet periods.	**G1:** areas with valleys and plains with gentle slopes, with saline soils and a high risk of physical deterioration. Irrigation and water quality are determining factors for their agricultural use.	Subsistence and semi-commercial agriculture of irrigated vegetables, aloe vera, sisal, irrigated orchards, extensive goat and swine farming for meat, and semi-intensive for dairy production.
		G2: undulating areas with hills and low slopes, in which water scarcity and geological erosion limit any use of the terrain.	Extensive goat and swine farming.

Source: Taken from INIA, 2016.

Table 8. Strategies of the National Plan for Agriculture, Irrigation and Land Remediation (PLANARSAT). Phase I (2015-2019).

- Design a National Irrigation Plan to address the high risks and vulnerability associated with the country's heavy reliance on agriculture, and strategic items using dry land systems.
- Strengthen the program to build small reservoirs, fishing lakes and lagoons, to increase surface water capacity and reserves in rural areas.
- Modernize the national inventory of underground water resources.
- Start a program to open and equip wells to increase groundwater use in a rational, sustainable manner.
- Create a program to strengthen and improve national coffee cultivation, as a crop with considerable social and economic impact, which protects mountainous regions.
- Reinforce the programs to manage and conserve river basins, in particular high basins that are the source of Venezuela's main rivers.
- Create a special program to increase the strategic storage capacity of non-perishable food, for human consumption and animal feed, to prevent food shortage crises caused by droughts.

Source: INDER (undated).

water-use efficiency in the agricultural, urban and industrial sectors. For Phase I (2015-2019), the State has planned to increase the irrigation area by 279,404 ha (with an expected impact on 37 crops) and the area reclaimed through drainage by 409,000 ha (with an impact on eight crops). (See general strategies in **Table 8**; INDER, undated).

b. Soil resources and challenges for the next fifty years

The variety of geological features, climate, terrain and biomes is reflected in the diversity of soils, comprising 12 of the world's 13 taxonomic soil orders (Rey, 2015), with a predominance of ultisols and oxisols (MPPAT and INIA, 2008). Only 2% of the territory has land without constraints on agricultural production; in the remaining 98%, the limitations are: 44% with excess relief; 32% with low fertility; 18% with poor drainage and 4% with aridity. This means these lands must be adapted to prevent low productivity levels or compromising long-term sustainability. Incorporating technologies (such as irrigation, the use of species tolerant to poor drainage, low fertility or acidity; drainage works, fertilization management, the use of alternative fertilizers and conservation management practices) would overcome some of these restrictions and define the following potential areas: 4% for a wide range of crops; 14% for a limited range of crops; 30% limited to livestock and approximately 52% for forests, recreation and water reserves (Comerma and Paredes, 1978). There is a significant gap between current use and these potential areas for meeting the goal of food sovereignty.

c. Energy challenges

Energy resources are substantial and diversified: oil; gas; coal; bitumens; hydropower and renewable energy. The oil industry generates 80% of revenue and 70% of the country's foreign currency income (MARN, 2005). The country has 5.8% of the world's probable oil reserves and 2.5% of natural gas, totaling 146.8 trillion cubic feet. Sixty-four percent of electricity is generated by waterfalls, while the hydropower potential amounts to 83.433 MW (Hernández, 1998). Challenges include the following: solving the problems of power failures and developing the necessary infrastructure to exploit energy resources. This sector constitutes the most important source of greenhouse gases, with emissions from the energy-industry subsector making a significant contribution. Although there are no energy supply and demand projections, opportunities have been identified for mitigation through the substitution of energy sources, equipment maintenance, technological upgrading to improve efficiency and the adoption of energy-saving and conservation standards (MARN, 2005).

d. Conflicts and challenges regarding biodiversity

Venezuela is one of the world's ten most biologically diverse countries, ranking sixth in America. Preliminary results indicate 15,353 plant species, 261 families and 2,482 genera. Approximately 2,964 of these species are endemic. Some important genera for food and agriculture have their center of origin and biodiversity in the South-American region and include cultivated, wild and semi-domesticated species (MPPAT and INIA, 2008). As for fauna, at least 203 species of terrestrial and aquatic vertebrates (5% of total Venezuela) are used as a food source by the country's rural and indigenous communities (González-Fernández, 2007a). Two wild species, the capybara (*Hydrochoerus hydrochaeris*) and the spectacled caiman (*Caiman crocodilus*), are rationally exploited through management programs based on their biology (Ojasti, 2011), under the supervision of the Ministry of Popular Power for Ecosocialism and Water. In the past 12 years, the capybara program has occupied an average of 215,000 ha annually (8% of the area of its optimal habitat), with 16,411 animals in 2004 (González-Fernández, 2007b). Its dried, salted carcass weighs 7.5 kg on average (Ojasti, 2011). The spectacled caiman program covered 76.430 specimens in 2004 with a production of 382,150 kg (De Sola and Velasco, 2007).

Four major direct threats to biodiversity have been identified: 1. Destruction, fragmentation and degradation of ecosystems; 2. Introduction, establishment and invasion of exotic species; 3. Unsustainable use of biological diversity, and 4. Introduction of genetically modified organisms. The national strategy for the conservation of biological diversity and its action plan has seven strategic lines: information management; species conservation; definition of strategic areas for the conservation, sustainable use, prevention, control and eradication of exotic species; control and monitoring of genetically modified organisms, and prevention and management of illegal trade in species (Ministry of Environment, 2013). This plan does not include a specific line for agricultural species. Deficiencies in resources and training have been identified, with consequences such as damage to or total loss of gene banks (mango, citrus, papaya, cassava), which translates into the loss of genetic heritage and reduces the chances of improving these species. MPPAT and INIA (2008) report that in the main plant areas, a total of 473 cultivars are used, mostly from breeding programs (**Table 9**). Preference for these materials and consumption patterns enhances uniformity, reduces the use of traditional or local materials and causes genetic erosion. The country does not have monitoring and warning systems on genetic erosion.

e. Consequences of forest trends

In 1950, The Venezuelan State has established a National System of Areas under Special Administration (ABRAE), under a management regime with special laws. By 2013, there were 400 areas with 67.9 million ha, including national parks, forest reserves, natural monuments, protected forest areas and wildlife refuges. Areas assigned for the sustainable management of Forest Heritage occupy 16.3 million ha, with forest reserves covering 12.8 million ha (79%) and Forested Areas Under Protection (ABBP), 3.4 million ha (21%) (MINEA, undated).

Table 9. Crops used in various agricultural products produced in Venezuela

Common name	Scientific name	Number of crops
Avocado	*Persea americana*	60
Chili	*Capsicum chinensis*	2
Cocoa	*Theobroma cacao*	7
Coffee	*Coffea arabica*	9
Sugar cane	*Saccharum oficinarum*	15
Cherimoya	*Annona cherimolla*	1
Citrus fruits	*Citrus sp*	6
Guanabana	*Annona muricata*	4
Guava	*Psidium guajaba*	3
Mango	*Mangifera indica*	26
Cashew	*Anacardium occidentale*	3
Medlar	*Manilkara achras*	1
Passion fruit	*Passiflora edulis var. flavicarpa*	1
Pepper	*Capsicum annum*	1
Tamarind	*Tamarindus indica*	2
Tomato	*Lycopersicum esculentum*	4
Sub-Total		**145**
Crops from improved agricultural products declared eligible by SENASEM		
Sesame	*Sesamum indicum*	15
Cotton	*Gossypium hirsutum*	22
Rice	*Oryza sativa*	15
Bean	*Phaseolus vulgaris*	26
Black bean	*Vigna unguiculata*	3
Corn	*Zea mays*	179
Potato	*Solanum tuberosum*	18
Sorghum	*Sorghum vulgare*	36
Soy	*Glycine max*	14
Subtotal		**328**
Total		**473**

Source: Estimates by the authors with December preliminary information (MPPAT, 2015).

Seventy percent of these areas are South of the Orinoco River (MARN, s/f). Total domestic production of round wood between 2009-2013 was 4.2 million m^3, 0.3 million corresponded to the volume harvested in forest reserves (natural forests) and 3.9 million m^3 to plantations (pine, eucalyptus, teak and melina wood) (MINEA, undated). According to MARN (undated), the greatest damage to the forest area occurs in the North where the population is concentrated, yet, according to MPPAT and INIA (2008), Guyana's forests are at risk. Six of the main causes of the decrease in forest area are the advance of the agricultural frontier, illegal logging, weaknesses in oversight/control mechanisms, invasions of land for forestry for agricultural purposes, mining and forest fires. Challenges include undertaking a national forest inventory; increasing forest management by adopting strict environmental measures and research; evaluating goods and services from the forest to design policies and make decisions for new forms of management and forest management; and a system for assessing the sustainability of forest resources based on Criteria and Indicators (MARN, undated).

f. Potential impacts of climate change

Climate change projections indicate a generally warmer and drier future, with variations according to the model used and the particular region. By 2060, average temperature increases of between 1 and 2°C are anticipated, particularly due to increases in the minimal temperature. Variations in precipitation, evapotranspiration, number of humid months and the estimated water balance are also expected. Overall, the percentage of the country with dry climates will increase to over 47% (MARN, 2005). Considering these variations, Ovalles et al. (2008) conducted a land evaluation of the three most severely affected main geographical areas: East; Central-West, and the Andes and the Maracaibo Lake Basin, concluding that wetlands will disappear at the expense of sub-humid areas and that most sub-humid areas will become dry. As for the central-western area, dry areas and erosion problems will increase. It is estimated that most of the western region will become sub-humid. Permanent crops will be most severely affected. Changes are not expected to be as drastic for livestock and annual crops, although the negative effect on pastures will affect animal feed. Since a total of 94.3% of agriculture is rain-fed, direct impacts are anticipated on crops (yield, reduction of cycles, water use, spatial distribution, pests and diseases) as well as on livestock production (livestock comfort and health and pasture availability) (MARN, 2005).

