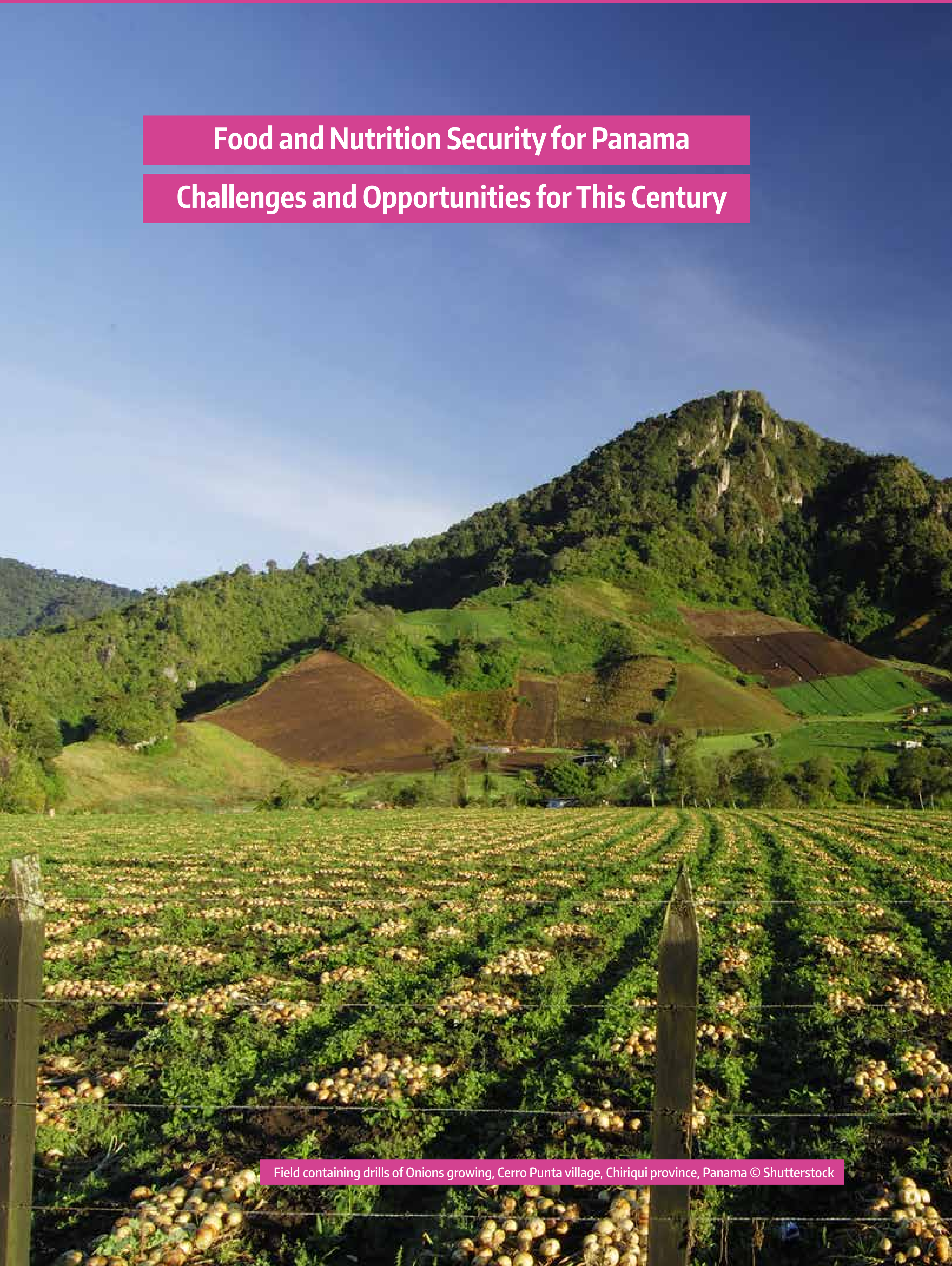
Food and Nutrition Security for Panama

Challenges and Opportunities for This Century



Field containing drills of Onions growing, Cerro Punta village, Chiriqui province, Panama © Shutterstock

Panama

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In Panama, the technological upturn is related to the development of value chains, one of the strategies required to optimize the use of national and international markets

Summary

Undertaking agricultural research, which leads to technological innovations resulting in food production, is an essential element in ensuring food and nutrition security for Panama. However, the country's social, economic and political scenarios must be analyzed within the context of the public policies for defining business strategies in order to facilitate access to national and international markets. Emerging scenarios should also be defined so that through knowledge generation, they will be able to strengthen the scientific and technological platform required to promote the necessary transformations. Therefore, investment in specialized human resource training, a variable that goes hand in hand with undertaking agricultural research, is a binomial that should be proposed in keeping with the challenges affecting food and nutrition security.

1. National characteristics

a. Physical characteristics and productive agricultural areas

Panama is located in the intertropical zone near Ecuador in the Northwest Hemisphere, between 7°12'08" (on Jicarita Island south of Coiba, in the province of Veraguas) and 9°38'46" north (in Tambor Island, off the coast of the province of Colón), 77°09'24" (at the 10-Alto Limón landmark, on the border between Panama and Colombia) and 83°03'07" west (at Auxiliary Milestone 60 on the border between Panama and Costa Rica). Panama is bordered on the North by the Caribbean Sea, on the South by the Pacific Ocean, on the East by Colombia and on the West by Costa Rica. The country has an area of 75,845.072 km2, equivalent to approximately 0.18% of the territory occupied by America. Located in the center of the American continent, it forms a link between North and South America. It consists of an isthmus with a width of 80 km at its narrowest point, which in turn links the Caribbean to the Pacific Ocean (ANAM, 2010). Agricultural land covers 30.4% of the country's total area (World Bank, 2016).

b. Demographic characteristics and future trends

In 2014, Panama's population was estimated at 3,913,275, comprising 1,965,087 males and 1,948,188 females (INEC, 2014), with an annual growth rate of 1.44%. A total of 66.6% of the population is concentrated in urban areas and only 33.4% in rural areas. A total of 5.9% of the economically active population is engaged in the primary sector, 19.9% in the secondary sector and 64.2% in the tertiary sector (UNDP, 2015). Although 9.5% of the population is undernourished, the country has achieved the target set in the Millennium Development Goals and is close to meeting the target established at the World Food Summit (FAO, 2015).

