

Challenges and Opportunities for Food and Nutrition Security in the Americas

The View of the Academies of Sciences



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Challenges for Food and Nutrition Security in the Americas

Costa Rica and its commitment to sustainability



Costa Rica

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Costa Rica should support development models that consider nature; **its production systems should be more environmentally friendly** by reducing the use of agrochemicals, and making more and better use of soil, pest control, water resources, waste and residue management practices

Summary

As a small nation with high biodiversity and an extensive system of protected areas, Costa Rica will face particular challenges regarding food security over the next few years. Thus, whatever development model the country chooses, it must achieve a compromise between conservation and production (agricultural, energy and so on). Although the country's malnutrition levels are below 5%, socioeconomic asymmetries - which have been increasing in recent years - put a growing proportion of the population at risk. Costa Rica also has a high disaster risk (due to volcanism, seismicity and climatic events), which is likely to be increased by climate change. Moreover, the country's population is aging and growing very little in absolute numbers, which is also reflected in the predominance of farmers growing older. It is important to mention that the country relies heavily on food imports, mainly of basic grains, to cover the needs of its population. Food production uses a large amount of imported seed and propagating material, which are often not suited to local conditions, as well as very intensive use of agrochemicals, with negative consequences for health and the environment. Over the next few years, it will be crucial to maintain solid public higher-education and research structures in the agricultural field. Although there is no shortage of water in the country in general, water is unevenly distributed at certain times and between regions. Another important challenge is that overweight and obesity show an increasing and alarming upward trend.

A comprehensive approach considering many actors and positions is required to ensure food and nutrition in Costa Rica over the next fifty years. To this end and to be consistent with a long tradition that has earned the country recognition, the government should continue with its policies to conserve protected areas and biodiversity. At the same time, it should increase productivity and yields in land with a clear agricultural vocation. This is important for reducing dependence on imported food in order to meet the basic needs of the country's inhabitants. In order to achieve broad access to sufficient nutritious food, it is essential to reduce the gaps in the population's socioeconomic conditions. Production systems should be more environmentally friendly by reducing the use of agrochemicals, and making more and better use of soil, and integrated pest, water resources, waste and residue-management practices. It will also be important to encourage, where possible, the use of local species or those adapted to local conditions, some of which are little known and underutilized, which are important for the diet beyond caloric intake (as a source of micronutrients, vitamins and functional compounds). This requires considering the enormous biodiversity present in the country and encouraging genetic improvement in order to reduce dependence on imported seed and propagation materials, since

these were often developed for other climatic and edaphic conditions, as well as different productive systems. It is essential to achieve greater differentiation of products that follow certain quality standards in terms of production, marketing and nutritional value over the next few years, and for this to provide some form of competitive advantage. Prevention and mitigation measures must be taken against disasters that can be caused by specific events (hurricanes, volcanoes, earthquakes, etc.) or climate change. It will be important to continue the construction and maintenance of water collection, storage and supply works to reduce water shortages in particular areas and at specific times. Agricultural activity must be made attractive so that young people choose to remain in the countryside rather than migrating to cities. State funding for research on priority issues for the country must be increased, and incentives created so that the private sector also becomes interested in supporting research. It is also necessary to continue promoting high-level human resource training, preferably at top universities abroad, to promote agricultural research. Likewise, technical and vocational education must be promoted with the participation of various institutions (such as the Instituto Nacional de Aprendizaje, technical and vocational colleges and dual education). The

country must consider a wide range of options for agricultural production with a view toward ensuring food and nutrition for its inhabitants. This framework must consider all the (bio)technological options, provided they do not conflict with the environment and health. It is also essential to continue and intensify programs that seek to promote healthy eating habits and encourage physical activity among the population.

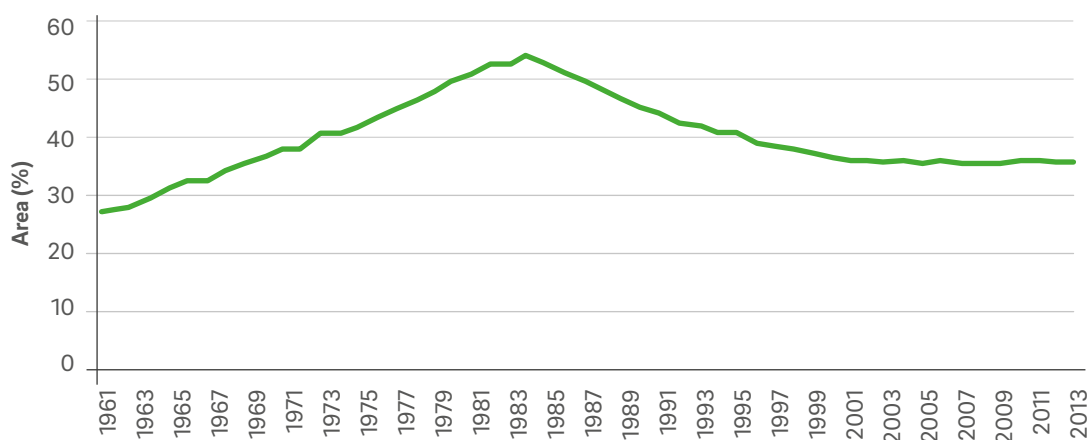
I. Features of the country

a. Physical dimensions, inventory of cropland, landscape and environmental diversity

Costa Rica, which has not had an army since 1948, is the third smallest country in Central America, with an area of 51,100 km². In the past 50 years the largest area devoted to agricultural activities was achieved in 1984, with 53.8% of the national territory. This figure gradually declined year after year until 2000, and thereafter remained fairly stable until it reached 35.6% in 2013 (**Figure 1**). Forest cover has increased since 2000, reaching 51% in 2010. That same year, 1.54% of the land under cultivation was irrigated.

Despite its small size, the country boasts a diversity of landscapes ranging from those at sea

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Figure 1. Area of country used for agricultural activities (%)

Source: The World Bank

level, through medium-sized mountains and the Central Valley (900-1,200 meters above sea level [masl]), where most of the population lives, to the high mountains - located mainly in the Central Volcanic Cordillera and the Cordillera de Talamanca (where Cerro Chirripó is located, its 3,819 meters making it the highest one in the country). The diversity of microclimates generated by such heterogeneous landscapes, as well as its geographic position, means that, despite its small area (0.03% of the earth's total), the country is home to nearly 4% of the species thought to exist worldwide, making it one of the 20 countries with the greatest biodiversity. All this is protected by an extensive system of conservation areas, which guarantees the protection of more than 25% of the country's territory.

b. Demographic features and future trends

On June 30, 2016, according to the Instituto Nacional de Estadística y Censos (INEC), the estimated population of Costa Rica was 4,890,379, with 22% of the population under 14, 17% ages 15 to 24, 44% between 25 and 54, 9% between 55 and 64, and 8% ages 65 and over. By 2013 the overall fertility rate was 1.76 children per woman, which is much lower than the replacement level (2.1 children per woman) and also 5.3% lower than it was

two years earlier, reflecting the tendency to have fewer children. The low birth rate, coupled with high life expectancy at birth (78.8 years in 2015), mean that Costa Rica's population is aging. It is estimated that by 2025, 11.5% of the population will be 65 or older (600,000 people).