g. Building resilience to extreme events

Resilience measures encompass legal, political, technological and educational aspects, at different levels of organization of society. Venezuela is incorporating drought-resistant crop varieties and management practices that prevent land degradation and improve sustainability (reduced tillage, use of modifications and fertilizers, land drainage, etc.). In the area of climate and integrated water-resource management, the National Institute of Meteorology and Hydrology has a system for tracking hydrometeorological conditions, forecasts and Numerical Weather Prediction (NWP). The challenge is to establish this in real-time, with location, geographical distribution and relief. In 2012, the first wind farm in Venezuela began operating on 575 ha in Paraguaná and in La Guajira, four wind turbines began to be tested. Eventually, 75.6 MW are expected to be generated from 36 wind turbines financed by Petróleos de Venezuela (PDVSA) so that it can be an energy-producing rather than just an oil-producing country.

h. Future projections

A national approach is required for FNS. Academics and productive sectors agree on the need to identify and strengthen production in areas where the country is competitive or has traditionally self-supplied, and imported goods that cannot easily be produced. There is enough suitable land to meet the food needs of the agricultural sector, for both arable and livestock farming until 2020. However, if one disaggregates the figures by type of farming system, there is a shortfall in available land for horticulture and mechanized annual crops (Abarca, 2010). Experts estimate that 1 ha is required to feed 10 people, meaning that about 4 million ha will be required to meet the needs of the population in 2050. There is an enormous livestock and forestry potential. Major engineering works should focus on drainage, since irrigation requires more technical training, trained personnel and technological packages. In addition to the availability of land, an institutional framework is required for technical assistance regarding sustainable land management, and there are potential conflicts over resource use triggered by the expansion of agricultural land and the security problems faced by producers.

IV. Technology and Innovation

a. The Role of biotechnology

Although some research centers in Venezuela have relatively modern equipment and infrastructure for conducting basic analyses of nucleic acids in tropical crops and other areas of agrifood interest, very few laboratories have new sequencing technologies and infrastructure to address omics or bioinformatics apparatus for handling large amounts of data. The most recent institutional initiative by the Venezuelan State to promote the development of biotechnology for agriculture was launched between 2004 and 2006: the FONACIT call for applications to "Strengthen the Biotechnology Sector for Food Security" with International Development Bank (IDB) funds, which financed over 30 research and development projects by public and private institutions. The funds were also used for the training of human talent and technology transfer, equipping several laboratories with what were state-of-the-art technologies at the time and creating working groups. Many projects were not continued due to the lack of institutional support, which led to the obsolescence of equipment and analytical capacity for emerging issues in agricultural areas. Obsolescence of equipment is perhaps one of the greatest obstacles to national scientific and technological development. For a number of years, the State's official position has been to reject biotechnology, crystallized in the recent Seed Act, which expressly prohibits the use, consumption, experimentation and cultivation of genetically modified organisms. Venezuela had a successful but unfortunate experience in the use of modern biotechnology in crops: the case of the transgenic papaya resistant to the ring spot virus created at the University of the Andes with proven efficacy (Fermín et al., 2004). Unfortunately, the field trials were vandalized by anti-GMO groups, bringing this and other related research to a premature end. Despite the potential of biotechnology, in both its broad sense and the one assumed in the Cartagena Protocol, the role of biotechnology in food security in Venezuela has had a limited impact on plants and livestock.

b. Possibilities for novel agricultural products

Although Venezuela has historically produced over 50 types of plant, with statistics available on cereals, legumes, vegetables and tubers, and fruits (**Table 3**), formal breeding programs only exist for fewer than a dozen of them, including cereals and sugar cane. This affects the quality of many of the items consumed in the country since they are not incorporated into a control system that guarantees the phytosanitary status of the seed or the products acquired by consumers. It also opens up the possibility of formalizing breeding programs and creating gene banks for secondary or non-traditional crops. There are gene banks for crops such as cassava, and accessions of sweet pepper, a traditional vegetable in Venezuelan cuisine, are being identified. As can be seen in Section VI, the typical Venezuelan diet formerly consisted mainly of flour (starch) and fat, with a low intake of protein and items that provide vitamins and micronutrients. There is a need to develop novel agricultural products to diversify the diet of Venezuelans.

c. Opportunities/barriers to new management technologies (Irrigation/Water/Fertilizers)

There are opportunities for technological innovation in agricultural management. There is interest on the part of farmers in innovating to achieve higher yields and profitability and confidence in research, as borne out by the active participation of producer associations in the discussion of laws such as the LOCTI, and links between the scientific and agricultural sectors. One obstacle is the lack of triangulation between the public and private sectors and science and technology. The public sector does not prioritize this triangulation, and instead imposes legal barriers such as the Seed Law, which penalizes the use of modern biotechnology, and encourages production systems with questionable productivity and viability on a large scale. LOCTI is essentially a tax mechanism to distribute, manage, control and discretionally assign the private sector's contribution to scientific activity.

V. Increasing the Efficiency of Food Production Systems

a. Possibilities of increases in agricultural production based on technology

Venezuela faces serious challenges in food production. Major cereal yields have not changed substantially over the past 15-20 years. Corn yield has not exceeded 4,000 KgHa-1, while paddy rice has a yield of approximately 5,000 KgHa-1 and sorghum, approximately 2,000 KgHa-1 (FAOSTAT, 2017). The situation compromises the achievement of food security, since estimates indicate that the population will increase by more than 10 million over the next 35 years. Despite the economic and political situation, farmers are willing to use new technologies (and *sensu lato* biotechnologies), which can increase production and profitability, such as drones for crop monitoring and land surveying, and geographical information systems for diagnosing crop anomalies and predicting yields (Pereira, 2016). Precision farming is gaining followers while bio-products can be used as a sustainable alternative to fertilizers and pesticides to increase production in a more environmentally friendly way. Examples include arbuscular mycorrhizae, of which the MicoVen product has been launched on the market on a small scale. Based on mycorrhizal native inoculants, it is marketed to small-vegetable farmers. Research on entomopathogenic nematodes applied to crops-of-interest is beginning to yield conclusive results. Nitrogen fixing bacteria have existed as a patented product for over 30 years. All this could help reduce the 200,000 to 300,000 tons of nitrogen fertilizer used annually (FAOSTAT, 2017).

b. Infrastructure needs (e.g., transport systems)

One of the country's main infrastructure needs are germplasm banks. At present, the storage capacity of propagules is limited, particularly if one attempts to include new crops or incorporate existing ones into a formal system of seed classification. Improving the provision of and training in Information and Communications Technology (ICT) for precision agriculture is urgently required so that stakeholders can have access to relevant information in real time, and improve the networks for measuring climate, soil, hydrology and water quality and their integration into systems to support decision-making, maintain agricultural roads, dams, irrigation canals and drainage as well as investment in new developments.

c. Points for food use and waste minimization

In Latin America, Food Losses and Waste (FLW) amount to 1.3 billion tons of food/year. Over 85% of this takes place from farm to fork. In Venezuela, one of the keys to reducing post-harvest losses is highways, which have remained unchanged since 1994 at 10.5 roads for every 100 km^2. Technical assistance and education are required to reduce post-harvest losses and those at every point in the food chain. Fruit and vegetable transportation is not in line with international standards, there is high degree of rotting, ethylene is not used on citrus fruits and the technological link between supermarkets and producers is weak. There are high losses at the retail level. Unlike Colombia, Mexico and Argentina, Venezuela has not estimated FLW. Various actions in the region are advancing toward the reduction of FLW such as the Regional FLW Strategy in Latin America and the Caribbean, which has national committees comprising public, private and civil society actors. This Strategy is in line with CELAC's 2025 Plan for Food Security, Nutrition and Hunger Eradication and the new Sustainable Development Goals (FAO, 2017). However, Venezuela is not actively involved. In 2010, a scandal shook public opinion: over 130 million kilos of food imported through the irregular use of foreign currency and over-invoicing were lost due to serious flaws in conservation, refrigeration, storage and transport.

These imports began in 2008. The ethical and financial loss to the nation was huge and investigated by the Comptroller General's Office itself (Transparencia Venezuela, undated).

VI. Health Considerations

a. Foodborne diseases

Publication of the weekly epidemiological bulletins that are supposed to be issued by the Ministry of Popular Power for Health was suspended for over a year: from October 2014 to February 2016. A communiqué from the Venezuelan Society of Public Health (SVSP) and the Let's Defend National Epidemiology Network (Oletta-López at al., 2016), with its own calculations based on official figures from the unpublished Weekly Epidemiological Bulletins from 2014 and 2015, reported an increase in outbreaks and cases associated with FoodBorne Diseases (FBD). These data refer to the morbidity in 2013 obtained from the Yearbook of Morbidity for that year (MPPS, 2013), subsequently updated on November 19, 2016. Mortality data have not been available for the past 4 years. **Table 10** presents the cases of diarrhea, amebiasis, acute typhoid fever outbreaks and those associated with FBD, with updated figures as of Epidemiological Week No. 46 of 2016. The SVSP painstakingly reconstructed the restricted data, as well as calculating national morbidity rates per 100,000 inhabitants for acute diarrhea and amebiasis between 2013 and 2016, and as well as the historical series of acute diarrhea and outbreaks and cases of FBD between 2006 and 2016 (data not shown), showing the upward trend in the incidence of cases of diarrhea and FBD over the past 11 years. Silence on epidemiological information does not contribute to the monitoring, or control, or reduce the threat of infectious diseases. On the contrary, it weakens the institutional and societal capacity for response to identify and address risk factors exacerbated by the precarious conditions of public services and environmental conditions. The main problems include: shortage of potable water, solid waste collection, wastewater treatment, proliferation of vectors, contamination of reservoirs and water sources, proliferation of informal food and beverages, shortage of staples, and the impoverishment of the population, which has led to the consumption of discarded food. Non-compliance with and ignorance of the rules for the sale, preparation, handling, transportation and storage of food multiplies the possibility of fecally/orally- transmitted infectious diseases, which is compounded by the limited availability