c. Population affected by lack of food and nutrition insecurity

Approximately 1,090,000 people live in poverty, and 481,000 in extreme poverty, accounting for 32.7% and 14.4% of the total population, respectively. A total of 19.1% of children under 5 showed delayed growth for their age (chronic malnutrition), 3.9% are underweight for their age (overall malnutrition) while approximately 1.2% are underweight for their height (acute malnutrition) (ENV 2008).

d. Agricultural production systems

Panama boasts a variety of agricultural, livestock, fishery and aquaculture production systems, the most important being rainfed and irrigated rice, bovine milk and meat, swine and avian production and wild-caught fish. Special attention should be paid to rural communities engaged in family farming, since they constitute a weak link in the production chain, given the challenges of climate change (Camargo et al., 2016).

e. Main agricultural and livestock imports and exports

Agriculture, fishing and forestry contributed 0.2% to the 2015 GDP, with decreases of approximately 0.6% being recorded in 2013 and of 0.6% in 2014 (INEC, 2015). Agricultural Gross Added Value (AGAV) reported a slight increase of 0.4% over the previous year, mainly in rice cultivation, which rose by 3.5%, and banana and melon production, which grew on the order of 4.7% and 17.9%, respectively.

The Gross Added Value of livestock production increased by 3.0%, due to a 6.2% increase in the slaughter of poultry and a 4.8% increase in that of swine (INEC, 2015). Cattle slaughter and the number of liters of milk obtained naturally fell by 2.8% and 1.8%, respectively. Since domestic production of grains such as rice, corn and beans fails to cover domestic demand, the shortfall is imported. Most grain corn imports are allocated to animal feed. However, local production meets human consumption needs (Capital Financiero, 2014).

Squash accounts for 41% of the production of farmers who planted 112 ha and harvested 1413.57 t during the 20132014 period (MIDA, 2015).

The rainfed production system includes several export crops such as bananas, pineapple, coffee and by-products from palm oil and sugar cane. Pineapple generated a return of 31% (MIDA, 2015), with 80% of production being assigned to the international market and the rest to domestic consumption.

According to data from the Comptroller General of the Republic, in 2013, banana exports totaled approximately B/. 90.6 million and in 2014, an increase of approximately B/. 92.8 million was recorded. This is due largely to the technification of farming methods, which yielded 1,800 boxes/ha.

Sugar production constitutes one of the main lines in agroindustrial activity for both sugar mills and the country as a whole. This commercial activity is regarded as a pillar of Panamanian industry. For many years, Panama has exported sugar, molasses and its derivatives to the US market. In 2013, 51.152 net t of sugarcane were exported with an FOB value of B/. 23,973,576.00.

Although increased private investment in the country has had positive consequences for the national economy, the management of the production areas of these agricultural commodities has negatively affected agricultural ecosystems.

f. Contributing factors to the instability of food security

Globally, the change in land use is one of the greatest threats to biodiversity, as it involves the loss of plant cover and the disruption of ecosystems. The expansion of the agricultural

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frontier is another variable to consider in the change of land use. Thus, 25% of the country (1.8 million ha) is suitable for agricultural and livestock activities. However, the actual use of land in these productive activities was estimated at between 2.8 and 2.9 million ha.

According to the INEC (2011), changes in land use indicate a decrease of approximately 70,000 ha of farmland between 2000 and 2011. The country's economic development has reduced the areas used for planting crops, which have been displaced by housing construction and urbanization.

River and sea pollution is caused by domestic and industrial waste, including agrochemicals from agricultural activity which reach the sea through runoff. In the soil, water sources and in areas adjacent to protected areas, one of the main causes of the pollution of these ecosystems is the use of agrochemicals which, as a result of leaching, are discharged into waste water of domestic, industrial and commercial origin. Villarreal et al. (2013) determined the soil quality index in areas under banana cultivation in Panama as a means of managing agricultural and environmental activity in cultivated soil in the Panama Pacific.

Mining activity also contributed to the pollution of soil, surface and groundwater, increasing erosion and therefore the sedimentation of rivers.

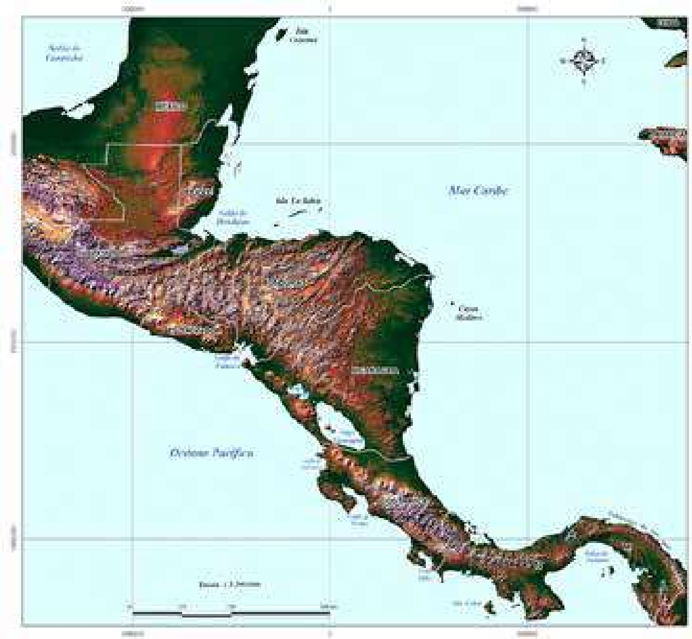
The main sources of instability affecting food security in Panama are related to climate variability and the lack of land-use regulations owing to the absence of adequate economic policies for sustainable food production. Thus, as a result of climate change, temperatures will increase, irreversibly affecting the demand for water in crop production.

g. Major challenges in food production

Climate change may increase dependence on food imports and exacerbate food insecurity in the most vulnerable groups and countries (FAO, 2002).

Integrating the government and private sectors into the search for mechanisms to provide solutions to these problems is a priority action, since Panama faces major challenges with regard to climate change (Mora et al., 2010).

Map 1. Geographical Position of Panama



Source: Atlas Ambiental de la República de Panamá, 2010.

