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

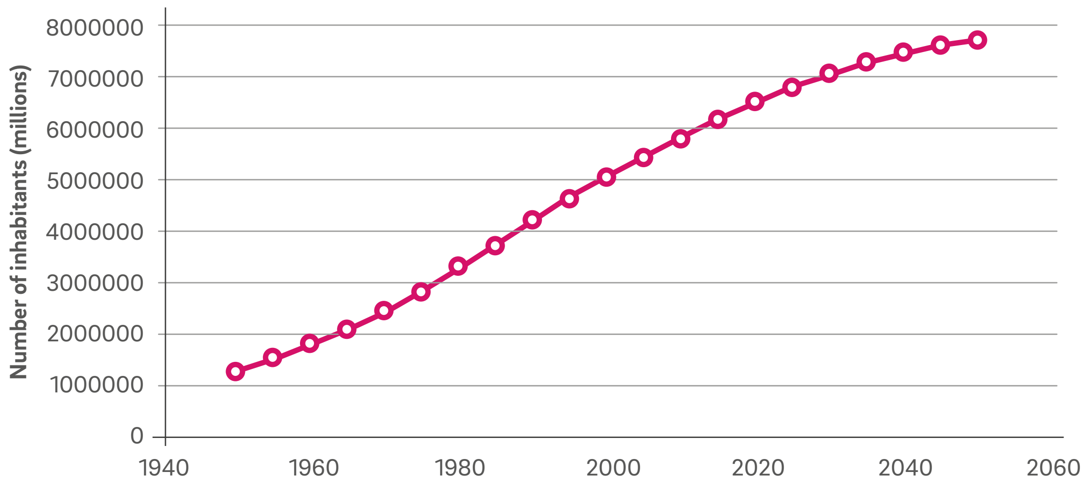
Nicaragua is the largest country in Central America with an area of 129,494 km^2. It can be divided into three major regions: the Pacific; the central or mountainous zone and the Caribbean. The Pacific region is characterized by flat agricultural lands stretching from the coast of that ocean approximately 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 km^2) and the Cocibolca or Nicaragua Lake (9,000 km^2). 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.