Table 10. Cases of diarrhea, amebiasis, acute typhoid fever, outbreaks and cases associated with foodborne diseases, with figures updated to epidemiological week N· 46 of 2016

Event	2013	2014	2015	2016
Diarrhea (A08-A09)	1,740,747	1,702,489	1,819,098	1,917,576
Amebiasis (A06)	96,285	86,043	88,205	88,894
Typhoid fever (A01.0)	3	0	4	5
Number of outbreaks of foodborne disease	34	31	30	64
Cases associated with foodborne sisease outbreaks	805	473	614	908
Type A acute hepatitis (B15)	2,795	2,883	5,840	3,883
Acute diarrhea < 1 year-olds	200,395	181,438		234,486
Diarrhea among 1-4 year-olds	455,152	448,828		507,355
Diarrhea among > 5 year-olds	1,085,200	1,072,223		1,175,735

SIS Form. EPI-12, from MPPS, 2016 and Weekly Epidemiological Newsletters, MPPS from 2015 and 2016 (until epidemiological week N· 46, November 19) undisclosed. Figures for diarrhea, by age group in 2015, not available.
Source: Oletta-López et al., 2016.

of equipment and supplies for the diagnosis and treatment of enteric diseases. The State must review the health regulations to facilitate poultry and swine breeding in urban environments (a practice that is not part of the national urban culture), as part of the policy announced to develop urban microeconomics in neighborhoods, by creating vertical chicken coops and pig pens (Oletta-López et al., 2016).

b. Excessive consumption: Venezuela's double nutritional burden

The Food and Nutrition Profile 2013-2014 (MINPPAL-INN, 2014) records Venezuela's progress and challenges in ensuring Food Security and Sovereignty, "seeking the full satisfaction of this fundamental right as part of the Nation's 2013-2019 Program for Socialist Bolivarian Management, to achieve the supreme social happiness of the people". In 2013, malnutrition caused by excess, identified as a product of capitalism, affected 4.0% of children under 5. "This figure is well below the WHO cutoff point (10%) so it is not considered a public health problem, but the vigilance and prevention of childhood obesity to prevent chronic diseases in adulthood is high priority for the Venezuelan State" (MINPPAL-INN, 2014).

Table 11. Overweight, obesity and deficit in Venezuela, in national and community samples

Sample and environment (National or community)	Malnourished	Excess
National study School pupils ages 7 to 12 (n= 5572) Teenagers ages 13 to 17 (n=6717)* (INN, 2012)	15% deficit 17% deficit	28% excess: 18% overweight, 10% obesity. 21% excess: 12% overweight, 9% obesity)
National study Individuals ages 15 to 40 (n=10.151) (INN 2012)	3.51% (thinness: weight for low height)*	28% excess: 18% overweight, 10% obesity 21% excess: 12% overweight, 9% obesity
External consultations at Antímano Infant Nutrition Center. CANIA. (n =72.158 pediatric patients) (Cania, 2016)	>50 % between 1995 and 2015	5.10 in 1995 to 22.8 in 2013 21.9 in 2014 to 19.4 in 2015
National nutrition status of children <15 years (n: 371.318) based on indicator weight – height ** (SISVAN 2007)	13.12 %	12.48 %
School communities in four states in Venezuela. 2008-2012 (n> of 6000 children). Fundación Bengoa (2012)	15-20%	16 - 20%
School communities in four states in Venezuela. 2015 (n: 1,269 niños). Fundación Bengoa (2016)	22.5%	10.4%
IV National Family Budget Survey 2008-2009. 12-80 years. 37.529 households 172.158 persons (BCV, 2009).	18.3%	24.8% overweight 12.8% obesity
ESCEL Study. Lara State, Venezuela 1987: 5272 persons >15 years 1997: 3707 persons >15 years 2008: 1264 persons >15 years (Infante et al., 2010)		1997. Men: 7.6% Women: 12% 1987. Men: 10% Women: 13% 2008. Men: 22.2 % Women: 21.4
CARMELA Study (2008). City of Barquisimeto. Lara State. 1848 middle-aged persons (45,1±11,3) (Schargrodsky et al., 2008).		23.5% among men 26.1% among women
Caritas de Venezuela in parishes, "sentinel sites" in four states. Children <5 years. n: 839 (Caritas, 2017).	11%	Overweight and obesity 15.8%

* BMI threshold of 17kg/m² (Frisancho 1993) rather than 18,5kg/m²

However, the latest report from SISVAN with 2007 figures states that chronic malnutrition, with stunting in children under 15 years, was the most prevalent form of malnutrition, the deficit had decreased and overweight was emerging as a health problem (INN -SISVAN, 2008). In a national study, the INN (INN, 2012) found both deficit and excess in children aged 7 to 12, and 13 to 17. **Table 11** presents these and other data from various sources, showing the double burden in Venezuela during the periods studied.

c. Expected changes in consumption patterns (consequences for imports)

In early 2017, the only available study is the National Food Consumption Survey (actual consumption) (ENCA) with information until the last quarter of 2015, published in June 2016 (INE, 2016). **Table 12** compares the frequency of consumption of 11 food groups in two periods (2013 and 2015): cereals; oils and fats, meat and fish; dairy and eggs, soft drinks; legumes; vegetables; tubers and plantains; fruits; alcoholic beverages and others. There has been a striking decrease in the consumption of fruits: from 17.7% in 2013 to 0.5% in 2015, and of non-alcoholic beverages from 22.8% to 16.8%.

ENCOVI (Landaeta de Jiménez *et al*., 2017) presented the distribution of the 10 most frequently purchased foods in households by socioeconomic level. Cereals (maize, rice, bread and pasta), fats and sugars accounted for over 45.5% in 2014. In 2015, weekly food purchases focused on cereals, which, together with fats, represented 38% of the total. Animal and/or vegetable protein decreased due to excessive price increases. Milk recorded a low purchase intention among both lower and upper strata, while cheese and eggs were not among the top 10 items. Fruits and vegetables, the consumption of which is a preventive factor in chronic diseases, were not available for the majority of people. The most affordable foods were the most calorically dense (flour, cereals, fats and sugars). The results of the 2016 ENCOVI (Landaeta de Jiménez et al., 2017) are striking since they indicate an abrupt change in Venezuelans' buying patterns: the first four products bought at all socioeconomic levels were: corn flour, wheat flour, rice and vegetables.

Table 12. Actual food consumption in Venezuela (%)

Most consumed foods (%)	ENCA 2013	ENCA 2015
Cereals	28.8	29.4
Visible oils/fats	2.6	3.2
Meat and fish	10.2	21.5
Non-alcoholic drinks	22.8	16.8
Dairy and eggs	9.3	9.3
Legumes	2.4	5.7
Vegetables	4.2	5.2
Other foods	4.2	4.8
Tubers and bananas	5.8	3.6
Fruit	17.7	0.5
Alcohol	0.09	0.013

National Survey on Food Consumption. ENCA (INE, 2013, 2015).

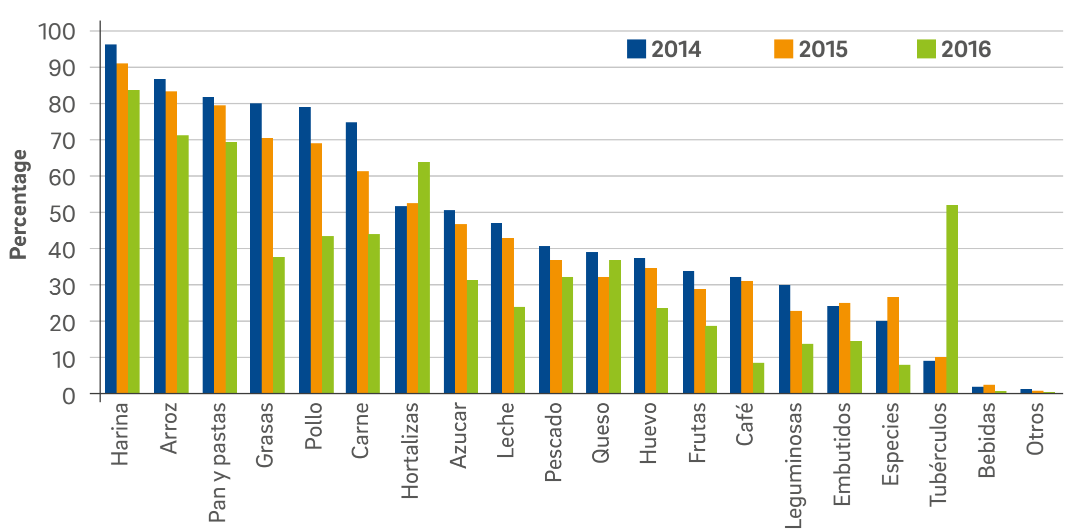
Vegetables and tubers replaced meat and chicken. **Figure 12** shows the variations in buying patterns during the 2014-2016 period according to ENCOVI.

Another feature of food purchases in Venezuela is that most people buy subsidized products in the public network, plagued by problems of availability and distribution. Consumers are forced to spend many hours in long lines (Landaeta-Jiménez et al., 2015; 2016). The same happens with the regulated food distributed in the private network. The situation deteriorated between 2014 and 2016, after which the state implemented a rationing system based on the assignment of a shopping day depending on the last number of the ID card. In April 2016, it created the Local Supply and Production Committees (CLAP), for the house-by-house distribution of basic products (pre-cooked corn flour, rice, oil, sugar, powdered milk, etc.), delivered through the Communal Boards, MPPAL and other organizations controlled by the government. In October 2016, companies were forced to sell up to 50% of their production to the government for CLAP, affecting the distribution of these products and excluding the vast majority of the population from the system. This has been analyzed and severely criticized by specialists, as discussed later.