In assessing these numbers it is important to consider the situation of immigration in Costa Rica. In 2011, 9% of the country's population was born abroad. Nearly 75%, or 386,000, were from Nicaragua, 4.3% from Colombia, 4.1% from the US, 2.9% from Panama and 2.4% from El Salvador. Here it is important to note, for example, that the overall fertility rate of women of childbearing age of certain other nationalities is higher than that of Costa Ricans.

By 2030, Costa Rica is likely to have a population of 5.6 million, a 15% increase over 2015. This will confirm the decline in the population growth rate due to a decrease in the birth rate and probably a reduction in immigration.

c. Status of Food and Nutrition Security

FAO data show that undernourishment levels in Costa Rica are below 5% and have remained stable over the past 25 years (FAO, 2015a). Global malnutrition (proportion of children under 5 with low weight for their age) for the 2005-2012 period in Costa Rica was 1.1%, the second lowest in Latin America after Chile. By 2015,

food availability was 2,960 calories per day per person, which is more than enough to meet the population's minimal requirements.

Most indicators show a clear trend toward a decline in the proportion of the population at risk of food insecurity, particularly of malnutrition in children under 5 and chronic malnutrition (FAO, 2015b). However, the latest report of the State of the Nation (Estado de la Nación), delivered in November 2015, indicates that the country does not have statistics that allow it to "accurately estimate its degree of food and nutrition security or insecurity", coupled with a situation of dependency and vulnerability in its food availability, as well as socioeconomic asymmetries affecting food access (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2015). Accordingly, a sector of the population does not have its right to food guaranteed, since it faces difficulties in relation to food access and availability.

d. Farming Modalities

Data from the 2014 Agricultural Census show that Costa Rica has a total of 557,888.6 hectares (ha) under perennial agricultural crop cultivation (excluding forest plantations) and 133,249.8 ha planted with annual crops (Table 1) (INEC, 2015a). Smaller productive units (farms) tend to grow crops such as maize, beans, vegetables, palm trees, fruit trees, coffee and some livestock (mainly dual-purpose), whereas larger farms produce

banana, sugar cane, rice, pineapple, orange, tilapia and milk. Compared with the situation in the rest of Central America, subsistence agriculture is extremely limited in Costa Rica (IICA, 2011).

e. Self-sufficiency in agricultural production

Costa Rica is not self-sufficient in terms of the production of the food consumed by its population. In basic grains, particularly rice, beans and corn, there is a clear trend toward a decrease in local production and an increase in the amount imported. A similar pattern can be observed in vegetable production. Conversely, from 2005 to 2011 there was a 65% increase in fresh fruit production, with a 20% increase in the area planted. Livestock production also saw an increase in the period 2003-2007 (Ministerio de Salud, 2011).

f. Main export/import crops and markets

In 2014, the Costa Rican agricultural sector accounted for 22.8% of the value of the country's exports (\$2,574.4 million USD), while the livestock and fishing sectors contributed 3.2% (\$366.5 million USD) (PROCOMER, 2014). 2012 Statistics show that the country's main agricultural products are bananas, pineapples and coffee and that it imports yellow corn, soybeans and wheat (Figure 2), all essential to the country's food security.

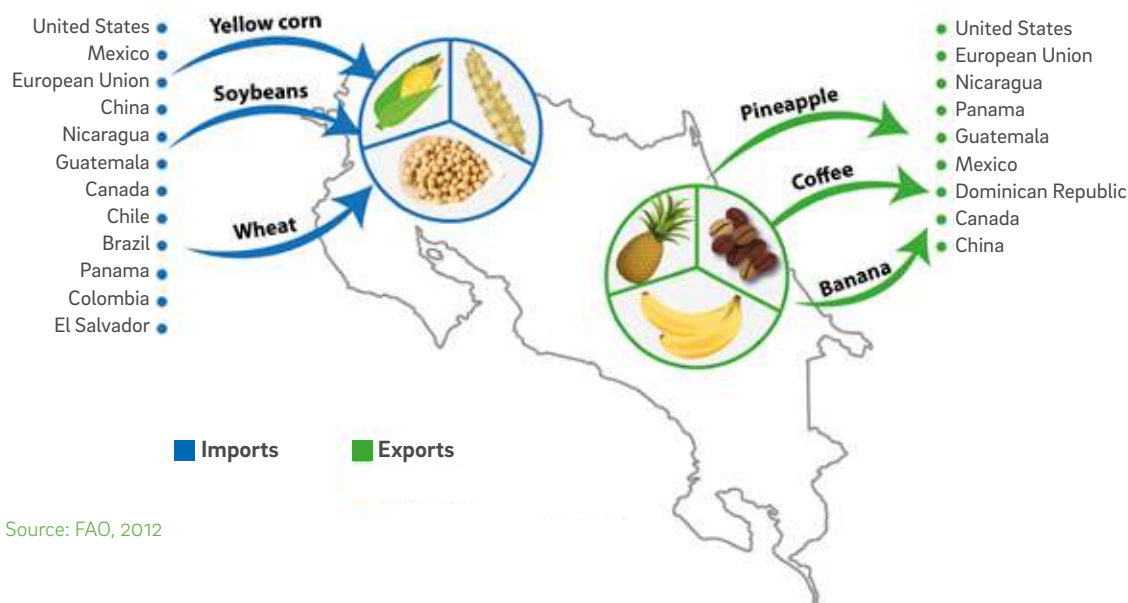
g. Potential sources of instability in Food and Nutrition Security

Costa Rica is prone to natural disasters, such as volcanic eruptions, drought, floods, hurricanes and earthquakes, which, according to the GlobalRisksReport 2016, makes it the world's fifth country most exposed to natural disasters and eighth on the risk index. Although over 120 mostly extinct volcanic formations have been identified, there are five active volcanoes, three very close to major population centers, whose emanations not only have a direct effect on people's health, but may also affect crops.

Although since the time historical records began to be compiled, Costa Rica had not directly experienced a hurricane hit until Hurricane Otto in 2016, it has suffered their indirect impact, mainly in the form of heavy rains and floods, as well as the effects of El Niño and La Niña. Moreover, the country's location in a subduction zone where three

Table 1. Main agricultural crops in Costa Rica according to the planted area, 2014

	Crop	Area (% of total area for this type of crop)
Perennial (557 888 ha)	Coffee	23.8
	Oil palm	18.8
	Sugar cane	18.4
	Banana	14.6
	Pineapple	10.6
Yearly (133 249 ha)	Rice	43.9
	Bean	14.6
	Corn	11.8
	Cassava	11.3
	Cantaloupe	4.4

Figure 2. Main agricultural products that Costa Rica exported and imported in 2012

Source: FAO, 2012

large tectonic plates interact (Cocos, Caribbean and Nazca) means that earthquakes are very frequent, sometimes with magnitudes of between 7.0 and 7.7. These earthquakes, as well as major meteorological phenomena, have repeatedly caused severe damage to road infrastructure and communications. At the same time, it is estimated that anthropogenic climate change will cause a nationwide temperature rise, with an increase in rainfall in the Caribbean and southern regions of Costa Rica and a decrease in N and NE areas (CCAFS, 2014).

h. Main agricultural challenges

The greatest challenges for agriculture in Costa Rica, in terms of food security, are probably linked to its current agroexport model, which has forced the country to import a considerable percentage of its basic foodstuffs. It is also important to achieve more environmentally-friendly production, which involves a careful review of agrochemical use, waste management and residual biomass use. The use of state-of-the-art technologies and varieties adapted to local conditions is also crucial to raising yields, since in some crops, these are far below world standards. Water management, for both irrigation and drainage, must be examined in regard to climate change. Socioeconomic aspects must be considered, especially farmers' access

to markets. This is crucial because farmers in Costa Rica are getting older, since young people do not wish to remain in the countryside.

