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Opportunities and challenges for research on food and nutrition security and agriculture in the Americas

Regional analysis prepared from country assessments by IANAS



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Contents

Foreword

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

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

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

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

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

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

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

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

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

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

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

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

Krishan Lal
Co-chair, IAP for Science

Volker ter Meulen
Co-chair, IAP for Science
and President, IAP

October 2017

Introduction

The goal of this report is to assess the current and short-term prospects for food and nutrition security in the Americas (North, Central and South America, together with the island states of the Caribbean). The Inter-American Network of Academies of Science (IANAS) approached this task by working with the academies of science in each country to commission country assessments. The result is a book-length report comprising assessments from 21 countries ranging from Canada in the north to Chile and Argentina in the south, together with one regional chapter covering many of the Caribbean islands (there are separate chapters for Cuba and the Dominican Republic). Some of the chapters are interspersed with boxes that highlight special issues such as gender aspects of food and nutrition security, technological opportunities, novel food sources and policy challenges. More than 200 experts contributed to the various country assessments and we are very grateful to our colleagues in the Americas for their patience and dedication to this important task. The resulting volume is entitled *Challenges and Opportunities for Food and Nutrition Security in the Americas: A View from the Academies of Sciences.*

The present document is a summary and synthesis of key elements of the country assessments. We have tried to identify big picture issues common to the countries of our diverse hemisphere and we have also attempted to highlight special threats and opportunities. In general, we find that the Americas are very fortunate in having an abundance of natural resources together with ample productive capacity and a range of science-based advances in agricultural productivity. Although food insecurity still exists in the Americas, the last generation has seen substantial improvements in food availability and living standards. At the same time, new threats have arisen such the impacts of climate change and environmental degradation, threats to essential water resources (especially groundwater resources), a slowing of the pace of technological advance owing to static public investment, and health related threats associated with foodborne diseases and poor nutrition reflected in the current obesity epidemic.

This project was commissioned by the InterAcademy Partnership (IAP) and supported by the German Federal Ministry of Education and Research through the Leopoldina (German National Academy of Sciences).
It began with a meeting of representatives of the four regional academy networks in Halle, Germany, in June 2015 where the initial plans for the project were mapped out. This summary for the Americas is intended to complement the summaries for Europe, Asia and Africa.

Michael Clegg
Project Coordinator

Summary and major findings

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

The major findings of the assessment of Food and Nutrition Security (FNS) in the Americas are presented in a brief, succinct bullet point format. The detailed arguments that support these findings and their resulting conclusions can be found in the chapters below.

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

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

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

- While STI capacity is substantial among large countries in the Americas, it is less well developed in many smaller countries, making regional cooperation especially important. In almost all countries, universities are crucial in training human capital for food systems and are key sources of research and innovation.
- There has been a long-standing practice of supporting international exchange in graduate education for agriculture and related subjects, but participation by the United States has declined, while increasing opportunities in Brazil and various European countries have, in part, compensated. In general, these exchange practices are not formalized into international governmental agreements and access to infrastructure and financial support varies greatly among countries.
- Broadly speaking, collaboration between universities and research centers is not robust, so it is important to create more stable and dynamic links. The CGIAR centers such as CIAT (International Center for Tropical Agriculture, Colombia), CIMMYT (International Maize and Wheat Improvement Center in Mexico), and IICA (Inter-American Institute for Cooperation on Agriculture, Costa Rica) stand out as an exception by connecting agricultural research throughout Latin America and the world.
- Public investment is essential for agricultural research in all the countries of the region. However, in many countries in the Americas, investment is far below the average of the most developed countries and even below those recommended by organizations such as the United Nations.
- Many countries do not have adequate databases for characterizing the status of their agricultural system and there is insufficient statistical information on the sector.
- The nations of the Americas are not very integrated with respect to agricultural trade and economic policies. A valuable first step is the regional network of public food supply and marketing systems for LAC to promote inclusive and efficient production

and marketing created in 2015 by Brazil, Bolivia, Chile, Costa Rica, Ecuador and Saint Vincent and the Grenadines, but more needs to be done.