2. Institutional Framework

a. National Agricultural Research System

i. Research capabilities that need further development

Designing a State Science, Technology and Innovation (CTI) Policy is an essential step toward CTI capacity building in Panama, which will allow this process to continue. Accordingly, the challenges currently faced by the country will be harnessed to improve the effectiveness of the policy and the instruments for its implementation, and increase its contribution to the development of science, research, technology and innovation.

Strengthening and empowering the National Secretariat of Science, Technology and Innovation (SENACYT) to determine the Science-Technology-Innovation policy (STI) supports the existing regulatory framework and increases investment in STI (PENCYT, 2015).

Panama's universities generally have limited research capacity since their professors are solely dedicated to teaching in higher education.

Moreover, collaborative research is scarce and lacking in multi- and transdisciplinary approaches.

A small number of researchers together with limited financial resources are a common denominator of these study centers. The creation of postgraduate, master and doctoral programs follows a logic of Market Trends in Continuing Education, which excludes creativity in the Research, Development and Innovation (R & D) process, contributing very little to STI capacities.

There are only a small number of professionals at the doctoral level in scientific areas, trained in various specialties (PENCYT, 2015).

ii. Local areas of strength

The SENACYT scholarship program, whose results are reflected in the programs offered by international, bilateral and multilateral cooperation, has enabled a total of 220 researchers to obtain doctoral degrees, 70% of whom have joined the country's labor force. Despite this, the number of human resources for the operability of National System of Science, Technology and Innovation (SNCTI) is still small. The country has a total of just 142 researchers per million inhabitants, a significantly lower figure than in Costa Rica, Brazil, Uruguay and Colombia. The evolution over time of the number of full-time researchers is proportional to the number of scientific papers listed in the *Web of Science*. It has been determined that the critical mass of researchers required to transform a country's economy is based on the knowledge generated by approximately one thousand full-time scientists per one million inhabitants.

A fundamental aspect that prevents the renewal of specialized human capital, based on the need to recruit young scientists who have completed their graduate studies, lies in the difficulty of creating job positions at universities and government and/or private organizations.

iii. Scientific collaboration networks inside and outside the country

International conventions linked to Plant Genetic Resources and Biodiversity have provided benefits in the regeneration of threatened *ex situ* samples, increased genetic enhancement, the expansion of the genetic base and support for seed production and distribution.

The most significant international conventions ratified by Panama are based on the conservation and use of natural resources and biodiversity, such as the United Nations Convention on Biological Diversity, the Cartagena Protocol on Biosafety, the Nagoya Protocol and the International Treaty on Genetic Resources for Food and Agriculture (ITPGRFA).

National Genetic Resources Operating Plans have also been developed, whereby each country promotes interaction through national commissions. Specifically, the AGROSALUD consortium includes various state institutions working on the development, evaluation and dissemination of biofortified crops in Latin America and the Caribbean, through the coordination of the International Center for Tropical Agriculture (CIAT). The purpose of this collaborative network is to improve the nutritional content of key crops for the nutrition of the Panamanian population. Accordingly, research has focused on crops such as rice, beans, yams, corn and potatoes in rural areas with severe malnutrition problems.

The Institute of Agricultural Research of Panama (IDIAP) is the leading research and innovation institution for the development of biofortified crops. Part of the initial funding for this project was provided by SENACYT, in conjunction with the Ministry of Agricultural Development (MIDA), the National Nutrition Service Trust, the Ministry of Health (MOH) and various farmers' organizations.

With respect to the collaboration of international centers, the International Potato Center (CIP) provides germplasm for potato and yam varieties for their evaluation in Panama.

The mechanism of access to rice germplasm through the International Center for Tropical Agriculture (CIAT), through the Latin American Fund for Irrigated Rice (FLAR), has permitted access to seeds in this area as a result of collaborative research. Thus, through competitive funds obtained from FONTAGRO projects, advanced lines of rice biofortified with iron and zinc have been created in addition to hybrids and interspecies crossing to expand the genetic basis with genes from wild species.

Collaboration between IDIAP and CIAT resulted in the project designed to create bean cultivars (*Phaseolus vulgaris*) biofortified with iron and zinc, adapted to Panama's production areas.

The Maize Germplasm Evaluation Program, run by the International Maize and Wheat Improvement Center (CIMMYT), provides IDIAP with varieties in order to evaluate their adaptability and stability in various agricultural ecosystems and production systems, making it possible to generate and release varieties and normal hybrids with high-quality protein.

iv. Data maintenance and access to databases on agricultural systems

Information on IDIAP's collections is not systematized in a unified database. Most of the data on the characterization, evaluation and regeneration of materials is found in scattered electronic Excel files.

Since 2010, the Project for Research and Innovation on the Collection, Characterization, Evaluation and Conservation of Plant Germplasm has promoted the entry of data on all of IDIAP's collections into the BDGermo database. However, the small number of crops that have been characterized by biochemical (isoenzymes) and molecular markers has been limited to Creole rice and improved varieties.

b. Universities and Research Institutes

IDIAP, established through Law 51 on August 28, 1975, is the government institution responsible for research to generate, adapt, validate and disseminate knowledge and agricultural technologies, framed within the policies, strategies and guidelines of the agricultural sector. IDIAP therefore focuses its actions and responds to the problems facing Panamanian agribusiness through mechanisms to involve customers, users and partners in the processes of identifying environmental, social, economic and technological demands, problems and challenges.

According to Stads and Beintema (2009), agricultural research is distributed as follows: 44% concerns agricultural production, 42% livestock production, 7% preservation and conservation of the environment and natural resources, and 1% aquaculture and fisheries. The rest of the productive sectors, equivalent to the remaining 6%, are grouped into activities involving agribusiness, management and agricultural marketing.

i. Scientific development and infrastructure

IDIAP, the institution responsible for agricultural research in Panama, has 18 sub-centers and nine research centers, distributed throughout the country. It also has ten laboratories with specialized equipment for research on applied molecular biology, soils, artificial insemination, plant protection and biological pest control, among other key areas. However, the need for technological innovation has meant that sufficient financial resources have been secured to meet the new challenges of the Panamanian agricultural sector. The implementation of a periodically updated Institutional Strategic Plan has made it possible to achieve the goals set in an orderly, systematic manner. Thus the goal was set to develop and boost the competitiveness of the agricultural sector in a globalized economy, and ensure an adequate affordable supply of healthy food for all Panamanians. Moreover, environmentally friendly agricultural knowledge and technology have been produced in order to preserve natural resources.

ii. Inter- and transdisciplinary research capacities and assimilation of technological innovations

Panama has a research and transfer system in which a number of agents interact such as IDIAP, which produces most of the country's agricultural research. The Faculty of Agricultural Sciences, the Promega Institute and the Faculty of Veterinary Medicine which belong to the University of Panama- and the Center for Agroindustrial Production of the Technological University of Panama also contribute to the development of research in this field of science. Other government institutions -such as the Aquatic Resources Authority of Panama (ARAP), MIDA and MIAMBIENTE- have also contributed to the country's agricultural research.