As for macro- and micronutrient intake, according to ENCA (official survey), in 2015, the proportion of adequacy of total energy consumption was 94%, close to the lowest recommended range (90-110%), with women covering their nutritional needs best. This modification of the average consumption of food energy fell in relation to the 2013 ENCA, when it was 99.7% (INN, 2016). Regarding protein intake, both sexes were within national recommendations. Iron requirements by sex, age, social class and geographical location are covered, with more than 200% sufficiency, attributed to the high consumption of fortified cereals, particularly pre-cooked maize meal. There is a large deficit in calcium requirements, 40% and 50% below recommended levels, except for preschoolers (100% of recommended dairy-product consumption). ENCA uses INN (2001) Energy and Nutrient Reference Values. The FAO/WHO/UNU (2004) Expert Committee recommended a new methodology for calculating energy expenditure and minimal calorie intake per capita for proper physical and mental health. Accordingly, Bengoa, ILSI Norandino and national universities and experts updated the 2000 requirements, taking into account population changes and adjusting values, considering that about a third of the population engages in light physical activity (Bengoa/ILSI North Andean Foundation, 2012). Officially, INN values continue to be used (2001), although the Reference Values for Energy and Nutrients for the Venezuelan population 2015-2016 are under discussion. According to MPPAL-INN (2014), the period from 1998-2013 saw an increase in the availability of proteins with a high biological value provided by food of animal origin (chicken, beef, eggs, dairy products), which amounted to 78% (57 g/person/day).

Although the state claims to have guaranteed the availability of "sovereign" items such as cereals, milk and dairy products, vegetables, roots and tubers, legumes, fruits, meat and meat products, the unions warn that meat consumption has decreased. For example, per-capita consumption of beef amounted to approximately 7 kg in 2016, and the same was true of chicken, pork and milk (Gutiérrez, 2017). Strategic items which, according to the state, exceeded 100% availability, included: powdered whole milk 101%; pork 108%; polished rice 120%: net corn grain 130%; mutton 148%; peas 181%; other grains 213%; chicken meat 222%; canned tuna 265%; farm cheese 382%, and various vegetables and roots with over

Figure 12. Variations in results of Quality of Life Survey (ENCOVI) Venezuela. Food. Percentage of families that purchase the product 2014-2016



Source: Landaeta-Jiménez, et al., 2017.

100% availability. This does not tally with statistics from MPPAT or the National Institute of Statistics (INE), which report a fall in the gross value of agricultural production/capita (VBPAPC) between 1998 and 2014, at constant 1997 prices (**Figure 1**). Between 2008 and 2015, the reduction in the production of major agricultural crops was exacerbated.

The eating pattern has been greatly affected. **Box 3** summarizes the results of recent research on the changes detected in this pattern, and shows that the lack of availability and problems of access to food are negatively affecting the population's diet, which will have severe effects on Venezuelans' nutrition and health.

Box 3. Venezuelans' eating patterns, based on various studies

1. In 1,099 households in the Metropolitan Area of Caracas:

- 98.2% stated that their diet had deteriorated due to shortages, high prices and decreasing income
- 61.3% stated that their diet was deficient or did not satisfy their appetite
- There was evidence of a reduction in legumes and foods providing vitamins and minerals (broccoli, cauliflower, cabbage), in addition to fruits, milk, yogurt and other similar products.
- In 389 households, all members reduced the amount of food consumed. (Cecodap-Cisor, 2016).

2. Based on a qualitative evaluation of the family food pattern, in four states:

- 42% of the population recorded a diverse, poor diet (food based on six to nine food groups)
- 52% reported a diverse, inadequate diet.
- 94% of families had a diet based on fewer than five food groups (of the nine to 12 ideal ones), of which two are sugar and fats.
- Meat, fish, eggs, grains, vegetables and fruits are consumed by less than 50% of households.
- In most households, the diet is based on only three basic food groups: tubers, cereals (maize or bread) and cheese, in addition to sugar and fats. (Caritas Venezuela, 2017).

3. According to Encovi (*) 2014 and 2015, the purchasing pattern approximates a survival diet:

- Little variety of carbohydrates and fats: monotonous, with few foods, predominance of cheaper sources of calories (cereals and fats), at the expense of quality (animal protein, vegetables and fruits).
- The purchase structure, represented by four foods – maize flour, rice, bread and pastas (or fats or a protein) – is a sign of nutritional alarm, a high risk of chronic nutritional diseases and hidden hunger due to a deficiency of micronutrients and malnutrition. (*) Encuesta Condiciones de Vida (Encovi)

4. According to Encovi 2016:

- There is an abrupt change in food patterns, based on product purchase.
- First five foods: maize flour, rice, bread, wheat flour and vegetables and tubers (V&T)
- V&T replace proteins with a high biological value.
- Fruits only appear in the purchases of non-poor Venezuelans.
- Food purchases have plummeted.
- Inequality in food quality and quantity has increased.
- Approximately 9.6 million Venezuelans eat two or less meals a day.
- 93.3% of households have an insufficient income. 74.3% of respondents reported non-controlled weight loss (8.7kg) in the previous year, and the poorest 9 kg. (Landaeta de Jiménez et al., 2015, 2016).

5. According to Estudio Latinoamericano de Nutrición y Salud (ELANS 2015), Venezuela Chapter:

- 93.9% of Venezuelans fail to cover their caloric requirements: women's calorie intake is 1749.1 Kcal/day and men's 2059 Kcal/day.
- Calorie intake decreases considerably as women's age increases.
- Fat intake decreases as age increases.
- Five consumption patterns, based on social stratification, were identified: the "richest", representing 6.1% of the population, followed by others, at 17.3%, 22.0% and 19.2%, with the "poorest" comprising 35.4% of the population. Only the "richest" covered the calorie recommendations for the Venezuelan population. (Ramírez, et al., 2017).

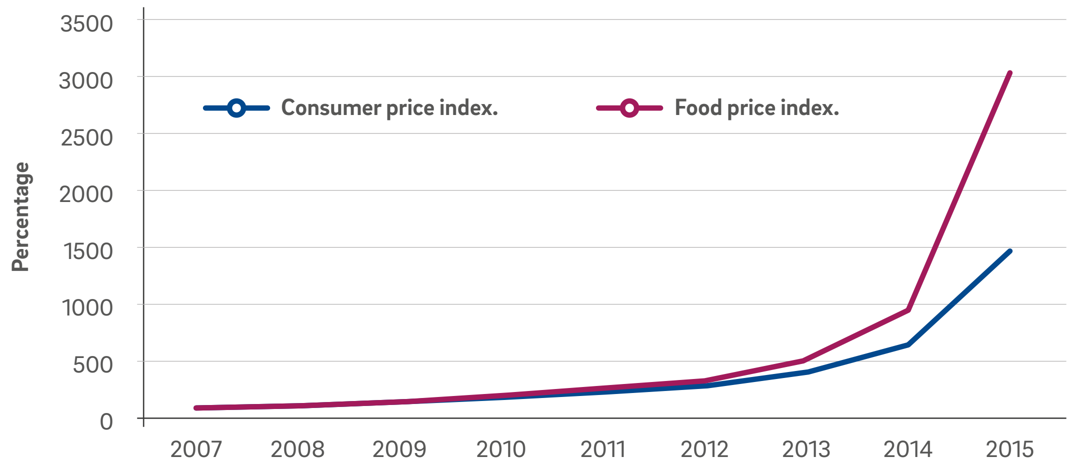
Imports. Consequences. As **Figure 2** shows, imports increased during the oil boom declined in 2009 and 2010 and with the new increase in oil prices, recovered until 2013. The availability of food/capita is assumed to have decreased because of the reduction in domestic production (in both agriculture and the food industry) and also of imports. There has also been an increase in illegal exports (Gutiérrez, 2017). This situation is not expected to improve over the coming years as long as economic policies and low oil revenues continue. In order to improve supplies, in 2016, the government created the Great Mission Sovereign Supply Mission, conducted by the National Armed Forces to inspect compliance with price control and exert more control over food production, distribution and imports. The Complementary Supply Program, whereby the government, in partnership with private sector, imports food at a parallel market-exchange rate, sold at above controlled prices with the permission of the regulating bodies. Access to food, affected by major shortages, improved slightly in December 2016 as a result of the easing of controls on imports by individuals and pricing at the non-preferential dollar rate, but worsened with regard to economic access (Gutiérrez, 2017). A systematic increase in food shortages has been experienced since 2012, with a rate close to 58% in 2014. Price controls, coupled with the decrease in inventories and barriers to distribution, have exacerbated shortages.

VII. Considerations regarding policies

a. Distortions created by subsidies and other policies

In 2003, the Mercal Mission, the government's most important for wholesale and retail food distribution program was created, which built mobile fixed sales centers (stores, small suppliers and supermarkets), and stocked them with food and other basic commodities, subsidized without intermediaries, and with large discounts. In 2004, the Ministry of Popular Power for Food (MPPAL) was created, with responsibility for matters of food security and an administrative network of bodies and entities assigned to discharge its broad-ranging functions. In 2008, the Decree-Law on Agro-Food Security and Sovereignty was passed, which supported expropriations. At the same time as it declared that all the links in the productive chain were of "public utility", it permitted the occupation of farms, enterprises, farms and any productive unit without due process or prior notification. In 2011, the Fair Costs and Prices Decree was passed, with the rank, value and strength of a law. Since then, price controls through modifications to the legal framework (decrees, Law of Costs and Fair Prices with their reforms) have been intensified, and expanded in terms of the food included and applied to various links in the agroproduction chain (producer, wholesaler, factory, retailer), making it difficult for markets to function properly. The Venezuelan Chamber of the Food Industry (CAVIDEA) has identified over 200 laws, decrees or resolutions that affect and influence final prices. Neither the legal frameworks for these controls, nor the organizations that regulate their application, functioned properly. At the beginning of 2017, the country had high levels of shortages of basic products, coupled with a fall in agricultural production, which averaged 27% between 1999 and 2014 according to official figures (other figures register 50%). The shortage of basic food products is between 60% and 80% (Gutiérrez, 2016, PROVEA, 2016, PROVEA, 2014). In January 2016, the name of the scarcity index (which measures product shortages) and has not been published since 2014 (24%), was changed to the "realization of the existence of hoarding" (87%), which speaks of a real shortage of approximately 90%. During the 1998-2013 period, real agricultural prices had an average positive annual growth rate of 2.6%; in the agricultural crop-production subsector they grew by 1.6% and in the animal and fishery subsectors they grew by 4.6% and 3.5%, respectively, with inflation increasing production costs by 40% and 50% (Gutiérrez, 2015). The National Superintendence for the Defense of Socioeconomic Rights (SUNDDE) recently attempted to regularize the situation by adjusting the price of pre-cooked maize flour (900%),

Figure 13. National Consumer Price Index (INPC) and Foods (ALIM). Venezuela. 2007-2015



Source: BCV. Central Bank of Venezuela.

chicken (1,000%) and pasteurized milk (1,973%). The delayed increase in these levels shows the inefficiency of the price-control policy. Venezuela also has the world's highest rate of general and food inflation (**Figure 13**), with food inflation being estimated at 315% in 2016 and over 700% for 2017.