II. Institutional environment

a. Universities and Research Institutes

Data from 1999 indicate that 60% of agricultural research in Central America was conducted in Costa Rica, with a very high percentage in the four public universities at that time - University of Costa Rica (UCR); National University (UNA); Technological Institute of Costa Rica (ITCR), and the State Distance University (UNED) - and mostly at UCR. Founded in 2008, the National Technical University (UTN) has also become increasingly involved in the agricultural sphere. Public universities usually have relatively highly qualified academic staff, a significant proportion of whom have completed postgraduate training abroad. These institutions have been growing their infrastructure as a result of which some centers and institutes have the latest technological advances in their respective fields. The country also has public non-state research centers focused on specific crops, financed by the producers themselves, such as the Sugarcane Research and Extension Division

(Departamento de Investigación y Extensión de la Caña de Azúcar - DIECA), the Center for Coffee Research (Centro de Investigaciones en Café - CICAPE) and The National Banana Corporation (Corporación Bananera Nacional - CORBANA). The National Biodiversity Institute (Instituto Nacional de Biodiversidad - INBio) is a non-governmental, non-profit organization focusing on research and management regarding the country's biodiversity. The recently founded National Biotechnology Innovation Center (Centro Nacional de Innovaciones Biotecnológicas - CENIBiot) seeks to link the country's business and academic sectors in order to scale-up agroindustrial research projects that will boost productivity. The Tropical Agricultural Research and Higher Education Center (Centro Agronómico Tropical de Investigación y Enseñanza - CATIE), the Inter-American Institute for Cooperation on Agriculture (Instituto Interamericano de Cooperación para la Agricultura - IICA), the EARTH University, the Tropical Science Center (Centro Científico Tropical - CCT) and the Organization for Tropical Studies (Organización para Estudios Tropicales - OTS) are international organizations located in Costa Rica, which have been important players in the country's agricultural research.

b. National Agricultural Research System

Although there were previous programs and initiatives, the current structure of the state regarding agricultural research dates back to 1996, when the Ministry of Agriculture and Livestock (Ministerio de Agricultura y Ganadería - MAG) set up the National System of Agricultural Research and Technology Transfer (Sistema Nacional de Investigación y Transferencia de Tecnología Agropecuaria - SNITTA) to promote technological changes in the sector, as well as the Foundation for the Development and Promotion of Research and Transfer of Agro-Technology (Fundación para el Fomento y Promoción de la Investigación y Transferencia de Tecnología Agropecuaria de Costa Rica - FITTACORI), as a private, non-profit entity for public utility that looks for resources from national agencies and international organizations to undertake projects in the agricultural sphere. In 2001, the National Institute for Innovation and Transfer

of Agricultural Technology (Instituto Nacional de Innovación y Transferencia en Tecnología Agropecuaria - INTA) was created within MAG, which took over the functions of the Research Management (Chaves-Solera, 2011).

- i. **Research Capacity Development.** The country has a limited number of trained personnel. Moreover, low investment in agricultural research is a serious handicap to implementing new technologies. There is also an urgent need to prioritize working lines of a multidisciplinary nature, particularly those that foster interaction between the private and public sectors, in a model that includes state universities and other centers. It is important to note that the existing infrastructure means that work is carried out on a limited scale. Investment is therefore required to enable research to be undertaken on a larger scale.
- ii. **Local strengths.** In addition to the fundamental role of public universities in training qualified professionals, as well as the research they conduct on current issues of enormous importance for the agri-food sector, the country has a number of strengths worth highlighting. On the one hand, the production of basic research as a result of projects owned by state universities and/or in cooperation with institutions abroad has allowed the generation of knowledge which in many cases is used in practical applications that have a favorable impact on the sector. There is also the knowledge gained from perennial crops over time, resulting of many years of research, which made the country a leading producer of crops such as coffee, bananas and pineapple.
- iii. **Scientific collaboration networks inside and outside the country.** RedCONARE is an advanced research and education network of the National Council of University Presidents (Consejo Nacional de Rectores - CONARE), in which the country's public universities participate. Through this network, the country is linked to RedCLARA, which develops and operates the only advanced Internet network in the Americas. The country also participates in several international networks linked to the agri-food field, such as: the Cooperative

Regional Potato Program (Programa Regional Cooperativo de Papa), organized and supported by the International Potato Center (CIP), the Regional Food Security and Nutrition Programme for Central America (Programa Regional en Seguridad Alimentaria y Nutricional para Centroamérica - PRESANCA II) and the Regional Programme for Food and Nutritional Security Information Systems (Programa Regional de Sistemas de Información en Seguridad Alimentaria y Nutricional - PRESISAN), both funded by the European Union (EU) and run by the General Secretariat of the Central American Integration System (Secretaría General del Sistema de la Integración Centroamericana - SG SICA). It is also important to consider the additional efforts that have allowed public higher-education institutions in Costa Rica to become involved in international networks. An example is the University of Costa Rica, which acts as regional coordinator for Latin America of the Food Security Center of the University of Hohenheim in Germany with the participation of partners in Thailand, the Philippines, Kenya and Benin.

- iv. **Access to and maintenance of databases for monitoring farming systems.** As for databases related to the sector, MAG hosts the Costa Rican Agricultural Sector Information System (Sistema de Información del Sector Agropecuario Costarricense - InfoAgro), which provides updated statistics on the economy, trade and agricultural production (www.infoagro.go.cr). INEC tools to enable users to find useful information for the agricultural, trade and health sectors include the National Information System on Food and Nutrition Security (Sistema Nacional de Información en Seguridad Alimentaria y Nutricional - sistemas.inec.cr/snisan), which provides the most significant indicators on nutritional status, anthropometry, and access to and the availability of food and basic services. The Costa Rican Forest Resources Information System (Sistema de Información de los Recursos Forestales de Costa Rica - SIREFOR) is a national program that collects, processes, analyzes, systematizes and

periodically publishes information concerning the condition of forest-related activities and resources in Costa Rica.