However, the transfer and adoption of technology has yet to reflect the impact of the technology generated by the research projects undertaken.

c. Development of a skilled workforce and the state of national education systems

In 2015, a total of 324 professionals were estimated to be engaged in agricultural research, 48% of whom were affiliated with government research institutions, as opposed to the 36% cited in the data presented by higher education centers, and 16% of whom were employed by private companies and non-governmental organizations.

The fact that academics are solely engaged in teaching at higher education centers is a variable that limits the development of agricultural research in Panama. Updated reports indicate that 10% of researchers hold doctorates, 47% master degrees and 43% bachelor degrees, and that the average age of Panamanian researchers is 55.

SENACYT has developed and implemented various scholarship programs for academic excellence, primarily designed for master and doctoral programs at universities abroad, and former grant holders are employed by government institutions and state higher education institutions.

d. Contributions by the public and private sector

Most of the funding for agricultural research has been from the government sector, although the latter's public expenditure on agricultural research has not exceeded 0.5% of the national budget.

Investment in agricultural research in Panama has shown a negative growth rate that has gradually increased over time.

e. Future outlook

In 2017, the IDIAP budget is B/. 19.5 million, accounting for 0.16% of the national budget, 65% of which corresponds to salaries and running costs. However, construction has begun on several facilities to strengthen agricultural research. Conversely, the Faculty of Agricultural Sciences at the University of Panama has seen a significant decline in government funding since 2010. This could reduce the sustainability of national agricultural research, given the importance of training specialized human resources and the development of research programs.

3. Characteristics of Resources and Ecosystems

a. Water Resources

Panama is regarded as one of the countries with the most abundant water resources, with more than 50,000 m^3 of water per capita, enabling it to operate an interoceanic canal for over 100 years. Although it receives copious rainfall during the rainy season, during the dry season, it experiences water deficits, which have increased due to Climate Change and/or Variability. Accordingly, the National Water Security Plan was implemented, which was approved by Cabinet Resolution no. 114 of 08.23.2016. The map of Panama's isohyets (Figure 1) defines the areas with a significant water deficit in Panama's Dry Arc, shown in bright red.

According to the World Development Indicators (World Bank, 2014), Panama has 35.32 cubic meters of freshwater per capita, more than twice the continental average. The dry season has historically been critical and, since the El Niño Southern Oscillation (ENSO) phenomenon in 1997, there have been recurrent water crises beginning in the Dry Arc and spreading to other regions. Increased human intervention alters the hydrological cycle, reduces infiltration and increases runoff.

Groundwater is not properly evaluated, due to the lack of a piezometric monitoring network, making it impossible to accurately gauge the amount of existing aquifers, their recharge areas and yield potential. During the last ENSO event in 2015, the water crisis affected the availability of water in 75% of the total area in the country, for various everyday activities involving human consumption and food production. Sustainable water management to cope with the growing water crisis is a challenge the country must systematically and efficiently address.

National agricultural production will be significantly affected, as a result of the growing water crisis due to climate change.

Future scenarios confirm the need for the implementation of an effective Integrated Water Resource Management Policy (WRMP).

b. Soil characteristics and challenges

Panama's soils are mostly acidic leached soils, corresponding to ultisols/oxisols and alfisols (FAO, 2013). There are more fertile soils associated with more fertile parent materials and intermediate precipitation regimes. Regarding the soils' capacity for agrological use, only 19.5% of the land is suitable for farming, whereas approximately 80% is suitable for the development of forest species and/or conservation. Agrological limitations have led to severe conflicts over land use, causing significant erosion and leading to soil degradation.

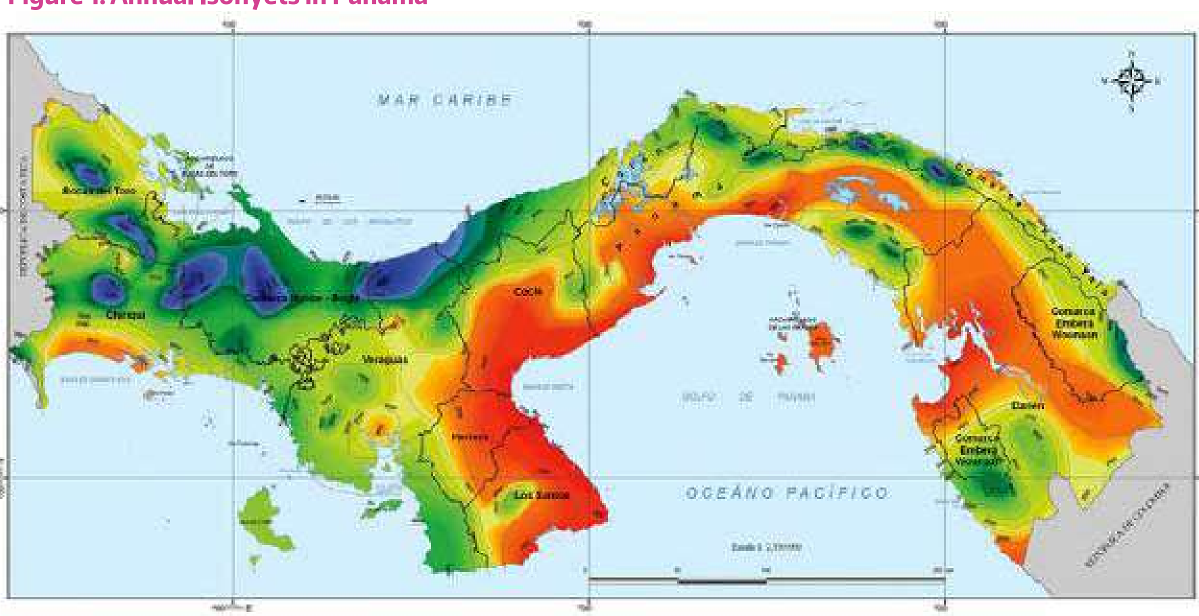
The use of forest soils with slopes unsuitable for mechanized agriculture produces considerable soil loss due to erosion. This is compounded by the reduction of fertility and water pollution due to sediment loads as a result of poor land use.