- There are very few private companies in the field of agriculture or agricultural biotechnology with their own research programs in most of the countries in the region. The United States, where approximately 60% of the agricultural research investment comes from the private sector, is an exception. Canada follows with roughly 12% of private sector investment.

- Effective collaboration networks between research centers and private companies are crucial, so that efforts in science and technology are focused on solving problems related to the needs of the productive sector.

- In many countries, the link between scientific research and the food and nutrition security needs of vulnerable populations is weak.

- Reducing food waste and loss is a joint task in which all actors – producers, distributors, retailers, consumers, research institutions and governments – must intervene decisively.

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

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

- Poor water quality and inefficient water management are among the greatest environmental challenges for the Americas. The Americas are rich in water resources, but STI-based improvements for water management, especially with respect to optimizing irrigation efficiency, are essential to meeting the food producing potential of the region.

- Periodic droughts exacerbate water management problems; years of high rainfall lead to over-use, followed by economically painful contractions in lean years.

- Water quality is increasingly degraded by unwanted contaminants, including pathogens, fertilizers, pesticides, decomposed plant material, suspended sediment, and other contaminants such as fuels and solvents. Runoff into streams and lakes causes turbidity that is harmful to fish and adds materials that, over time, reduces the volume of lakes and reservoirs. Eutrophication of surface waters due to agricultural inputs such as phosphorus and nitrogen is a continuing problem.

- The focus is shifting from land productivity to water productivity, which requires changes in cropping patterns, innovative irrigation approaches, crop improvement strategies, novel policies and greater investment in research and capacity development.

- Institutions and protocols need to be developed and implemented for groundwater management. Groundwater resources are important as buffers to drought and supplements to surface supplies. There are many instances throughout the Americas where groundwater resources will be prematurely depleted if left unmanaged.

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

- It is important to identify the energy forms that use large amounts of water and to gradually replace them with ones with the potential to reduce water use.

- Innovations in solar and wind energy production have almost no impact on water.

- The water requirements used to irrigate crops grown for biofuels can be much larger than for the extraction of fossil fuels. Biofuel-based subsidies that incentivize farmers to pump aquifers at unsustainable rates have led to the depletion of groundwater reserves and such practices must be discouraged.

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

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

- Most areas of the Americas are facing great challenges related to the destruction and fragmentation of habitat. This is caused by the expanding agricultural frontier, urbanization, tourism and other land and commercial developments, together with changing consumption habits.

- Deforestation in many areas of the Americas has a high impact on quality of life especially for poor and rural populations.

- Deforestation has multiple economic and social drivers including (1) population growth, (2) land use changes (spread of the agricultural frontier), (3) unsustainable economic expansion, (4) poverty, and (5) corruption.

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

- The abundance, incidence and severity of pest and disease attacks is one of the major predictable threats of climate change.

- In situ and ex situ preservation of local genetic resources is an important insurance policy against climate change.

- The Caribbean is particularly vulnerable to environmental degradation and at the greatest risk of climate related disasters. The Caribbean is also the most vulnerable region for FNS, because it is heavily dependent on imports and suffers from a weak, undiversified economy. More attention must be focused on the special needs of the Caribbean region.

- A focus on average climate statistics obscures the fact that it is the extreme events that cause most damage. It will be important to manage for extreme events and to recognize that what were once believed to be 100-year events are now more likely to be decadal or even more frequent. Strategies to minimize risk will become essential tools.

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

- On the basis of the ranking of 25 countries in the 2016 Food Sustainability Index (including measures of food waste, sustainable agriculture and nutritional challenges), the countries in the Americas that were ranked occupy mid to low levels: Colombia 10, United States 11, Argentina 14, Mexico 15, and Brazil 20. This suggests that there are substantial opportunities for further improvement in the Americas.

- An important step forward will be the adoption of the circular economy model of reducing, reusing and recycling in production. This model should promote sustainability and encourage the process of value addition for products such as processed foods, probiotics, prebiotics, nutraceuticals, bioenergies and biomaterials, thereby strengthening and diversifying local economies.

- Modern technologies, such as biotech crops and precision agriculture, are critical to producing more healthy food without increasing agricultural acreage, while at the same time reducing GHG emissions and wastage.