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

In Costa Rica, both primary and secondary education (for a total of 11-12 years, depending on the modality) are compulsory and free in the public education system. In 2012, 91.1% of elementary students and 87.3% of middle school students attended public schools and high schools. By 2012, practically 100% of the population of the corresponding age had completed elementary education while 75% had finished middle school (Castro-Valverde 2013). For diversified education, which includes the last two to three years of high school, there are several options including scientific, humanistic, artistic, environmental, sports and other institutions. Professional technical education includes the following modalities: trade and services, industrial and agricultural. In addition to the five state universities mentioned earlier, the country has over 50 private universities approved by the National Council of Private Higher Education (Consejo Nacional de Enseñanza Superior Universitaria Privada- CONESUP). There are over 20 public and private higher education institutions that offer technical degrees (instituciones parauniversitarias) approved by the Higher Education Council (Consejo Superior de Educación). There is also the National Learning Institute (Instituto Nacional de Aprendizaje - INA), a free, public, autonomous entity, created in 1965 to promote and develop professional training and education for those ages 15 to 20 who have successfully completed at least sixth grade.

d. Relative contributions of the public and private sectors

In 2014, Costa Rica invested 0.58% of GDP in Research and Development, an increase of 0.02% over the previous year, yet still well below the average for Latin America and the Caribbean (0.82%). As for human resources, in 2014, the country had 1.1 researchers (equivalent to full days) per thousand inhabitants of the economically active population, above the regional average of 0.8, and surpassed only by Argentina and Brazil.

The contribution of public funds to research and development, provided mainly by state universities and the public sector, was 67% in 2013 (\$184 million), more than twice that of the business sector (32%). The remaining 1% was provided by non-profit organizations.

e. Outlook for the future

The Costa Rican Government, through the Ministry of Science, Technology and Telecommunications (MICITT), expects to reach the leading country in the region in terms of the number of researchers equivalent to full days per thousand inhabitants of the economically active population: Brazil (1.2). Regarding technological innovation, it would be important to strengthen research with state and private funding. The Costa Rican Development Bank System (Banca para el Desarrollo) should establish a credit plan for innovation, and encourage the development of products that take advantage of the country's biodiversity, often underused and barely researched. In terms of human resource training, university education must be renewed by reviewing the curricula, which in many cases, have not been changed for years, and by identifying and establishing new, more interdisciplinary degree programs. It is also important to strengthen technical training in the country. The "Dual Education" proposal (currently supported by Germany) is an alternative worth pursuing.

III. Resource and Ecosystem Features

a. Water resources and challenges in the next 50 years

The country has experienced severe water shortages, mainly for human consumption in the Central and Central and North Pacific regions, with a seasonal regime of up to five months without rain between November and May. Because of the total amount of rainfall, there should not be any water shortage in any region. It is therefore essential to improve water management and expand the area under irrigation with the same water available. The problem of

overexploited aquifers has also been exacerbated, not only by the extreme water demand for new housing and tourist developments and insufficient recharge, but also by saline intrusion in Pacific coastal aquifers. The high cost of developing new sources of water in the required amounts - especially in a context of the depletion of traditional sources - coupled with the lack of water in the dry season, pose a short-term challenge, which will probably require the enactment of new laws. However, despite all the planned and ongoing efforts, in the future it may be necessary to implement non-conventional measures such as geo-engineering. This will imply, at least, more mega- water collection works in areas with high precipitation and rain flow, probably in conjunction with the country's hydroelectric generation and with the ultimate goal of providing water to cities. On the Pacific coast, especially the North and Central parts, the situation will be extremely severe and it may become necessary to implement seawater desalination plants.

b. Soil resources and challenges over the next 50 years

The variety of Costa Rican soils is as great as that of the agroecosystems developed in the various ecological niches by domestic and international farmers and researchers who have encouraged the use of increasingly environmentally-friendly agricultural management practices. Past soil-management mistakes serve as lessons to prevent their repetition, although they still prevail in large-scale, industrial export crop plantations. Thus, new agricultural practices - such as the use of soil inoculants (*Rhizobium* and mycorrhiza) and compost, minimal tillage, planting associated crops and greenhouse operations - are common in the Costa Rican landscape. These new approaches are expected to improve soil conservation, both from the point of view of chemical contamination and that of physical erosion. It is therefore essential for studies in the next fifty years to continue exploring areas such as carbon sequestration, degraded land reclamation, organic/biological agriculture, inoculant use, nutrient use by plants and bioindicators development, all with the participation of a greater number of farmers in the generation of new knowledge.

c. Energy challenges

The electric power market in particular is a centralized system within the largest generator, buyer and state distributor: the Costa Rican Institute of Electricity (Instituto Costarricense de Electricidad - ICE). Energy availability in Costa Rica could soon be limited by its (in)efficient use, resulting from cultural, material and political peculiarities that are not unique to the country. The following considerations support the previously mentioned statements:

- i. As for energy for transport, aspects related to poorly designed road infrastructure, as well as bad driving behavior and insufficient concience related to the use of public transportation, impose a high entropic cost on the use of thermomechanical energy and obviously the finances assigned for importing fossil fuels.
- ii. In the agroindustrial field, the use of process heat generation and electric cogeneration is limited by significant thermodynamic inefficiencies. However, efforts are currently underway in the water-food-energy nexus, which suggest that agroindustrial waste as well as alternative forms of alternative energy in the rural sector will soon be used.
- iii. Bad practices regarding electricity use at home and in businesses continue to exist. Although a number of state institutions have developed certain social communication initiatives in this regard, they have not been continuous.
- iv. Public and institutional policies have a number of flaws. The 2015-2030 National Energy Plan presents some timid proposals to "reward" companies that demonstrate improvements in energy-use efficiency, especially when it comes to renewable sources such as biomass. However, there are no efficient legal mechanisms to sanction those who fail to comply with them.

d. Conflicts and challenges in relation to biodiversity

In Costa Rica, the main causes of biodiversity loss and deterioration have been found to be linked to the growth of urban centers, lack of good agricultural practices (increased use of mechanization, agrochemicals, loss of live fences, etc.), illegal logging and forest fires, and to a lesser extent, to the fragmentation of natural