The challenge for the future is to produce more food within the limitations of soil assigned for agricultural use and existing production systems. Sustainable land management, through the use of management practices and soil conservation in keeping with their capacity for use, is the only option for ensuring food production in sufficient quantity and quality, in the medium and long term, which guarantees the environmental and and productive sustainability of soils.

c. Energy resources

In 2014, Panama's energy sector had a total installed capacity of 2,828.57MW (National Secretariat of Energy, 2016), 57.4% of which (1623.41 MW) corresponds to hydroelectric power stations using approximately 16,000 Mm3 of water annually and 40.6% (1147.8 MW) to

Figure 1. Annual Isohyets in Panama



Isohyets

Average annual rainfall values in millimeters

- 1,275-1,500
- 1,501-1,800
- 1,801-2,100
- 2,101-2,400
- 2,401-2,700
- 2,701-3,000
- 3,001-3,300
- 3,301-3,600
- 3,601-3,900
- 3,901-4,200
- 4,201-4,500
- 4,501-4,800
- 4,801-5,100
- 5,101-5,400
- 5,401-5,700
- 5,701-6,000
- 6,001-6,300
- 6,301-6,600
- 6,601-6,900
- 6,901-7,000

Source: Hidrometeorología, ETESA (2007).

thermal plants using different technologies, while the remaining 2% corresponds to wind energy, which began to be used in 2013. Solar energy began to be utilized in early 2014.

The period 1970-2013 saw an eleven-fold increase in electricity consumption in the country, while the use of petroleum derivatives increased by a factor of four and a half.

Increased energy consumption has led to greater reliance on oil imports, causing negative effects for the economy and the local and global environment. The main source of energy is hydropower and in recent years, wind energy. The main challenge for the energy sector is the diversification of the energy matrix. Thus, the National Energy Plan achieves electricity savings of 39.8% through rational, efficient energy use as well as design and construction improvements.

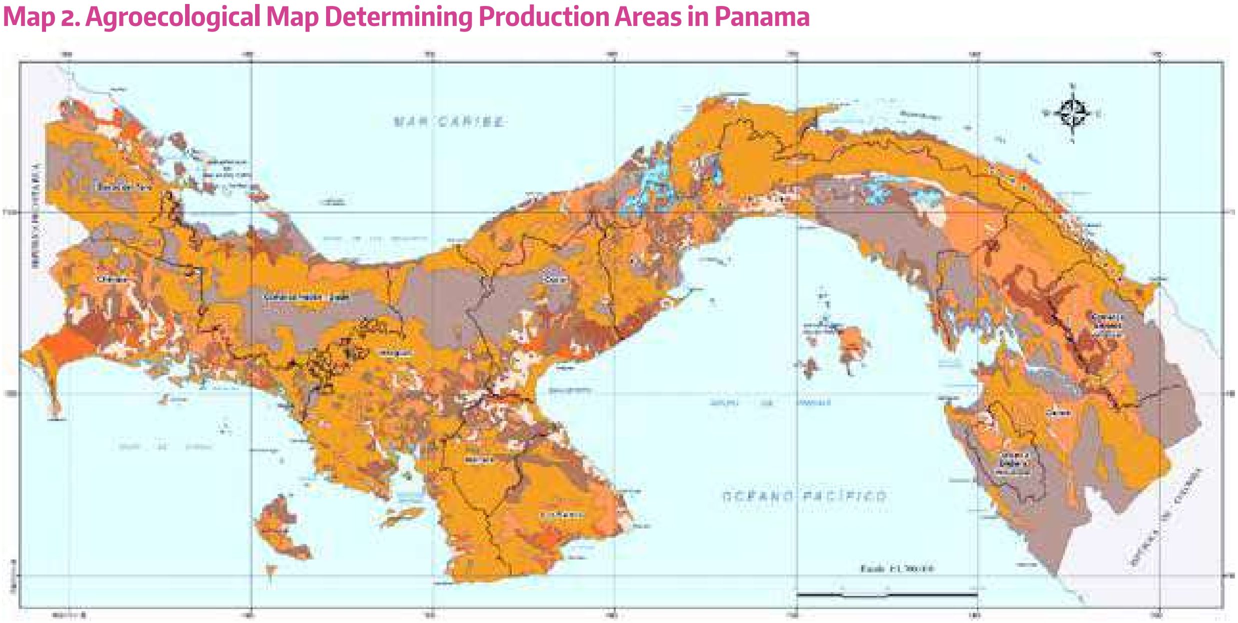
Diversification of the energy matrix is a clear objective of the national energy policy, which envisages the promotion and use of renewable energy, and increased use of wind and solar energy as a rational, efficient long-term measure.

d. Biodiversity

According to the Fourth National Report on Biodiversity (ANAM, 2010), Panama is one of the countries with the greatest biodiversity of species in the Central American region, and serves as a natural connector between North and South America. Four percent of the vascular plants reported for Panama are endemic. Biodiversity contributes to human welfare in many respects biodiversity, as regards both the production of raw materials and health.

According to UNEP (2011), the past 50 years have seen the rapid loss of biological species. Recent temperature variations, caused by climate change, have already had a significant impact on the biodiversity and ecosystems, increasing the risk of extinction of species. The main threats to the country's biodiversity are: a) river and lake pollution; b) habitat loss and fragmentation; c) deforestation; d) the introduction of exotic species and their adaptation to natural ecosystems; e) the adaptation of invading species to ecosystems; f) species extraction, and g) poor land use.