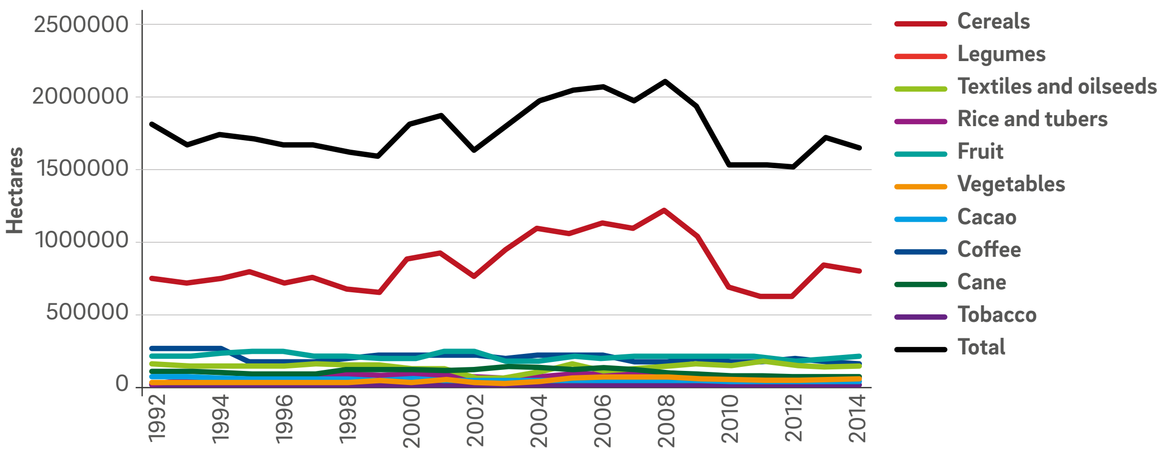
b. Promotion of nutritionally sensitive agriculture for healthy, sustainable diets

Delayed agricultural price setting, combined with rising production costs, inflation and the scarcity of inputs, do not guarantee the kind of profits that encourages agricultural production (Gutiérrez, 2015). The confiscation of land and the expropriation of farms and haciendas have all affected productive capacity. The 2001 Decree with the Rank, Value and Strength of Law on Land and Agrarian Development (LTDA), with reforms in 2005 and 2010, provides a framework for these effects on production, supported by the 2008 Organic Law on Agro-Food Security and Sovereignty. Since 2004, there has been an increase in invasions, expropriations, land recoveries and interventions, without fair compensation. A climate of uncertainty has been created for producers, exacerbated by the low productivity of nationalized units and the failure of the social organization cells of the new production model (Zamorano funds, socialist production enterprises) (Gutiérrez, 2015; Obuchi et al.) As a result of this policy, the state became the sole supplier of certain staple foods such as coffee and nationalized most of the distribution of inputs and seeds, granted by the registration and permits for organizations that are politically similar to the government. MPPAT declared that in 2010, it had “recovered” over 3.67 million ha, enough land to supply three times the country’s cereal needs, but this has not translated into an increase in agricultural production, nor has the Land Act led to spectacular increases in the amount of land incorporated into production. The harvested area for the period 2004-2013 averaged per year (according to official statistics) the number of hectares harvested to 2013, which is below the maximal value of the past three decades, before such a radical land policy was implemented (Gutiérrez, 2015). **Figure 14** shows the harvested area in Venezuela by family of agricultural products (1992-2014). The largest harvested areas correspond to the 2006/2007 period. It is noteworthy that the harvested area in 1992 was approximately 1.8 million ha and that the population has increased by more than 33% since then. **Figure 15** shows primary production per inhabitant during the 1992-2014 period. Gross agricultural production per capita (animal, plant and fisheries) has declined from 823 kg/person/year in 1992 to 595 kg in 2014. This situation was exacerbated in 2015 and 2016. The greatest impacts on the volume of production are found in sugar cane, with a decline of nearly 4 million tons, while there has been a significant reduction in the number of cattle and coffee, rice, corn and potato production, coupled with stagnation in the production of fruits, vegetables, roots and tubers.

c. Policies that develop human resources (for example, education, gender, equity)

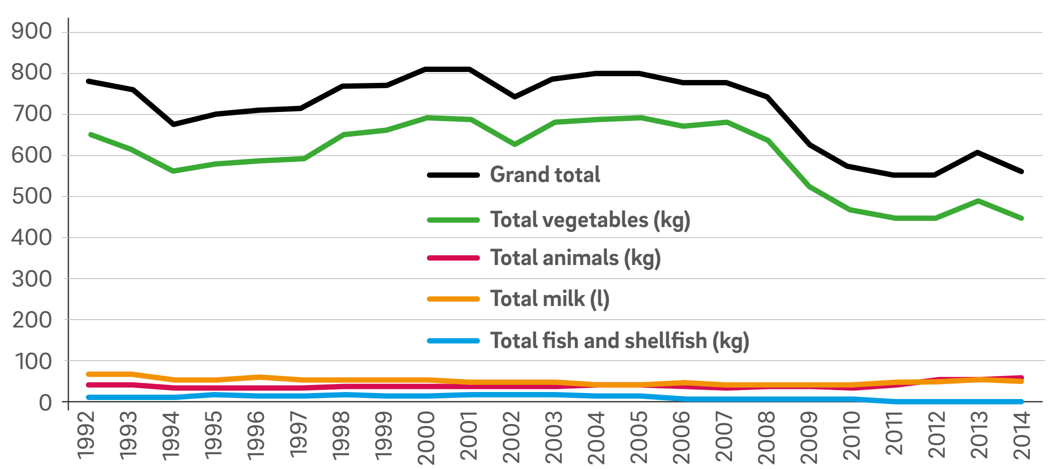
Government policies have tended to discourage technological innovation and human resource training/maintenance. The amounts of the post-graduate scholarships are insufficient, which has been compounded by the no application for or desertion of teaching posts. Official figures from the National Observatory of Science, Technology

Figure 14. Area harvested in Venezuela by family of agricultural items (1992-2014)



Note: The period 2006/2007 saw the largest area harvested. Approximately 1.8 million hectares were harvested in 1992, and the population has increased by 33% since that year (10,000,000 persons, INE, 2016). Sources: 1992-2006 MAC (Ministry of Agriculture and Livestock), MPPAT (Ministry of Productive Agriculture and Land 2007-2014. Authors' estimates (Machado Allison, 2016).

Figure 15. Primary production per inhabitant 1992-2014



Source: Estimates (1992-2007) based on the official Annual Agricultural Statistics; 2008-2014, authors' estimates using various non-official sources (Machado-Allison, 2016).

and Innovation indicate that the percentage of researchers accredited by PEII and engaged in agricultural research has declined from 23% in 2012 to 11% in 2015, equivalent to a loss of 520 agricultural researchers in four years. According to the PEII, in 2015, 61% of those accredited were women, while the number of projects decreased from 286 in 2014 to a mere 62 in 2015. Financing for agricultural research has been granted haphazardly through programs such as the Ministry of Agriculture and Lands' Zamora Plan with the participation of the ministries of Science and Technology and University Education, without no public calls for applications.

d. Policies to promote the consumption of healthy foods

The role of agriculture and agri-food systems in nutrition and creating a healthy supply of food and proper diets has been noted by international agencies, governments and academia (FAO, 2017). Distribution policies and government food marketing have not promoted healthy habits nor do they offer a balanced diet for healthy eating. They have constituted a universal food subsidy, not designed with nutritional objectives in mind but rather to achieve access to food. Social programs for food and nutrition, called the "Food Mission," have a large food supply network: Bicentenary Supermarkets, Mercal (Mercado de Alimentos S.A.), Productora y Distribuidora Venezolana de Alimentos, SA, (PDVAL), open-air fairs, mobile warehouses, among other initiatives, which, according to FAO (Resende, 2015) based on MINPPAL information, reached 22,000 points of supply throughout the national territory, serving 17.5 million people, with 61% coverage of the Venezuelan population and a 78.7% subsidy on total food prices, for which Venezuela earned recognition from FAO. These figures, however, are higher than those of the 4th National Survey on Family Budgets of the BCV itself. By 2017, the Mercal Network has decreased its presence in local markets, small stores and open markets. The School Meals Program (PAE) exists to serve schools in the public basic education system that depend on PDVAL, PDVSA's food distribution network. Problems have been reported in all states. In 2014, the National School Meals Corporation was created to strengthen the School Meals System (SAE), PAE's new name, promising to supply it with local production, a strategy included in the public policy of food production via local agriculture, including in urban spaces, whose results have not been evaluated. Prepared foods have been marketed through fixed and mobile establishments (Arepera Venezuela, Venezuela Bakeries Network, Nutritional Venezuela Restaurants). Some INN strategies have been implemented in the education, employment and community sphere (Nourishing Consciences), such as the Venezuelan School of Food (parallel to the traditional Nutrition Schools) and the Network of Defenders of Food Security and Sovereignty.