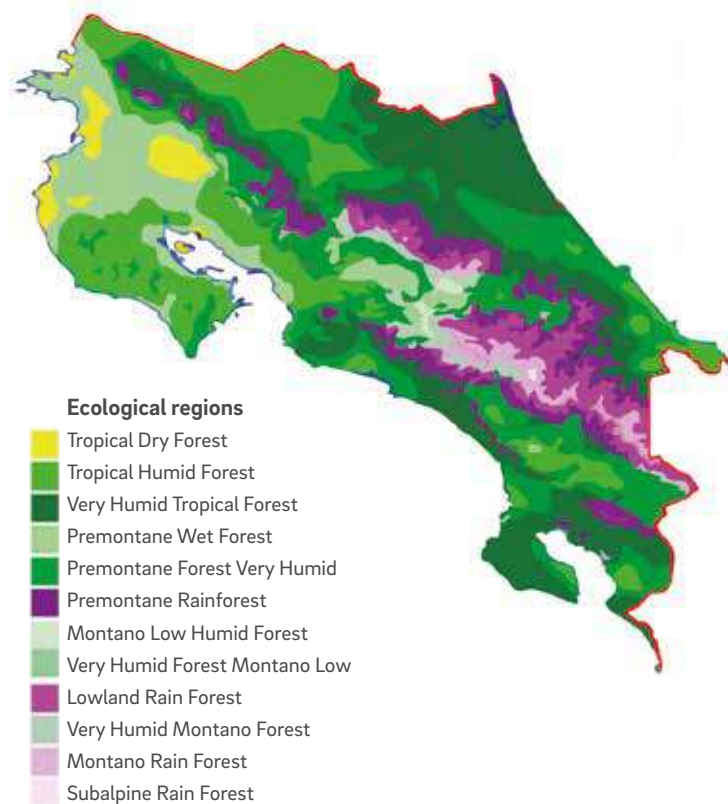
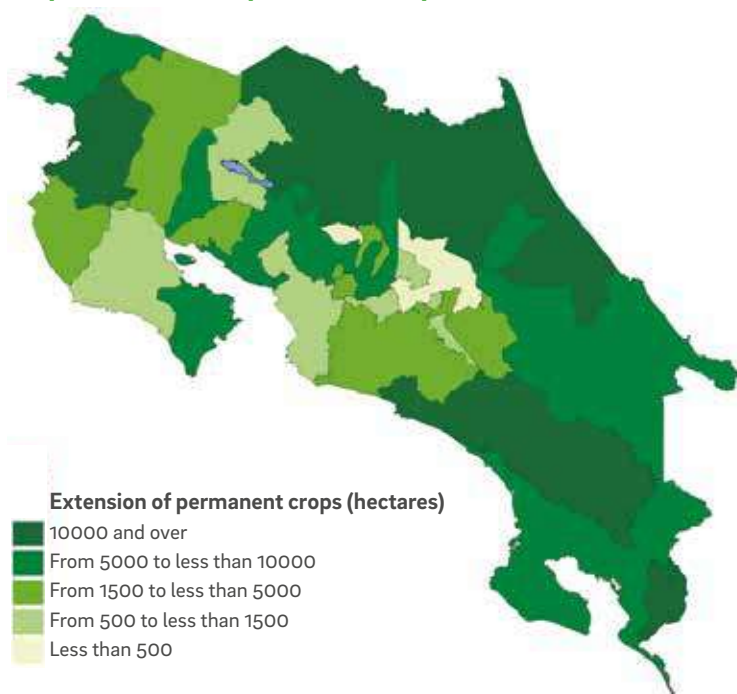
covered areas, hunting and the introduction of exotic species. In 2015, the country issued a National Biodiversity Policy for the next 15 years with four main pillars. The second one briefly mentions the agricultural field, indicating that "policies and/or measures that promote market access and the linkage of products or services to environmental characteristics (organic certification, sustainable tourism, coffee, cocoa, fishing, aquaculture and livestock under good environmental and social practices)" will be encouraged (CONAGEBIO/SINAC, 2015).

e. Forestry sector trends

The country's forest cover has doubled in the last three decades, from approximately 25% of the territory in the 1980s to 52.38% in 2013. This is thought to be a result of the prohibition of land-use change established by Forest Law 7575, passed in 1996, the implementation of the Environmental Services Payment Program (PPSA) in 1997 and a change in the national productive system due to the reduction in extensive livestock production, for example. However, pressure remains on the urban areas in the country's Greater Metropolitan Area to expand. It is also important to consider the ecological quality of forest cover since, outside large national parks, it is highly fragmented and secondary in nature.

f. Potential impacts of climate change

Factors such as climate change and extreme weather events pose challenges which, if left unaddressed, could increase the likelihood of food and nutrition insecurity for the public. It is therefore useful to know the reality of the country in this respect and to identify specific challenges, in order to obtain information for the debate on the strategies required (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2015). The National Meteorological Institute (Instituto Meteorológico Nacional - IMN) has been studying the possible impacts of climate change on Costa Rican agricultural activities, first with the Central American Program on Climate Change (Programa Centroamericano sobre Cambio Climático - PCCC) and then through the Netherlands Climate Change Studies Assistance Programme. As a result of events related to climate change, many cantons

Map 1. Ecological Regions of Costa Rica**Map 2. Extension of permanent crops in Costa Rica**

Source: INEC. VI National Census of Agriculture, 2014

will lose areas suitable for crops that are the basis of their economy, while the socioeconomic conditions prevailing in others will enable them to address the situation more effectively. It is important to consider the sensitivity of various crops to changes in climatic conditions. Of the main crops in Costa Rica, coffee and beans are probably among the most sensitive, while sugar cane, corn and cassava are the most tolerant. In order to encourage certain productive activities, the country established the first PPSA system in the region and subsequently passed Law 8408, in 2004, which recognizes environmental benefits in the agricultural sector (Bouroncle et al., 2015).

g. Developing resilience to extreme events

The Costa Rican agricultural sector has been working on the implementation of initiatives for over two decades with the aim of conserving natural resources and increasing agricultural production. In the early 1990s, technical principles were established to increase productivity, increase vegetation cover, conserve soil and improve conditions for water and carbon cycles. During the first decade of the 21st century, climate-smart agriculture was promoted through the Program Promoting Sustainable Agricultural Production (Programa de Fomento de la Producción Agropecuaria Sostenible - PFPAS), focusing mainly on coffee, sugar cane, vegetables and beef and dairy farming. Other programs designed to increase productivity and competitiveness, which consider aspects of mitigation, adaptation and resilience, are the National Organic Agriculture Program (Programa Nacional de Agricultura Orgánica), the Blue Flag Ecological Program (Programa Bandera Azul Ecológica), the National Plan for Sustainable and Healthy Gastronomy (Plan Nacional de Gastronomía Sostenible y Saludable), the Low Carbon Livestock Strategy (Estrategia para la Ganadería baja en Carbono), The Adaptation Fund (Fondo de Adaptación), Nationally Appropriate Mitigation Actions (NAMA) for coffee, cattle and sugar cane, the 2013-2030 Water Agenda and the BANACLIMA Program of CORBANA.

h. Outlook for the future

In the context of population growth and other uses for water, such as irrigation and industry, and given the uncertainty of the various climate-

change scenarios, the next fifty years will probably see a change in the country's population distribution. The relatively sparsely populated region of the Caribbean, with far more rainfall than the Pacific, and without a defined dry season, could become more important and possibly a center of urban growth and industrial development, as well as increased crop and livestock farming. As for energy, a key challenge for its proper use is the achievement of optimal energy-efficiency levels. Moreover, in order to ensure high, efficient levels of agricultural productivity, it is essential for the country to consider environmental aspects. In the short term, food produced with good agricultural and social practices and the supporting certification will have a greater presence on the market.

IV. Technology and Innovation

a. The role of biotechnology

According to a CENIBiot study, in Costa Rica, agricultural biotechnology is the field in which most research activities are carried out at public R&D centers (46%) and companies (64%). Biotechnology applications in the agricultural field include *in vitro* culture for mass propagation and the development of plants with particular characteristics through genetic engineering. In Costa Rica, there are several plant tissue culture laboratories (both public and private) dedicated to micropropagation - mainly through meristems or nodal segments - of species such as banana, strawberry, roots and tubers (potato, taro, cocoyam), oil palm, bamboo and various ornamental plants (such as orchids, anthuriums and calla lilies). Moreover, particularly in public university laboratories, research is being conducted on other *in vitro* techniques, oriented mainly to genetic improvement, such as the culture and fusion of protoplasts -to produce new plant genotypes through the hybridization of somatic cells-, cultivating haploid cells - which could reduce the time required to obtain new genotypes - and somatic embryos - which could lead to the use of synthetic seeds. The cultivation of genetically modified organisms in