- However, the adoption of modern technologies is slowed by constraints on infrastructure that are common to all countries in the Americas. These constraints include the development of adequate irrigation systems, adequate water and food storage capacity, sufficient transport and road systems, and adequate investment in STI producing institutions.

- Big data and modern Information Technology (IT) offer substantial opportunities to advance sustainable management practices. These approaches can be especially valuable in anticipating and mitigating climate related impacts, enhancing water use efficiency and improving agricultural efficiency.

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

- In several countries in the Americas, a reduction in poverty and malnutrition over the past 10 years has been associated with an increase in obesity. Thus, poverty reduction is a necessary, but not a sufficient condition for adequate, healthy diets.

- Non-communicable Diseases represent the main cause of morbidity and mortality in the United States, Argentina, Uruguay and Chile and impose heavy costs on health care systems.

- More behavioral research is needed to determine how food choices are made and how they can be modified, together with a more rapid assimilation of science-based best practices into the food production system.

- It is crucial to recognize, and incorporate into policy, the key role gender plays in food production, food preparation, food selection and nutrition.

- There is a strong need for more effective systems for water purification and distribution. Safe drinking water remains an important issue in the Americas and has a clear link with the incidence of foodborne disease.

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

regional and global cooperation in STI, and partly on the development of more uniform policy frameworks.

- STI is essential, not only to achieving food and nutrition security, but also to eradicating poverty, protecting the environment and accelerating the diversification and transformation of economic conditions.

- Agriculture is increasingly seen as a dynamic sector, driven by STI, for the transformation of national economies in the future. However, it will be important to generate an enlarged framework for STI cooperation and coordination in the Americas with respect to FNS.

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

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

- It is hard to overemphasize the importance of governance and public policy in achieving both food and nutrition security and in supporting the development of more sustainable agricultural policies. One only needs to consider the present situation in Venezuela where an otherwise well-endowed country is suffering from food shortages, owing to poor public policies.

- There is a trade-off between high investment-high efficiency agricultural systems and small holder agriculture in many countries in the Americas. This social trade-off is a major public policy issue.

- Trade in agricultural products has historically been distorted by subsidies and barriers to market access. These distortions will need to be reduced in the future.

- Most countries in the Americas are in need of better functioning policies and more effective enforcement to promote the sustainability of forest, marine, inland and groundwaters, and all other terrestrial ecosystems and their biodiversity.

- Poverty eradication and food and nutrition security are closely linked goals that must be pursued together.

- The secondary effects of agricultural policies should be taken into account, such as migration of the rural population to urban centers, and impacts on land use and conservation.

- In many countries, regulations relating to such things as pesticide use, overuse of antibiotics, organic agriculture and the reduction of food waste, are inadequate.

- Evidence-based regulation should be improved to more effectively combat foodborne diseases.

- There is an important role for international aid donors and NGOs in advancing STI-based FNS in many countries in the Americas.

- The potential for involving the Organization of American States more actively in facilitating STI-based approaches to FNS must be explored.

Organizations such as IANAS can also accelerate progress by reaching out to national policy makers and advocating for evidence-based FNS policies. IANAS has a significant presence in most countries in the Americas through the national science academies.

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

- The low research participation of the private sector in most counties is deemed a major deficit.

- There is a need for better methods for communicating STI advances and investment opportunities to national policy makers and the public.

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

Michael Clegg
Project Coordinator

Chapter 1
The Americas

Michael T. Clegg

North to south the hemisphere of the Americas extends more than 14,000 km from the Arctic to the Antarctic. It covers almost every conceivable environment from arctic tundra to tropical forest to montane regions and extensive deserts. About 28% of the land area of the Earth is included within the Americas, while the region hosts only about 13.5% of the human population. According to the World Bank, about 10.9% of the Earth's land is arable – that is, under cultivation – while a larger percentage is agricultural (approximately 36%). (Much of the land classified as agricultural is not suitable for cultivation, but includes pastures, open range and grazed forest lands.) For LAC almost 9% of the land area is arable and almost 38% is agricultural. About 16.9% of US land was arable in 2014 having declined from about 19.7% 50 years ago (about 44.6% is agricultural), while Canada's arable land has increased from 4.5% 50 years ago to 5.1% in 2014 (World Bank data, http://www.nationmaster.com/country-info/stats/Agriculture/Arable-land/Hectares). So, the American hemisphere has substantial agricultural capacity.