In order to combat overweight and obesity, the INN has launched the campaign, "Be informed, eat healthy and be active," as a food/nutrition education strategy, promoting health eating patterns and lifestyles. Its scope has not been evaluated. The latest attempt by the state to correct the problems of food access and consumption in 2017 was delegated to the Minister of Defense, in the operation called "Great Mission of Sovereign Supply," as part of a presidential State of Emergency and Exception Decree. CLAPs distribute and allocate bags or boxes with products at regulated prices. Since the volume of food required is not guaranteed through domestic production, imports are being used. The goal for 2017 is to reach six million families. **Box 4** presents some observations on CLAP.

e. The country's comparative advantages in agriculture

Venezuela has the potential to develop tropical productive systems. It has an area of 916,000 km², equivalent to 91.6 million ha. A study by Marín (1999), which can be extrapolated to the present, indicates a clear predominance of lands with aptitude for livestock and forestry for a total of 55 million hectares analyzed: approximately 38 million ha and about 7 million agricultural ha, respectively. It also indicates 36 million ha, close to 80% of this total, with livestock potential (27 million ha). Land for plant agriculture is only approximately 7 million ha, for which the possibilities of agriculture are varied. The most important agricultural system comprises annual mechanized crops, with advantages for rice, sesame, cotton and sunflower. The country's agroclimate offers advantages for high-level plantations such as coffee, tropical crops such as cocoa, sugarcane, African palm, coconut, cashew nut, fruit trees (pineapple, mango, papaya, melon, watermelon, orange, mandarin, plantain, banana, avocado, etc.), roots and tubers (cassava, potato, ocumo, yam, mapuey, sweet potato), horticultural crops such as tomatoes, onions, cabbage, lettuce, garlic, broccoli, eggplant and legumes such as black beans and beans. Of the land suitable for livestock raising, 28 million ha, the greatest productive potential, is for extensive (10 million ha) and semi-intensive systems (6.5 million ha) of livestock raising, including breeding, raising and fattening. Only 5% of total land availability (1 million ha) is suitable for intensive livestock raising, mainly for fattening and milk.

f. International trade matters

The country is highly dependent on imported goods, particularly agri-food items. Food self-sufficiency is limited and the agri-food trade balance is negative with regard to its main trading partners. Venezuela is known in the international trade field as an oil exporter and net food importer, which is highly dependent on international oil prices. At the beginning of 2017, it had experienced three years with a consecutive fall of 50%: from over $100 USD/barrel in 2012 to an average of nearly $35 USD/barrel. This was immediately reflected in a significant drop in international reserves: from $43.127 billion USD in 2008 to $10.977 billion USD by the end of

Box 4. Observations on the distribution of basic foods in Venezuela through the Local Supply and Production Committees (CLAP)

1. The content of bags/boxes:
   - Does not cover families' energy and nutrient requirements.
   - Is not designed with nutritional objectives, and therefore does not guarantee proper nutrition for those vulnerable to malnutrition.
   - Is not balanced, for example it lacks fresh products such as vegetables and fruits, coupled with a frequent shortage of key products like chicken, oil, maize flour and powdered milk.
2. Is not distributed in accordance with specific schedules that would allow families to plan.
3. The food distributed is repackaged in containers and bags bearing ideological logos and messages.
4. There has been a change in traditional visual elements that served as identity markers for Venezuelans.
5. There is no information on the hygienic conditions of the packages or compliance with the regulations for supplementing micronutrients.
6. Dependence on production volumes that the national system is unable to supply, as a result of which it resorts to imports, and consumers are not informed of their compliance with health regulations.
7. High possibility of corruption in imports and resales, despite the State's efforts to supervise and punish these acts.
8. Managed by an organization with a popular politicized base that favors discrimination in food allocation.
9. Undermines the constitutional principle of equality of all citizens.
10. Excludes the vast majority of the population, who are left at the mercy of the supply of these foods at inflated prices (black market with the same items from CLAP) or at prices above those controlled and imported legally at parallel market exchange rates.
11. Affects the national distribution network, since foods are removed from it to be centralized by the government.
12. Lack of support in nutritional education.
13. Lack of rigorous monitoring and evaluation of the program and its consequences on Venezuelans' diet and nutrition.

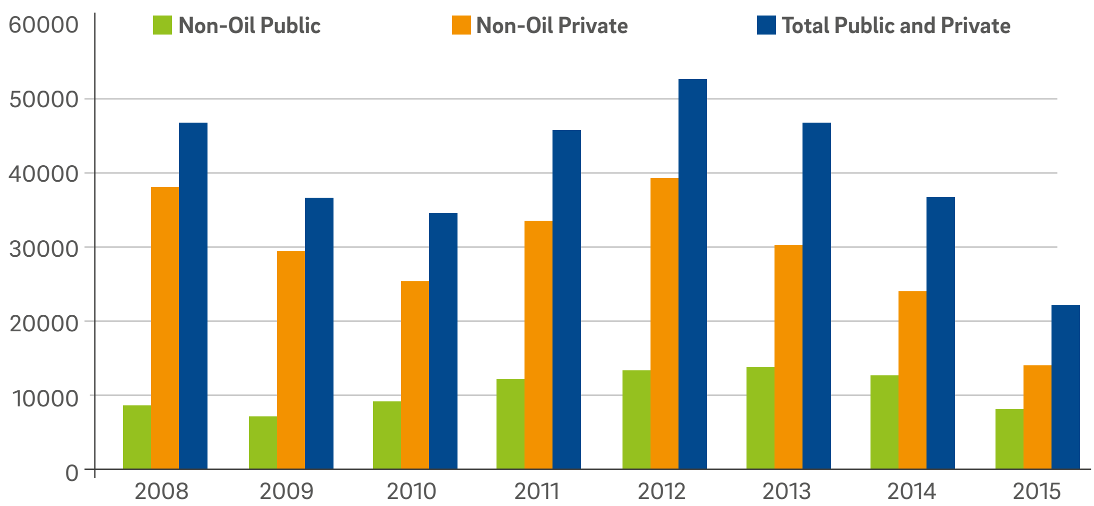
Adapted from the request for a hearing submitted to the Inter-American Commission on Human Rights, Organization of American States, Washington by Venezuelan NGOs. January 2017.

Table 16. International reserves. Venezuela

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016 *
Billions US$	43,127	35,830	30,332	29,892	29,890	21,481	22,080	16,370	10,997

Source: BCV (http://www.bcv.org.ve/c2/indicadores.asp) 2016*: Figure subject to review.

Figure 16. Decrease in imports of non-petrol goods. Venezuela. 2008-2015



Source: BCV. Central Bank of Venezuela. Non-oil imports 2016: $ 6,800 million USD. Figure subject to review.

2016 (**Table 16**), with a resulting decrease in non-oil-goods imports from $46.724 billion USD in 2008 to $6.8 billion USD in 2016 (**Figure 16**).

g. Market challenges

The main challenge is to diversify the economy because oil exports and the income they generate no longer produce economic growth and sustainable development, but rather volatile growth, linked to oil-price fluctuations. Oil has historically generated a high income, the problem being the use of these resources and macroeconomic management, since governments have failed to invest to diversify the economy, or build reserves to compensate for the oscillation of hydrocarbon prices.
The trend toward an appreciation of the real exchange rate of the oil income lowers the price of imports of agri-food goods and agricultural raw materials, and increases the price of and discourages domestic production and non-oil exports. Agri-food management that extends the supply of products with the potential to expand into international markets must be based on macroeconomic policies that correct the exchange rate distortion caused by oil revenues, with a stable real exchange rate that restores competitiveness to the production of tradable non-petroleum goods, including agri-food items. There is a need to review regulated prices throughout the chain (from producers to consumers), ensure the profitability of production, reincorporate the private sector, contain expropriations of private property, make exchange control more flexible and move toward a single, floating exchange system, to expedite the delivery of foreign currency to importers of food, inputs, spare parts and agricultural machinery and reinforce direct food programs for vulnerable groups (pregnant women, infants, children and schoolchildren) (Marrero, 2005; Gutiérrez, 2016).

VIII. Abstract

a. Some potential national agricultural scenarios for agricultural production in the next fifty years

Over the next fifty years, the Venezuelan population will continue to grow at a lower rate than the current one (1.3% annual average), with virtually the entire population living in urban areas. The great challenge for the country is to increase national production, reduce the deficit of the agricultural trade balance and extreme dependence on imports, and insert itself into international markets by exporting agri-food products with comparative and competitive advantages. It needs to achieve a radical change in general economic and agri-food policies, reduce imports and stimulate the export of particular items, without relying on regressive subsidies paid at the expense of the majority, and implement temporary, gradual, selective and concerted regulations. The state has a wide margin to dictate all types of measures to achieve strategic levels of self-sufficiency. It must correct market failures and guarantee the institutional quality that generates confidence for investors. State and markets must be complemented and coordinated to achieve these changes and guarantee the food security of Venezuelans.

b. High-priority actions to achieve agricultural sustainability

Agricultural sustainability requires environmentally friendly technologies and biodiversity, and a coordinated effort by the state and the private sector to develop research, transfer and technological-progress programs, as well as price and subsidy policies for the production of agricultural items adapted to agroecological conditions. Institutional and legal changes are required to use advances in biotechnology to reduce agrochemicals and increase yields for intensive agricultural growth without expanding the agricultural frontier. Constitutional provision 305 stipulates that the state will promote sustainable agriculture for rural development that will ensure the FNS. Policies must be designed for the rational management of natural resources in agriculture, orienting them toward productive systems, prioritizing items with comparative advantages, such as coffee and cocoa, rice, most tropical fruit trees and beef cattle (most soils are suitable for grassland). Venezuela must close its still-open cycle of agrarian reform through a program of assisted and integral delivery of full land ownership to peasants and other agricultural producers who qualify, with the follow-up of these programs through technical assistance and technological support. Macroeconomic policies should be established to stabilize the currency, and prevent the distortion of consumption and production caused by the temptation to appreciate the real exchange rate. It is essential to strengthen the Food and Nutrition Surveillance System for Venezuela (SISVAN) and to resume the regular publication of updated data on the population's nutritional status, as well as the statistics on scarcity, domestic production, inflation and poverty, update and maintain databases on the country's agricultural situation, ensure coordination among planners, the productive sector and the scientific/university sector, and reconcile sometimes conflicting interests (political justification) in order to provide a scientific basis for policies to improve the country's compromised national food security.