Costa Rica began 22 years ago, for both research and seed reproduction. From 1991 to 2012, the release into the environment, for experimental purposes or seed reproduction, was authorized for taro, corn, soybean, cotton, banana, rice, pineapple and banana, with some of the following features: insect resistance; herbicide tolerance; resistance to diseases caused by fungi and viruses; slow maturation, and improvement of the nutritional quality of fruits. Thus, in 2012, a total of 283.63 ha of genetically modified crops were authorized to be planted. Costa Rica does not yet produce genetically modified organisms for human or livestock consumption. It only produces seeds for export, which are not sold on the domestic market. For pests and disease management through biotechnological strategies, Costa Rican companies have begun to commercialize biofungicides made from microorganisms with antagonistic action on microorganisms that affect crops.

b. New agricultural products

Novel agricultural products include plants that are currently underutilized, or new varieties resulting from genetic improvement. Public universities, particularly the UCR, are currently undertaking several projects designed to identify, evaluate and conserve tropical fruits that can make important contributions to human nutrition, such as anona, pitaya, peach palm, papaya and guava. This institution also undertakes projects for the plant breeding of rice, beans, guava, papaya, tomato and bell pepper. CATIE and CICAPE have genetic improvement programs for cacao and coffee, respectively. Last, the private sector has research initiatives for crops with economic and food importance such as the oil palm (ASD de Costa Rica) and rice (Semillas del Nuevo Milenio - FLAR). Many of the crops mentioned above provide the livelihood for many communities in Costa Rica, therefore, it is important to conduct research and develop them in order to guarantee the purchasing power of the producers.

c. Opportunities and obstacles to the use of new technologies

The country's particular conditions offer a series of opportunities which, at the same time, pose

challenges to the sustainable use of resources such as soil, water, marine ecosystems, forests and biodiversity in general. Thus, the research undertaken – both now and in the future – should also offer options to small farms to reduce losses and achieve proper waste management, in addition to meeting increased demands. The doors should not be closed to new technological options, particularly those derived from agricultural biotechnology, provided efforts are made to minimize risk situations, particularly with respect to the country's biodiversity. Although agricultural irrigation has advanced considerably – with about 100,000 ha currently under this system –, the advance of an irrigation culture that uses water efficiently has been slow. An increase in the use of more efficient irrigation systems, such as dripping or micro-spraying, should be accompanied by intensification of production and diversification toward cash crops, as well as the use of advanced techniques such as precision agriculture and satellite monitoring. As for fertilization, opportunities include generalizing the use of more environmentally-friendly technologies (fertigation and foliar products with microelements), extending the use of fertilization in the forestry sector, employing precision agriculture to adjust the dose of agrochemicals applied, updating and using the management plans for the national territory, and strengthening rural education programs with curricula that incorporate new technologies.

There are a number of obstacles that could hamper the implementation of new technologies. Some have to do with opposition to varying farming practices, even among large companies, as well as the existence of cumbersome administrative and regulatory processes. It is also important to note that, regardless of the efforts made in recent years, there is a lack of economic support for research, as well as incentives to increase the number of professionals in science and engineering, especially with higher degrees (M.Sc. and Ph.D.).

d. Development of marine resources and aquaculture

Despite the upward trend in domestic demand for fish and other seafood with an annual per-capita fish consumption of 7.2 kg, the output of domestic

marine fisheries for local consumption has declined considerably: 46% in just over a decade. This is due to a number of reasons, including legal restrictions and regulations, competition with imported aquaculture products, and declining fish stocks. At present, aquaculture in ponds – by far the main aquaculture activity with about 30,000 tons per year – has barely increased, either for freshwater – tilapia being the main species and trout the second – or for brackish water – with white shrimp being the sole species. Although it has developed slowly, aquaculture directly in the sea has advanced over the previous decade. Given the growing need for adaptation to climate change, marine aquaculture in the coming decades will be able to provide alternative food sources, particularly since it does not need freshwater. Moreover, implementing techniques to improve fish production, rather than merely restricting fishing – such as artificial repopulation with fast-growing species and the use of fish aggregation devices – together with marine aquaculture, will help turn the sea into a much more valuable resource, by promoting its conservation and proper management (Radulovich, 2008).

V. Efficiency of food systems

a. Perspectives of technological progress in agricultural production

It is only through the development of appropriate technologies that it will be possible in the future to increase agricultural production in harmony with nature. Thus, genetic improvement will allow the development of more nutritious varieties, with lower input requirements and greater resistance/tolerance to biotic and abiotic factors, which are better adapted to the conditions expected as a result of climate change. Increasing the use of productive systems that have not yet been implemented in the country on a large scale could also be an alternative means of boosting productivity. By 2012, only 5% of the country's farms had agricultural production units under protected environments (INEC, 2015a). The development and exploitation of protected tropicalized environments could increase

vegetable production. The fact that Costa Rica is one of the countries with the highest use of agrochemicals per growing area provides an opportunity to modify agroecosystems in order to promote greater diversity of species and increase the biological interactions that facilitate biological pest and disease control. It is also important to register new agrochemicals that are more effective and environmentally-friendly so that farmers have new production tools, and to reinforce the use of good agricultural practices.

b. Infrastructure needs

Internal haulage in Costa Rica is largely undertaken by road. Costa Rica's road infrastructure is one of the densest in Latin America. However, its functionality has virtually collapsed (62% is classified as deficient or extremely deficient), it is largely concentrated in the Greater Metropolitan Area and has very little room to expand. As a complement to road transport, the Costa Rican Railway Institute (Instituto Costarricense de Ferrocarriles - INCOFER) must reactivate freight transport between San José and the Pacific and Caribbean ports (Puntarenas and Limón, respectively), and expand the rail network to other parts of the country, such as Guanacaste. The country has already achieved and continues to achieve significant progress in modernizing its ports, in both the Caribbean and the Pacific. However, work remains to be done on port infrastructure and nearby road traffic networks, since Costa Rica is one of the countries in the region ranked lowest in this respect. It is necessary to overhaul the storage and drying infrastructure for grains and seeds, particularly basic grains such as rice, beans and corn. It is also important to rehabilitate irrigation and drainage areas, and work on flood control and water transfer for irrigation. Laboratories must be set up to ensure that foods that are marketed, including basic grains, meet established quality and safety standards (SEPSA, 2008).

c. Food-use problems and waste minimization

In Costa Rica, 30% of the food produced is lost or wasted. Costa Rica's Food Bank (Banco de Alimentos de Costa Rica), created in 2012, is a private non-profit that seeks food donations to

supply at-risk populations. Companies donate food and provide infrastructure, equipment, services and strategic capacities to operate the scheme. The Food Bank was declared an issue of public interest by the government. The Costa Rican Network for Food Loss and Waste Reduction (SaveFood Costa Rica) was set up in 2014. Studies have been carried out on dairy and tomato agrochains, while attempts have been made to reduce waste in business and institutional kitchens.

d. Conflicts between food production and energy and fiber production

Land use for the development of energy crops to the detriment of food crops has become a significant problem in some countries. Fortunately, Costa Rica is protected from this situation, since Article 18 of Decree 35091 on liquid biofuels states the priority of food production for human and animal consumption over biofuel production. This safeguard is also established in Article 23 of the draft of the new version of the decree, currently under development. Costa Rica looks forward to become a "carbon-neutral" country. In other words, net emissions of greenhouse gases into the atmosphere should be equivalent to zero by 2021. To this end, there are several programs and research projects on clean energy production to replace the use of fossil fuels and reduce their imports. An example of this is the Biofuel Development Program (Programa para el Desarrollo de Biocombustibles), which aims to develop research projects on this issue, to harness agroindustrial waste or use products or by-products to create biofuels (SEPSA, 2011). Suitable crops include oil palm, castorbean, jatropha, sugar cane, bitter cassava and sorghum. Other alternatives are also being explored, such as second-generation fuels, which are not part of the food chain (such as used oil waste, straw and wood), as well as microalgae to obtain oil.