Map 2. Agroecological Map Determining Production Areas in Panama

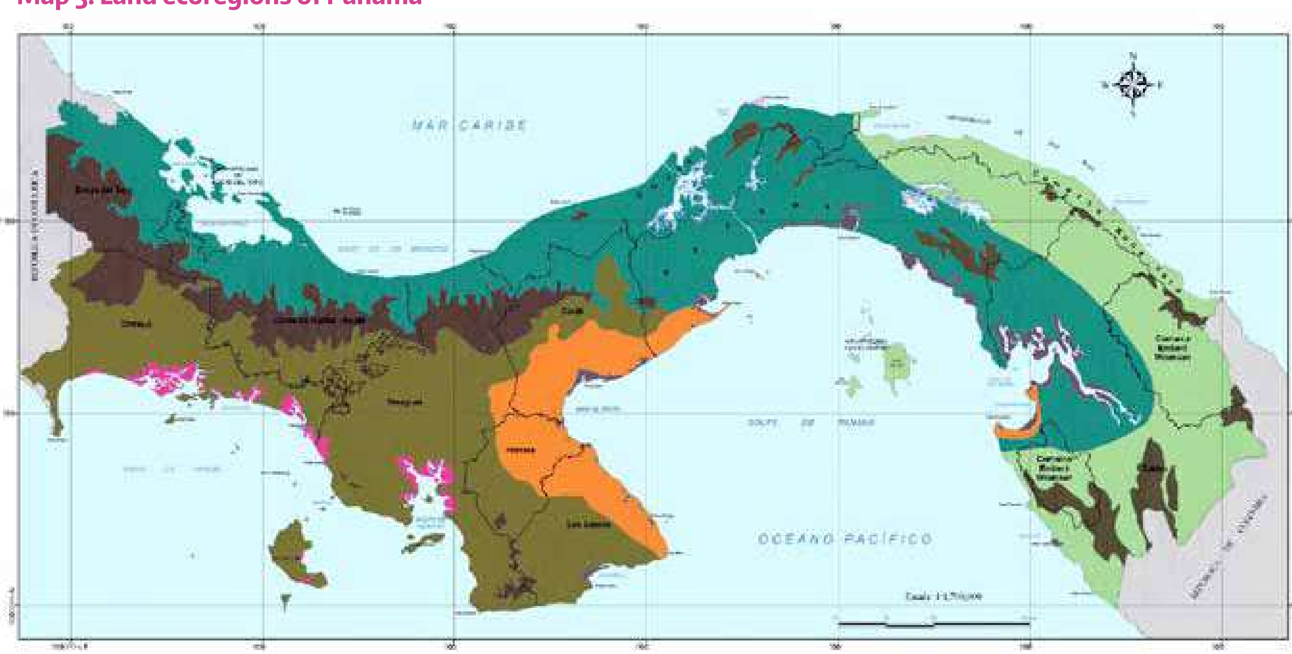


Agroregions of Panama

II Arable, some limits on plant selection
III Arable, severe limitations on plant selection
IV Arable, very severe limitions on plant selection
V Non-arable, low risk of erosion
VI Non-arable, with severe limitations
VII Non-arable, with very severe limitations
VIII Non-arable, with limitations preventing their use in commercial plant production

Source: Atlas Ambiental de la República de Panamá, 2010.

Map 3. Land ecoregions of Panama



Land ecoregions of Panama

- Humid forests of Chocó/Darién
- Humid forests of the Atlantic side of the Isthmus
- Humid forests on the Pacific side of the Isthmus
- Montane forests of Talamanca
- Montane forests in the east of Panama
- Dry forests of Panama
- Mangroves of Bocas del Toro-Isla Bastimientos-San Blas
- Mangroves on the humid Pacific coast
- Mangroves in the Gulf of Panama

Source: Atlas Ambiental de la República de Panamá, 2010.

The implementation of a general land-use plan and the establishment of the monitoring and evaluation framework for the conservation of biodiversity should promote options for the preservation of species in ecosystems.

e. Forest resources

Panama's forest resources are characterized by mature forest cover, intervened and secondary forests, which accounted for 61.9% of the land area in 2014. All these forests play an important role in protecting the country's watersheds, offering multiple eco-systemic services such as the regulation of water resources, biodiversity conservation, soil protection and the stabilization of erosion.

Prior to 2000, the annual deforestation rate was estimated at about 50,000 ha. Subsequently, the records indicated that by 2014, forest cover had been reduced to 30% of 2000 figures.

As a result of the commitment made at the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in 2015, Panama committed to the establishment of an International Center for Tropical Forest Management, whose Panama office promoted the Alliance for a Million Reforested Hectares Initiative, projected for 2035.

f. Potential impacts of climate change

Global climate change is the greatest threat facing food production systems and natural ecosystems (IPCC, 2015). Rising temperatures directly proportional to evapotranspiration and water demands affect crops, livestock production and the health of the human population.

g. Building resilience to extreme events

The occurrence of more frequent and intense extreme weather events is associated with climate change, and requires technological adaptation and the creation of mechanisms of resilience to provide vulnerable rural communities with alternatives for coping with the increasing scale of natural disasters and their impact on feeding the population. The first step to building resilience is to reduce vulnerability to climate variability and climate change in the medium and long term.

Building resilience to extreme events such as floods, hurricanes and landslides and providing access to water is implemented through the adoption of available technologies and the efficiency of production systems. Prioritized technologies are designed to achieve the sustainable use of farmland and efficient water use (drip irrigation and micro sprinklers) and storage. Forestry and agroforestry systems increase resilience by establishing production systems with a high biodiversity of species in the various forms of mixed production, such as agroforestry and silvopastoral and agro-silvopastoral systems.

The role of national and international institutions and government policies is crucial to building systems resilient to extreme events. Training qualified human resources and securing the funds required to meet the goals set are also essential.

Figure 2: Guaymí Bull in IDIAP's genetic resource conservation program

h. Future outlook

In 2009, the International Food Policy Research Institute indicated that climate change would not only reduce the yields of agricultural crops and animal products, but also increase food prices. Consequently, it is predicted that by 2050, the reduced availability of calories needed for child development will be reflected in 20% of child malnutrition.