Current News

At the end of this chapter two important events occurred:

- The Food Security Information Network (FSIN), which includes FAO and UNICEF, issued the Global Food Crisis Report 2017: A study on food security in 48 countries, in which they note that insufficient evidence and data did not permite reliable estimates for Bolivia, Cuba, Dominican Republic, El Salvador, Eritrea, Kyrgyzstan, Pakistan, Papua New Guinea, Philippines, Republic of Congo, Sri Lanka, Timor-Leste, Vanuatu or Venezuela. Regarding Venezuela, it declared that the deterioration of the economic situation "could cause severe shortages in consumer goods", including food and medicine, and should therefore be monitored

- In May 2017, the Ministry of Popular Power for Health published the 52 epidemiological bulletins for 2016 and the 26 missing since July 2015: 30% more children died before their first year and 64% more women died during pregnancy or within 42 days after delivery in 2016 than in 2015. Although data on malnutrition and infant mortality from undernutrition are not published, one can infer that some of the deaths in children under one are due to the profound alteration of the nutritional status of mothers and therefore infants. UNICEF reacted by showing "deep concern" over these statistics, described as "clear evidence" of the health crisis the country is undergoing.

References

Abarca, O. y Bernabé, M. (2010). Proyección de la demanda de tierras agrícolas en Venezuela, A partir del análisis de las necesidades alimentarias al año 2020. *Agronomía Tropical.* 60(1), 5-22.

Banco Central de Venezuela (BCV). Indicadores. www.bcv.org.ve/c2/indicadores.asp [consulted 27/01/2017]

Cania - Centro de Atención Nutricional Infantil Antímano (2016). Consulta externa. Asistencia de los pacientes pediátricos a CANIA según diagnóstico nutricional. Caracas, Venezuela. Available in: www.cania.org.ve/estadisticas/triaje/tablas/Ninos/triaje-ninos-por-diagnostico.pdf

Cáritas de Venezuela (2017). Monitoreo de la Situación Nutricional en Niños Menores de 5 años. VENEZUELA. Distrito Capital, Vargas, Miranda y Zulia. Octubre 2016 - Abril 2017. Mayo, 2017.

CECODAP-CISOR (2016) Efectos de la crisis económica y política en niños, niñas y adolescentes en el Área Metropolitana de Caracas. Available in: https://politikaucab.net/2016/12/16/efectos-de-la-crisis-economica-y-politica-en-ninos-ninas-y-adolescentes-en-el-area-metropolitana-de-caracas/

CENDAS - FVM. Centro de Documentación y Análisis Social de la Federación Venezolana de Maestros. 2017. https://goo.gl/HvPQze [consulted 25/01/2017]

Comerma J. and R. Paredes. (1978). Principales limitaciones y potencial de las tierras en Venezuela. Agronomía Tropical 28(2):71-85.

Datanálisis (2015). Escenarios económicos, políticos y sociales de Datanálisis. Informe para clientes. Caracas, Venezuela.

De Sola, R.R. y Velasco, A. (2007). Babas. En: *Los Recursos zoogenéticos de Venezuela* (E. González-Jiménez y F. Bisbal (Eds.). Caracas, Ministerio del Poder Popular para el Ambiente. pp. 249-260.

FAO - Food and Agriculture Organization (2017). 2016 América Latina y el Caribe. Panorama de la seguridad alimentaria y nutricional. Sistemas alimentarios sostenibles para poner fin al hambre y la malnutrición. Organización de las Naciones Unidas para la Alimentación y la Agricultura y Organización Panamericana de la Salud. Santiago. Available in: https://goo.gl/pk2L1u [consulted: 20/01/2017]

FAO/OMS/UNU (2004). Human energy requirements. Technical Paper Series, N1. Rome, 2004.

FAOSTAT (2017). www.fao.org/faostat/en/#home [consulted: 20/01/2017]

FEDEAGRO (2017). http://www.fedeagro.org/produccion/ [consulted: 15/04/2017]

Fermín G., Inglessis V., Garboza C., Range S., Dagert M. y Gonsalves D. (2004) Engineered resistence against papaya ringspot virus in venezuelan transgenic papayas. *Plant Disease*, 88(5): 516-522

Frisancho, R. (1993). Human Adaptation and Accommodation. University of Michigan Press. 532 p.

Fundación Bengoa. (2002). Programa Educando en alimentación y nutrición 2007-2012. Informe Técnico. Caracas.

Fundación Bengoa – ILSI Nor-Andino (2012). *Valores de referencia de energía y nutrientes para la población venezolana*. Revisión 2012. Maritza Landaeta-Jiménez Yaritza Sifontes, Carla Aliaga (editores). Caracas, Venezuela. Disponible en: https://goo.gl/bE4J2H

Fundación Bengoa (2016). Fundación Bengoa informa. *Anales Venezolanos de Nutrición*. 29(1).

González, E. y Matos L. (2012). Manejo de los recursos hídricos en Venezuela. En: *Diagnóstico del agua en las Américas*. Jiménez C., B. y Galizia T., J. (Eds). México, IANAS-Foro Consultivo Científico y Tecnológico, AC. pp. 437-445.

González-Fernández, M.J. (2007a). Recursos de la fauna silvestre de uso tradicional. En: *Los Recursos zoogenéticos de Venezuela* (E. González-Jiménez y F. Bisbal, Eds.). Caracas, Ministerio del Poder Popular para el Ambiente. pp. 218-235

González-Fernández, M.J. (2007b). Chigüires. En: Los Recursos zoogenéticos de Venezuela (E. González-Jiménez y F. Bisbal, Eds.). Caracas, Ministerio del Poder Popular para el Ambiente. pp. 236-248.

Gutiérrez S., A. (2015). El Sistema Alimentario Venezolano (SAV): Evolución Reciente, Balance y Perspectivas. *Revista AGROALIMENTARIA*. 21(40), 1-42

Gutiérrez, S.A. (2016). Venezuela y su crisis agroalimentaria. Available in: https://goo.gl/92bOQ9

Gutiérrez, S.A. 2017. Balance Agroalimentario 2016. *Revista SIC*, Enero - Febrero 2017. Caracas, Venezuela, Centro Gumilla. On press.

Hernández C. 1998. Recursos de Venezuela. Available in: http://www.pdvsa.com/lexico/venezuela/recursos.htm

INDER.- Instituto Nacional de Desarrollo Rural (s/f). Plan nacional de agricultura de riego y saneamiento de tierras Fase I, 2015 – 2019. Caracas, Venezuela. 95 pp.

INE - Instituto Nacional de Estadística (2016). Encuesta Nacional de Consumo de Alimentos (ENCA). Informe Resultados Preliminares Abril-Septiembre, 2015. Ministerio del Poder Popular de Planificación. Instituto Nacional de Estadística. Available in: www.ine.gob.ve/documentos/Social/ConsumodeAlimentos/pdf/informe_enca.pdf

Infante, E., Navarro, A., Finizola, R., Zevallos, J., Moya, D., Alvarado, S., y Finizola, B. (2010). Estudio de la salud cardiovascular en el Estado Lara (escel 2008): metodología del proyecto y perfil de la muestra estudiada. Avances Cardiológicos. 30(4):316-325.

INIA - Instituto Nacional de Investigaciones Agrícolas, VE (2016). Aproximación agroecológica para el nuevo modelo de producción agrícola en Venezuela. Maracay, VE, Instituto Nacional de Investigaciones Agrícolas. 90 pp.

INN - Instituto Nacional de Nutrición (2012). Sobrepeso y obesidad en Venezuela. Prevalencia y Factores Condicionantes. Colección Lecciones Institucionales. Caracas. Available in: www.inn.gob.ve//pdf/libros/sobrepeso.pdf

INN - Instituto Nacional de Nutrición (2001). Valores de referencia de energía y nutrientes para la población venezolana. Revisión 2000. Ministerio de Salud y Desarrollo Social. Caracas, Serie de Cuadernos Azules N°53.

INN - HBA - Instituto Nacional de Nutrición. Hoja de Balance de Alimentos 1998-2013. Caracas, Venezuela. Available in: https://goo.gl/8ju6x6

INN - SISVAN - Instituto Nacional de Nutrición (2008). Anuario del Sistema de Vigilancia Alimentaria y Nutricional (SISVAN), Año 2007. Información Preliminar Caracas, Venezuela. Available in: https://goo.gl/W919F1

Instituto Nacional de Investigaciones Agrícolas (2016). *Aproximación agroecológica para el nuevo modelo de producción agrícola en Venezuela.* Maracay, VE, Instituto Nacional de Investigaciones Agrícolas. 90 pp.

Landaeta-Jiménez, M., Herrera Cuenca, M., Vásquez, M., y Ramírez, G. (2015). La alimentación y nutrición de los venezolanos: Encuesta Nacional de Condiciones de Vida 2014. *Anales Venezolanos de Nutrición*. 28 (2), 100-109.

Landaeta-Jiménez, M., Herrera Cuenca, M., Vásquez, M., y Ramírez, G. (2016). La alimentación de los venezolanos, según la Encuesta Nacional de Condiciones de Vida 2015. *Anales Venezolanos de Nutrición*. 29(1), 18-30.