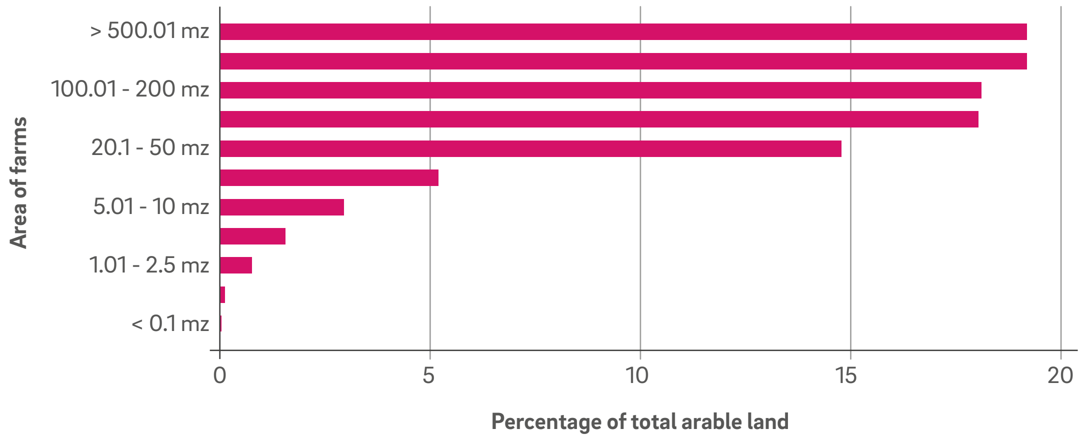
Key agricultural activities

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

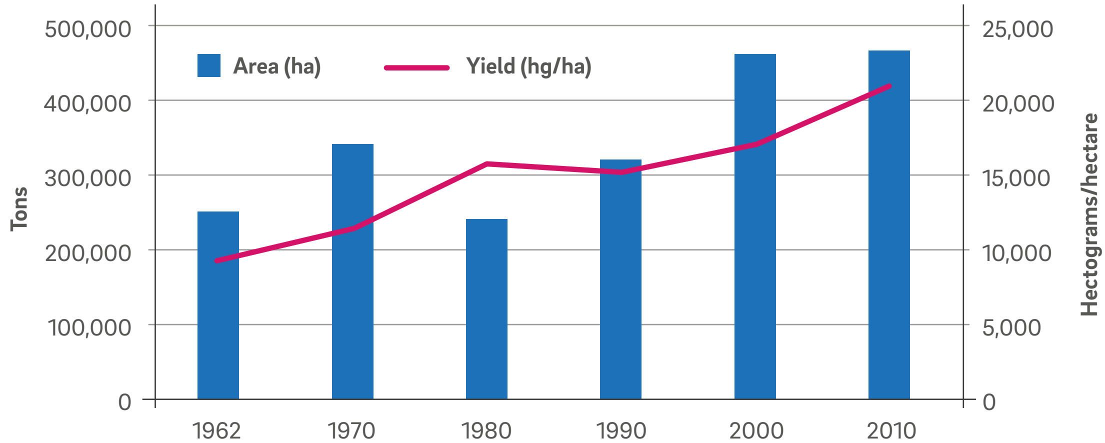


Source: Compiled by the authors with data from CENAGRO (2011).

northern Nicaragua, although yield was higher than in the 1970s.

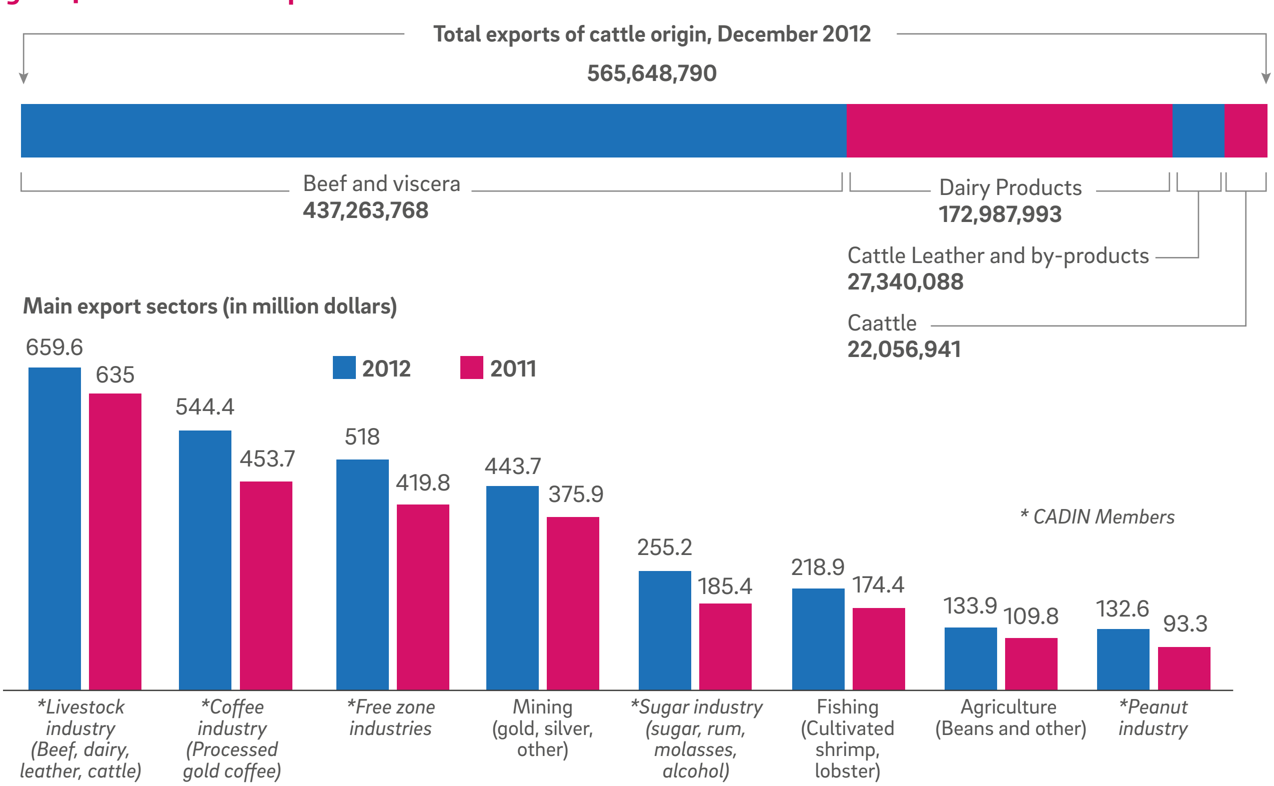
The livestock sector has accounted for a large share of the economy in recent years, proving to be the sector with the highest growth in exports for the 2011-2012 period, above the coffee sector, free zones and mining (CADIN, 2013). Of the total exports for 2012, the highest growth was in the meats and 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**).