4. Technology and Innovation

Knowledge of genetic diversity, sources of resistance, biology and the behavior of plant and animal species, nutritional quality, medicinal properties of plants and resilience are advances in science, technology and innovation that have permitted the conservation, assessment and use of wild foods as a genetic basis for the improvement of agricultural products. Moreover, one of the key points in CTI is the assessment of nutritional quality through the use of technologies that promote the development of new products from wild foods. Producers prefer to use improved cultivars, which have higher yields and are pest- and disease-resistant, among other features, without ruling out the cultivated plants traditionally used by indigenous communities.

a. Plants

The progress of STI has positive effects on the production of wild foods. Moreover, undertaking projects has made it possible to determine nutritional quality and envisage new products extracted from wild species. However, farmers prefer to use improved cultivars, such as Creole rice, and varieties of maize, wild tomato, roots and tubers (IDIAP, 2016).

b. Livestock

As for the genetic improvement of livestock, progress has been made in assessing the nuclei of Creole cattle, which permitted the establishment of eight core conservation zones for Guaymí (**Figure 2**) and Guabalá Creole cattle. This group is located in the IDIAP experimental field in Ollas Arriba, Capira, Panama, with a livestock population of 191 head of cattle.

Improving tools for the diagnosis of Enzootic Bovine Leukosis (EBL) made it possible to declare all herds technically free of this disease, a significant achievement in the field of animal health. The results presented by this project made it possible to establish the Enzootic Bovine Leukosis protocols with GAG, TAX and ENV genes for cattle. The diagnostic protocol was adjusted by PCR in real time for Bluetongue in cattle and sheep (IDIAP Annual Report, 2016).

c. Pests and diseases

Mixed production systems can be promoted through the implementation of rational management strategies together with the application of agrochemicals. Rainfed crop production systems include management of the Panicle Rice Mite (*Steneotarsonemus spinki*), which caused significant losses in rice production (IDIAP Annual Report, 2016).

Tomato growing involves major economic investment, because the *Begomovirus* complex has caused significant economic damage, due to its association with *Bemisia tabaci* vector biotypes, since it is identified with the genetic diversity of the virosis of polymerase (PCR) and the fragments amplified by PCR were subjected to a Single Strand Conformation Polymorphism analysis (SSCP). This made it possible to identify the presence of *Begomovirus* in 135 samples collected in the provinces of Chiriquí, Herrera, Los Santos, Veraguas and Panama. These results strengthen genetic improvement programs for tomatoes designed to achieve resistance to these viroses (IDIAP, 2016).

In recent years, IDIAP technicians have morphologically identified 29 isolates of native entomopathogenic fungi (17 isolates of *Beauveria bassiana*, one of *Isaria lilacinus* and one of *Trichoderma* sp.), by performing pathogenicity tests on insects-pests of horticultural crops under abiotic, laboratory-controlled conditions. They also molecularly characterized various strains collected from these pest species (IDIAP, 2016).

Other technological innovations that create cleaner production alternatives include the use of biological pest agents, such as *Trichogramma pretiosum* and *Telenomus podisi*, egg parasitoids of the species complex of *Pentatomidae* and *Lepidoptera*, respectively (IDIAP Annual Report, 2016). This reduces the pollution of water sources and protects the biodiversity associated with agricultural ecosystems.

d. Outlook for novel agricultural products

Corn with high protein quality carries the opaque-2 gene, rich in lysine and tryptophan, which has doubled the concentration of amino acids in the varieties in this category (IDIAP, 2016). The germplasm used was provided by CIMMYT, creating four varieties of biofortified corn (IDIAP MQ-02, IDIAP MQ-07, IDIAP MQ-12, and IDIAP MQ-14).

e. Opportunities for new management technologies

The water crisis, which will be exacerbated in the coming years as a result of climate change, has confirmed the existing water deficit in our agricultural ecosystems. Accordingly, drip irrigation, micro sprinklers and fertigation systems have been developed, permitting water savings of up to 95%. In Panama, this technology is available and operating efficiently in production systems.

Vertical agriculture, with climate-controlled systems, is being employed in horticultural products, although use of this technology is limited by its high cost and lack of funding. However, the training of specialized personnel for its operation has not been ruled out.

f. Development of aquaculture and marine resources

As one of the basic components of the Panamanian diet, the aquaculture production system affects the health and quality of farmland, as well as water sources. However, economic growth has fueled projects involving shrimp farming for export. Science and technology have generated key information in the quest for sustainability in the production of these species.

5. Improving the efficiency of the food system

a. Increasing agricultural production based on technological expectations

Banana and sugar cane crops, which are economically important for the country, utilize extensive irrigation systems. In the 2015 crop year, it was estimated that existing irrigation projects used approximately 50% of their potential.

Fruit and vegetable production in controlled settings is on the rise. As a result, producers have begun to engage in vertical-farming *Farm Factories* as a result of a cooperation initiative between Chiba University, Japan, and the University of Panama.

IDIAP has also undertaken significant research on greenhouse production in various ecological zones throughout the country, especially in horticultural areas.

b. Infrastructure for storing food and logistics for transporting it to distribution markets

The Panamanian State has created the Executive Secretariat for the Cold Chain, through Executive Decree No. 20 issued on July 2, 2009. This agency is responsible for planning and implementing this system, designed to extend the shelf life of agricultural products through low temperature storage, preventing losses estimated at between 10% and 60%, depending on the agricultural product, locality and efficiency of the logistics system. The program focuses on 24 perishable goods such as onions, lettuce, tomatoes, broccoli, beans, carrots, cassava, yams, otoes and potatoes. There are currently four collection centers, called Postharvest centers, located in three places: Volcano, Cerro Punta and Dolega, all in the province of Chiriquí, 400 kilometers from the capital. This part of the country produces 80% of the vegetables consumed nationwide. In addition to the collection centers in the province of Chiriquí, another center has been set up in the center of the country in the town of El Ejido in the province of Los Santos to store 12% of national horticultural production. The purpose of this project is to have retail public markets in all the capitals of the provinces of Panama. At present, there is one operating in the market in the city of David, in the province of Chiriquí.

The purpose of this government initiative is to strengthen the transportation logistics of these agricultural products, reducing postharvest losses.