Landaeta-Jiménez, M., Herrera Cuenca, M., Vásquez, M., y Ramírez, G. (2017). La alimentación de los venezolanos, según la Encuesta Nacional de Condiciones de Vida 2016. *Anales Venezolanos de Nutrición*. En prensa

Machado-Allison, C. (2009). *La alternativa agrícola. Una agricultura como la que no hemos conocido transformará al país*. Caracas, Editorial Libros Marcados.

Machado-Allison, C.E. (2016). Base de datos estadísticos agropecuarios (1992-2016).

Marín, R. (1999). *Disponibilidad de tierras agrícolas de Venezuela*. Caracas, Ediciones Fundación Polar. 53 pp.

MARN- Ministerio del Ambiente y de los Recursos Naturales (2005). Primera Comunicación Nacional en Cambio Climático de Venezuela. MARN, GEF, PNUD. Caracas. 141 pp.

MARN - Ministerio del Ambiente y de los Recursos Naturales (s/f.) Breve descripción de los recursos forestales en Venezuela. En: depósito de documentos de la FAO. Available in: www.fao.org/docrep/007/ad102s/AD102S15.htm

Marrero, J.F. (2005). Orientaciones y herramientas de política pública para la seguridad alimentaria en Venezuela. At: Políticas de seguridad alimentaria en los países de la comunidad andina. Salcedo, S. (ed.). FAO. Oficina regional para América Latina y el Caribe. Santiago, Chile. Cap. 7. pp. 154-170

MINEA- Ministerio del Poder Popular para el Ecosocialismo y Aguas (s/f). Estadísticas Forestales. Compendio período 2009 / 2010 / 2011 / 2012 / 2013. Serie 13. Caracas.

MPPA- Ministerio del Poder Popular para el Ambiente (2013). Estrategia Nacional para la Conservación de la Diversidad Biológica 2010-2020. 4ta impresión. Caracas.128 pp.

MPPS - Ministerio del Poder Popular para la Salud. República Bolivariana de Venezuela. (2013) Anuarios de morbilidad 2013. Available in: www.mpps.gob.ve/index.php?option=com_content&view=article&id=941 Acceso 31 de enero de 2017.

MINPPAL-INN. Ministerio del Poder Popular para la Alimentación- Instituto Nacional de Nutrición. (2014) Perfil Alimentario y Nutricional 2013-2014. Available in: https://goo.gl/Ng94c1

MPPAT, Ministerio del Poder Popular para la Agricultura y Tierras. República Bolivariana de Venezuela. (2015). Memoria 2015. Caracas.1327 p. Available in: https://goo.gl/YpR8M1

MPPAT-INIA (2008) Segundo Informe Nacional sobre el Estado de los Recursos Fitogenéticos para la Agricultura y la Alimentación. Available in: https://goo.gl/8KIeBT

Obuchi, R., Abadí, A. y Lira, B. (2011). *Gestión en rojo. Evaluación de desempeño de 16 empresas estatales y resultados generales del modelo productivo socialista.* Caracas, Ediciones IESA. Serie Políticas Públicas.

OIE (2017). Mapa del estatus oficial de fiebre aftosa de los Países Miembros de la OIE. https://goo.gl/ozd2mf

Ojasti, J. (2011). *Estudio biológico del chigüire o "capibara".* (Segunda Edición). Caracas, Venezuela, Academia de Ciencias Físicas, Matemáticas y Naturales / Editorial Equinoccio. Colección conjunta ACFIMAN / Equinoccio USB.

Oletta-López, J.F., Orihuela, A.R., Walter, C., Carvajal, A., Godoy, O., Castro, J., Peña, S., y Barreto, A. (2016) Enfermedades transmitidas por alimentos en Venezuela y el riesgo de desaplicar las Normas y Regulaciones nacionales para la fabricación, manipulación, almacenamiento y transporte de alimentos para el consumo humano. En: Red Defendamos la Epidemiología Nacional [lista de discusión en internet] Caracas, Venezuela. Sociedad Venezolana de Salud Pública. 31 de julio de 2016. [acceso 30 de enero de 2017] [4 pantallas]

OMS-Organización Mundial de la Salud (1994). *El estado físico: uso e interpretación de la antropometría. Informe de un Comité de Expertos de la OMS.* Serie de informes técnicos 854. Ginebra. 513 pp.

Ovalles, F., Cortez, A., Rodríguez, M., Rey, J., y Cabrera-Bisbal, E. (2008). Variación geográfica en el impacto del cambio climático en el sector agrícola en Venezuela. *Agronomía Tropical,* 58(1), 37-40.

Peña-Cedillo, J., y Flores-Urbáez, M. (2006). Evaluación de las agendas de investigación e innovación en Venezuela. *Revista Venezolana de Gerencia,* 11(33), 29-46.

Pereira L (2016). *Propuesta metodológica para la estimación del rendimiento y la identificación de anomalías con sensores remotos en el desarrollo del cultivo de arroz, parroquia payara, estado portuguesa, período 2014-2015.* Trabajo Especial de Grado. Escuela de Geografía, Universidad Central de Venezuela.

PROVEA - Programa Venezolano de Educación-Acción en Derechos Humanos. (2014). Informe anual Enero/Diciembre 2013 sobre la Situación de los Derechos Humanos en Venezuela. Caracas

PROVEA - Programa Venezolano de Educación-Acción en Derechos Humanos (2016). Situación de los Derechos Humanos en Venezuela Informe anual Enero/Diciembre 2015. Caracas.

Ramírez, G.; Herrera-Cuenca, M.; Vásquez M.; Landaeta-Jiménez, M.; Hernández, P.; Meza, C.R; Kovalskys, I.; Gómez, G. and Fisberg, M. on behalf of the ELANS Study group (2017). The Impairment of Food Patterns in Venezuela: Preliminary Results from the Latin American Study of Nutrition and Health (ELANS) –Venezuelan Chapter. Abstract submitted to the Food Nutrition Conference and Expo (FNCE) 2017. (On press).

Resende, M. (2015). Reconocimiento de la FAO a Venezuela 2015. https://goo.gl/pNddQQ [consulted: 25/01/2017]

Rey, J.C. (2015). Limitaciones y potencialidades de los suelos de Venezuela. *INIA-Divulga* 31. pp. 61-66.

Schargrodsky, H., Hernández-Hernández, R., Champagne, B.M., Silva, H., Vinueza, R., Silva-Aycaguer, L.C., et al. (2008). CARMELA: Assessment of cardiovascular risk in seven Latin American cities. American Journal of Medicine. 121:58-65.

Schejtman, A. (1994). *Economía política de los sistemas alimentarios en América Latina.* Santiago, FAO/RLAC. 252 pp.

SISVAN - INN - Instituto Nacional de Nutrición (2007). Información Preliminar. Anuario del Sistema de Vigilancia Alimentaria y Nutricional (Sisvan) Año 2007. Caracas, Venezuela. Available in: http://www.inn.gob.ve/pdf/sisvan/anuario2007.pdf

Soto de Sanabria I. (2016). Desnutrición Grave: Un llamado de atención. *Archivos Venezolanos de Puericultura y Pediatría.* 79 (3), 85

Transparencia Venezuela (s/f). De PEDEVAL a Pudreval. Available in: https://goo.gl/R4gWZx [consulted 25/01/2017]

UNICEF (2013). Mejorar la nutrición infantil: el imperativo para el progreso mundial que es posible lograr. © Fondo de las Naciones Unidas para la Infancia (UNICEF), Abril de 2013.

UNICEF (2015). https://goo.gl/2SDDkV [consulted 25 / 01 / 2017] UNICEF. Indicadores Básicos. Venezuela: https://goo.gl/0dZugM

Acknowledgments

Juan Luis Hernández (INNOVAVEN: www.innovaven.org/); Hernando Hernández, Acción Campesina; Alfredo Layrisse, Aníbal Rosales, Anselmo Pérez Tabares, Edgardo Monteverde, FEDEAGRO; Fernando Ajmad, Jesús Alezones, Luis Ferráz, Luis López Méndez, Manuel Delgado C., Núcleo de Decanos Universitarios del Agro y del Mar; Pedro Raúl Solórzano and Tirso Pacheco.

This book was printed in November 2017
with a print run of 1,000 at Surtidora
Gráfica, SA de CV workshops

The Inter-American Network of Academies of Sciences (IANAS), is a regional network of Academies of Sciences created to support cooperation to strengthen science and technology as tools for advancing research and development, prosperity and equity in the Americas. IANAS is regional member of the Inter Academy Partnership (IAP)

North America
The Royal Society of Canada: The Academies of Arts, Humanities and Sciences of Canada
The National Academies of Sciences, Engineering, and Medicine
Mexican Academy of Sciences

Central America and the Caribbean
Cuban Academy of Science
Academy of Sciences of the Dominican Republic
Academy of Medical, Physical and Natural Sciences of Guatemala
National Academy of Sciences of Costa Rica
Nicaraguan Academy of Sciences
Panamanian Association for the Advancement of Science
National Academy of Sciences of Honduras

South America
Academy of Physical, Mathematical and Natural Sciences of Venezuela
Colombian Academy of Exact, Physical and Natural Sciences
Brazilian Academy of Sciences
National Academy of Sciences of Peru
National Academy of Sciences of Bolivia
Chilean Academy of Science
National Academy of Exact, Physical and Natural Sciences of Argentina
National Academy of Sciences, Argentina
The National Academy of Sciences of Uruguay
Academy of Sciences of Ecuador

Regional Members
Latin American Academy of Science
Caribbean Academy of Sciences
Caribbean Scientific Union

The Inter-American Network of Academies of Sciences
Academia Mexicana de Ciencias
Calle Cipreses s/n
Km 23.5 Carretera federal
México-Cuernavaca
14400, Tlalpan, Ciudad de Mexico
Phone: (+52-55) 5573-6501
Fax: (+52 55) 5849-5112

Free public access of this book in English and Spanish at www.ianas.org

ISBN: 978-607-8379-29-3

SPONSORED BY THE

Federal Ministry of Education and Research

ISBN: 978-607-8379-29-3