VI. Health considerations

a. Foodborne diseases

For Costa Rica, food safety is a public health issue. In 2003, Executive Decree No. 30945-S established mandatory notification for 45 diseases, including

some food- and waterborne ones, and classified these as salmonellosis, shigellosis, food and marine- products poisoning, as well as cholera. In 2015, approximately 312,000 cases of diarrhea were treated. Seventy-five people are estimated to die of diarrhea annually, mainly children under 5 and senior citizens. Since 2010, Costa Rica has had a National Food Safety Policy (Política Nacional de Inocuidad de Alimentos) designed to “define and establish the general guidelines to be followed regarding the safety of produced, processed, imported and marketed foods in order to ensure the protection of people’s health and consumer rights” (Ministerio de Salud, 2011).

b. Overeating

Data from the 2008-2009 National Nutrition Survey indicate that a high percentage of the population is overweight (**Figure 3**), which increases with age and is generally higher in women than men. Among children under 5, 8.1% (height/weight indicator) are overweight. Studies by both the Ministry of Health (Ministerio de Salud - MS) and the Costa Rican Institute for Research and Education on Nutrition and Health (Instituto Costarricense de Investigación y Enseñanza en Nutrición y Salud - INCIENSA) and the Costa

Rican Social Security Fund (Caja Costarricense del Seguro Social - CCSS) show alarming figures for the incidence and prevalence not only of obesity but also of type 2 diabetes, arterial hypertension, hypercholesterolemia, and triglyceride and uric-acid disorders. Accordingly, one of the areas of intervention described in the National Policy on Food and Nutrition Security 2011-2021 (Política Nacional de Seguridad Alimentaria y Nutricional 2011-2021) of the Costa Rican Ministry of Health addresses overweight and obesity.

c. Expected changes in eating patterns

Development strategies influence variations in eating patterns. In the case of Costa Rica, where the service sector has become a significant pillar of the national economy, tourism has led to a significant change in eating patterns driven precisely by the need to meet visitors’ needs. The existence of better options for access to information (Internet, social networks, etc.) has also caused clear changes in the general population’s eating patterns. New trends indicate that consumers are increasingly concerned about convenience foods (that have been canned, frozen, precooked or minimally processed), and keen to eat foods with direct health beneficial

Figure 3. Prevalence of overweight and obesity in population over 5 in Costa Rica, 2008-2009



Source: National Nutrition Survey, 2008-2009

effects (because of their nutritional and functional properties) or differentiated foods (organic, ethnic, solidarity and so on). These changes in eating patterns directly affect the various supply chains, whether they are wholesalers, supermarkets, retailers or even hotel chains. Food-supply strategies must change to meet these new trends.

d. Toward a change of behavior in food and nutrition

The efforts made by the Ministry of Public Education (MEP) and other state institutions, as well as non-profit organizations, which seek to instill a culture of healthy eating in schoolchildren, will have an effect in the medium and long terms and drive changes in behavior patterns related to eating. As will be mentioned later, Dietary Guidelines - an educational instrument developed in the country by the Intersectoral Commission on Dietary Guidelines (Comisión Intersectorial de Guías Alimentarias) - can also contribute to the acquisition of good eating habits by the population. Likewise, the College of Nutritionists, in collaboration with Costa Rica Institute of Technical Standards (Instituto de Normas Técnicas de Costa Rica - INTECO), has proposed an initiative to achieve a positive change in eating habits. This will improve the Costa Rican population's health by enabling them to eat according to their specific needs. This program, called ProNutri, proposes that nutritionists should be the drivers of change. The personalized nutritional prescription is made out in the CCSS' public hospitals, in private hospitals and clinics and in public and private universities, as well as private practices. Orthomolecular (personalized) nutrition is not yet available in the country.

VII. Political considerations

a. Subsidies and other agricultural policies

In Costa Rica, there are no direct subsidies for agricultural production. Agricultural inputs and equipment are imported tax-free. Tariffs are applied to the imports of certain agricultural products, as is the case of rice, to defend national production. In the case of beans,

trading companies must first buy the national production and, once a declaration of shortages is issued, import permits are granted.

b. Nutrition-sensitive agriculture

In the quest for nutritionally sensitive agriculture - which facilitates the availability of and access to healthy and nutritious food - Costa Rica is now promoting the inclusion of sustainable diets that consider aspects with a low environmental impact and contribute to food and nutrition security, as well as healthy living. The country has contributed to nutrition education initiatives through strategies such as urban gardens, public spaces where crops are grown on a very small scale in order to educate consumers and promote agrochemical and pesticide-free agriculture for self-consumption. Initiatives, both public and private, have combined to create educational, equitable and productive spaces under the principles of fair trade and sustainable production, which result in differentiated products at farmers' markets. Costa Rica also has a National Plan for Sustainable and Healthy Gastronomy, led by the Costa Rican Chamber of Restaurants (Cámara Costarricense de Restaurantes y Afines), with the collaboration of institutions such as MS and MAG.

c. Policies that encourage technological innovation

In order to promote technological innovation in Costa Rica, MICITT, as the governing body, has established a set of policies and actions that seek to strengthen and diversify this field. Thus, the National Science and Technology Fair Program (Programa Nacional de Ferias de Ciencia y Tecnología - PRONAFRCYT) builds learning processes, in collaboration with MEP, the National Council for Scientific and Technological Research (Consejo Nacional para Investigaciones Científicas y Tecnológicas - CONICIT) and public universities, which encourage interest in science and technology, and the development of critical and creative thinking in students. There is also the National ExpoINGENERÍA Program, with the participation and collaboration of MICITT, MEP and Intel Corporation, designed to encourage interest

and curiosity in engineering. MICITT Incentive Fund supports funding of innovation, science and technology development projects. The MICITT also has the PROPYME Fund to promote and improve the management and competitiveness of small- and medium-sized businesses.

d. Human resource generation policies

In terms of human capital formation, MEP's Department of Technical Education and Entrepreneurship (Dirección de Educación Técnica y Capacidades Emprendedoras - DETCE) seeks to continuously train and provide opportunities to improve skills for the student population in vocational technical education programs in the third cycle and diversified education. Specifically in the agri-food sector, there is a trend toward strengthening human resources. The strategy is geared toward technical careers and there is acceptance toward new degree programs and proposing new disciplines. Some of these, such as biotechnology and the development and use of precision farming equipment, are part of the new trends in this regard. Public universities, as well as other institutions mentioned earlier, participate in this human resource training, with a significant contribution from INA and technical colleges.