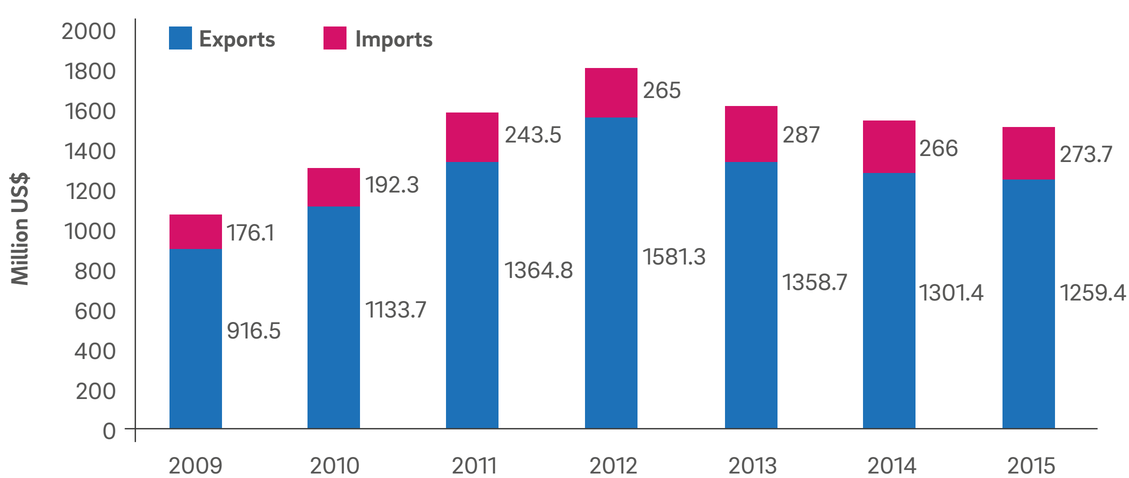
Challenges of family farming

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

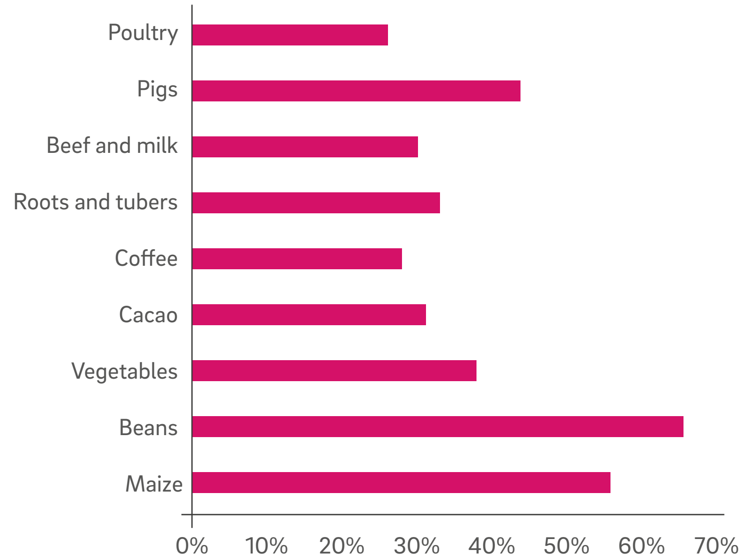
Water status

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 km^2, 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 km^2 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.