6. Health Considerations

a. Nutritional deficiency as a precursor of diseases

Its humid tropical climate means that the country offers conditions for the survival and multiplication of microbial and parasitic agents that may contaminate food, affecting consumer health. The occurrence of food poisoning must be reported to the authorities in the industry, governed by Decree 268, issued on August 17, 2001 (Cedeño et al., 2009).

b. Overconsumption of food

In 1982, the prevalence of obesity in men and women was 3.8% and 7.6%, respectively. By 2003, these figures had risen to 14.4% in men and 21.8% in women. Moreover, it is estimated that obesity-related diseases were responsible for the deaths of 8,517 Panamanians, accounting for 49% of the total number. **Table 1** presents data on the nutritional status of adults from 2003-2014, where high rates of overweight and obesity were recorded (Sasson et al., 2014).

Table 1. Nutritional Status of Adults (2003-2014)

Domain	1997	2003	2008
National	16.7	22.2	19.1
Not Poor	5.01	11.0	6.8
Not extremely poor	12.51	19.5	16.1
Extremely poor	38.4	43.3	46.2

c. Malnutrition indicators

The Human Development Index (HDI) is an indicator of countries' average progress in terms of longevity, encompassing health, education and quality of life. The most recent Global Human Development Report confirms that Panama is ranked 60th of 188 countries, placing it among the countries with high human development (UNDP, 2015).

d. Malnutrition in marginalized areas

Despite Panama's economic development in recent years, malnutrition and food insecurity persist in rural areas, where there are high levels of poverty and extreme poverty.

Table 2 confirms the direct relationship between poverty and malnutrition among children under five (MINSA, 2009).

Table 2. Prevalence of Chronic Malnutrition in Children under Five (1997-2003)

Domain	1997	2003	2008
National	16.7	22.2	19.1
Not Poor	5.01	11.0	6.8
Not extremely poor	12.51	19.5	16.1
Extremely poor	38.4	43.3	46.2

Poverty directly affects access to food, therefore food security. A number of surveys conducted in 2008 reported that approximately 32.7% of people are poor, and that poverty rates are higher in rural areas (50.7%) (Dieguéz, 2016).

7. Policy considerations

a. Distortions created by subsidies and other agricultural policy models

Agricultural policies in the 1960s and 1970s, as well as the first half of 1980, prioritized self-sufficiency in commodities together with the expansion of traditional and nontraditional export goods. The agricultural Gross Domestic Product (GDP) rose to 20%, which led the creation of specialized agricultural institutions, such as the Institute of Agricultural Marketing, the Agricultural Research Institute of Panama, the National Agricultural Machinery Company, the Agricultural Insurance Institute and the Institute of Renewable Natural Resources (now MiAmbiente), among others. The Institute for Agricultural Development was renamed the Agricultural Development Bank. This confirms the interest in food security and sovereignty, which formed the backbone of national agricultural development.

The commercialization of agricultural goods took place in a market with high levels of intermediation, operating costs and post-harvest losses.

b. Promotion of sustainable agriculture, with healthy products that provide nutrients to the diet, at affordable prices

IDIAP is promoting a national program for the biofortification of food, in order to increase consumption of vitamins and minerals in basic food items. The Agricultural Marketing Institute (IMA) has implemented the Food Solidarity Program, which seeks to produce food at lower prices, using open markets or the direct selling of products as a platform, avoiding intermediation.

In 2014, in order to address food inflation, the government installed a program to freeze prices for the main basic food items, which included rice, onion, tomato, certain cuts of meat, eggs, milk and beans, among other products.

c. International trade agreements

In 1984, national economic policy underwent a significant change due to the introduction of macroeconomic measures designed to achieve structural adjustment and reduce state intervention in the economy. The agricultural sector was reoriented toward technical assistance and focusing on non-traditional export crops. Moreover, redefinition of the objectives of the state agricultural institutions has been reinforced on the basis of the premises of the free market and trade liberalization. This process promoted the conversion of agricultural production guided by demand and linked it to agricultural exports. That is why they have promoted free trade agreements and trade with Central America, Taiwan, Mexico, Chile, Singapore, USA, Canada, Peru and the European Union, regarding trade as the basis for this initiative. The Strategic Government Management Plan 2015-2019 sought to improve the competitiveness and productivity of the primary sector. For the first time in decades, the premise of recovering food sovereignty, which is not sustainable, was considered.

d. Policies for the adaptation of technological innovations

The Science, Research, Technological Development and Innovation for Sustainable Development implemented by SENACYT focuses on the creation of a permanent dialogue on the problems of food security. In this process, it is essential to understand the dynamics of social behavior with respect to problems and solutions regarding development, which defines the need to implement research projects based on production systems and their relationship with water, soil quality and health, with a view to guaranteeing food security in order to integrate and analyze the elements required to mitigate climate change (PENCYT, 2015).

8. Executive Summary

In Panama, climate change has affected the agricultural sector and the population's food security. The analysis of the development of both variables is directly linked to the implementation of research and projects focused particularly on the adaptation of biodiversity and agricultural areas to climate change, with an approach aimed at water resource management and increasing resilience to climate variability.

Agriculture and food are key issues in the Millennium Development Goals. In addition, from this approach, the perspective of alleviating poverty confirms the need to generate knowledge by strengthening national agricultural research institutes (INIA). However, this does not exclude the implementation of national innovation systems in the current political, economic and social scenario faced by the country and the world.

Nowadays, indicators that include the political factor focus on the change of era, linking it to agricultural development. Thus, the reduction of incentives in development strategies is essential to addressing challenges such as the development of sustainable farming systems and food production.

Knowledge generation and the innovation of agricultural technology are key elements in defining the emerging scenarios required to implement the necessary changes. Global trends propose the implementation of agricultural policies focusing on technological innovation, which are incorporated into the development of the food sector. The technological upturn linked to the development of value chains, integrated markets and proper distribution at the level of production systems is one of the strategies required to optimize the use of national and international markets. However, there is very little investment in agricultural research, coupled with a lack of specialized human resources. In this respect, the appropriate scenario is not proportional to the level of opportunity mentioned earlier.

The role in the generation of technological innovation of National Agricultural Research Institutes (INIA) must be reframed on the basis of certain objectives, such as: a) describing the challenges they face and consolidating the scientific basis within the political, social and economic framework; b) contributing ideas that support the changes that must be made to leverage opportunities and meet the current challenges, and c) identifying the specific processes required for the practical implementation of the transformations required.

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