e. Policies that seek to redesign agricultural ecology

The goals of the Policies for the Agricultural Sector and the Development of Rural Territories 2015-2018 (Políticas para el Sector Agropecuario y el Desarrollo de los Territorios Rurales 2015-2018) include the redesign of agricultural ecology. The aim is to define joint strategies among the public, private and financial sectors, in order to incorporate the necessary financial resources for the promotion of green businesses and the payment of environmental services for environmentally-friendly products. Tax incentives, the responsible use of green seals and encouraging the use of biomass sources to generate clean energy, as well as promoting research on production systems that help reduce the carbon footprint, are also part of this policy. Last, a strategy has been developed for producers to increase the use of the C-neutral standard and encourage consumers to purchase products with this label (SEPSA, 2015).

f. Policies to promote the consumption of healthy foods

There are a number of organizations in Costa Rica whose goal is to promote healthy eating. On the one hand, there are intersectoral commissions that promote healthy eating, such as the Intersectoral Commission on Dietary Guidelines (Comisión Intersectorial de Guías Alimentarias - CIGA), which develops specific guidelines for the various age groups in the population, and the "Red 5 al Día", which develops strategies to promote the consumption of fruit and vegetables. The School Health and Nutrition Commission (Comisión de Salud y Nutrición Escolar) is responsible for coordinating the School Health and Nutrition Program (Programa de Salud y Nutrición Escolar). Institutions offering food service include the Centers of Education and Nutrition and the Centers for Child Nutrition and Integral Attention (Centros de Educación y Nutrición y Centros Infantiles de Nutrición y Atención Integral - CEN-CINAI), the National Network of Child Care and Development (Red Nacional de Cuido y Desarrollo Infantil - REDCUDI) and school cafeterias. One of the areas of intervention of the National Food and Nutrition Security Policy 2011-2021 (Política Nacional de Seguridad Alimentaria y Nutrición 2011-2021) of the MS deals with eating habits and healthy lifestyles. The MS itself, in coordination with the National Breastfeeding Commission (Comisión Nacional de Lactancia Materna), and national and international health guidelines and policies, passed the Public Policy on Breastfeeding for Costa Rica (Política Pública de Lactancia Materna para Costa Rica) (Ministerio de Salud, 2011). The MEP's School Child and Adolescent Food and Nutrition Programme (Programa de Alimentación y Nutrición del Escolar y del Adolescente - PANEA) provides supplementary meals for the student population. The program promotes healthy eating habits, hygiene and appropriate behaviors regarding a person's daily diet. The National Orchard Program (Programa Nacional de Huertas) operates under the Directorate of Equity Programs (Dirección de Programas de Equidad) within the MEP's Department of Food and Health. It is based on the principle of providing the country's educational centers with the necessary resources to launch

agricultural projects that supply school cafeterias with fresh, healthy foods, and develop healthy eating habits in students and encourage them to eat balanced diets. In order to promote students' health by maintaining healthy eating habits, MEP defined the type of foods that could be sold at school cafeterias (Executive Decree 36910 of 11/22/2011). It stipulates that a daily supply of fresh fruits and vegetables must be provided, sets maximal sugar limits on the preparation of beverages and prohibits the sale of certain prepackaged products that fail to contribute to a healthy diet. Costa Rica joined the efforts of the Pan American Health Organization (PAHO) to formulate the 2011-2021 National Plan for Reducing Sodium and Salt Consumption in the Population (Plan Nacional de Reducción del Consumo de Sodio y Sal en la Población 2011-2021).

g. Comparative advantages of Costa Rica in agriculture

Costa Rica has high national Information and Communication Technologies (ICT); 94% of rural households have access to a mobile phone and 46% to the Internet (INEC, 2015b). This allows useful tools to be developed for farmers using ICT. Costa Rica's agricultural areas also have technical high schools, university campuses, centers dedicated to agricultural research and agricultural outreach agencies with trained professionals, which facilitates the assimilation and implementation of new technologies to improve production processes (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2014). The existence of a wide network of national parks contributes to the protection of watersheds and the conservation of biodiversity and water resources (Programa Estado de la Nación en Desarrollo Humano Sostenible, 2015).

h. International Trade

The agri-food sector remains an extremely dynamic sector that contributes a great deal to the national economy. Of total exports, which amounted to \$9.65 billion USD in 2015, US \$2.45 billion were produced by the agricultural sector and US\$ 335 million by the livestock/fisheries sector. Of all the goods exported in 2015, 22%

corresponded to "medical devices", 9% to bananas, 8% to pineapple, 3% to gold coffee, 3% to syrups and concentrates for the preparation of soft drinks and 2% to fruit juices and concentrates. This accounts for 25% of the total exported goods.

i. Market challenges

Market challenges can be divided into those involving the domestic or national market and those for the export markets. Access to national markets is relatively simple. On the other hand, the international market involves higher costs regarding transportation and packaging, as well as the mandatory or voluntary certifications some destinations now require. Voluntary certifications are varied and may include ISO standards, organic production and good agricultural practices. Quality factors are another major challenge that must be met in accessing markets and ensuring the food supply. Both national and international markets are developing increasingly stringent standards that must be complied with. This is particularly important concerning nutrition, safety and even more tangible aspects such as packaging and preservation, not to mention the increasing concern with environmental protection.

VIII. Abstract

a. Some potential national agricultural scenarios for agricultural production in the next fifty years

If by 2030, there is a 1.3°C increase in the average annual temperature coupled with changes in rainfall distribution patterns, as some models suggest, this will lead to the redistribution of areas suitable for particular crops. As mentioned earlier, areas with most sensitive crops would be reduced, whereas others might benefit (Bouroncle et al., 2015). A potential scenario for the next fifty years would be one in which technological innovations and the value chain, as well as ICT, would determine agricultural production. The opening of markets (through free trade agreements) will probably continue to be a determining policy, meaning that production schemes must be clearly defined. Food security

will continue to be a concern, since the needs of an increasingly large population will have to be met. On the other hand, agrobiodiversity requires a new paradigm for it to be exploited. Climate change is impacting all productive sectors and will continue to play a major role.

b. High-priority actions to achieve agricultural sustainability

Priority actions that will need to be considered to achieve agricultural sustainability are likely to be related to climate change. The impact of climate change at the national level should be monitored efficiently in order to feed mathematical models that will ensure more accurate forecasts and therefore make it possible to design long-term mitigation strategies for each of the country's agricultural regions (Bouroncle et al., 2015). The mitigation and adaptation strategies implemented will directly affect the agricultural sustainability not only of the country, but also at the global level. Moreover, local breeding programs should be strengthened and expanded, either conventionally or through genetic engineering,

while new irrigation technologies should be implemented in traditional and new crops. The aim is to obtain a diversity of plants adapted to the new agricultural conditions and products with higher nutritional quality, to strengthen the country's food security and increase production without expanding the agricultural frontier. If the current production system (agroexport model) is maintained, agreements with countries interested in permanently supplying the demand for basic products should be signed, water collection and distribution projects should be substantially improved, agricultural production systems should be diversified to include other components that will enable producers to improve their incomes and remain in the countryside, internal transport (roads and railways) and transport to external markets (harbors and airports) should be upgraded to improve economies-of-scale, and strategic alliances should be promoted. It is also important to develop new productive opportunities in rural areas in order to reduce migration to cities. In this respect, ecotourism and agroecotourism would have activities that could have a more significant impact on rural families' economy in the future.

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