While land is a primary requirement, modern agriculture is also heavily dependent on energy, water resources, soil quality, and infrastructure investments ranging from transportation to research and education systems. Fortunately, the American hemisphere is well-endowed with various energy resources (Milhone and Estrada, 2015), while water resources are abundant in some regions, scarce in others (Jimenez-Cisneros and Galizia-Tundisi, 2013). Soil degradation is a challenge that requires further attention, especially in improving our understanding and effective utilization of soil microbial diversity. There are also continuing needs for infrastructure improvements in all countries in the Americas. At present water scarcity (or excess) appears to be perhaps the most critical limiting resource, and this, coupled with the uncertainties of climate change, will become a growing issue over the next 50 years.

The total human population in the Americas is about 950 million. According to the United Nations it is expected to grow to 1.2 billion by 2050. (Fewer than 100 million will be migrants. The rest are projected to be born in the Americas.) The rate of population growth in most countries in the Americas has declined substantially over the past 50 years, accompanied by generally improving standards of living. While Canada, the United States, Brazil, Argentina and Mexico make up about three quarters of the land area, the three most populated countries are the United States, Brazil and Mexico, accounting for more than 60% of the hemisphere's human population. The Americas are the most urbanized of the global regions (>80% of the population in urban areas; World Bank https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS) and São Paulo, Mexico City, New York City, Buenos Aires, Los Angeles, Rio de Janeiro are classified as mega-cities (>10 million) with Chicago almost there at 9.98 million.

Levels of economic development vary greatly across the Americas from high to low on the Human Development Index. Haiti is the only country ranked at the low end, while several countries of Central and South America rank at the next level (medium); Canada (10), United States (11), Chile (38) and Argentina (45) rank very high. The remaining countries fall into the high category. Another measure of the progress in the Americas comes from the Millennium Development Goals (MDGs), where progress in eradicating hunger (note that food insecurity and hunger are not the same) has been impressive. For example, hunger in Latin America declined from 15.3% to 6.1% between 1992 and 2014. Another important MDG measure is under-five mortality which declined by 69% between 1990 and 2015, dropping from 54 deaths per 1,000 live births to 17 (MDG Monitor progress, 2015). These gains have been driven by science-based increases in agricultural productivity, improved health systems, broad-based economic growth and improved systems of governance.

There are several important trade agreements spanning parts of the Americas, such as the North American Free Trade Agreement (NAFTA, now subject to renegotiation), MERCOSUR (that includes Argentina, Brazil, Paraguay, Uruguay and Venezuela), the Pacific Alliance (Chile, Colombia, Mexico and Peru), the Caribbean Community (CARICOM) and the Regional Nutrition and Food Security Program for Central America. However, recently the United States withdrew from the proposed Trans Pacific Partnership which would have included Pacific Nations from South America, together with Mexico, the United States and Canada, and a number of Asian nations. At present, further economic integration in the Americas seems a distant dream.

The Americas created the world's oldest regional inter-governmental organization – the Organization of American States (OAS) – between 1888 and 1890. The OAS attempts to coordinate and promote cooperation among the countries in the Americas and serves as a valuable forum, especially in resolving conflicts. But the OAS does not have the quasi-governmental powers of the EU and it has a very limited impact on national food and nutrition policies.

The Americas are fortunate in having substantial scientific and technological capabilities, particularly among the largest countries such as the United States, Brazil, Mexico and Canada. Numerous research collaborations exist between individual scientists in these countries and their counterparts in other less developed countries, both in the Americas and elsewhere in the world. In the case of the United States, basic research collaborations are supported through a number of philanthropic foundations and by government agencies such as the US Agency for International Development (US AID). For example, a novel US AID program (PEER: Partnership for Enhanced Engagement in Research) links US researchers who have funding from any of several government science agencies (National Science Foundation, National Institutes of Health, US Department of Agriculture and other agencies) with researchers in many developing countries. The PEER program is independently administered by the US National Academy of Sciences; US AID provides funding for the developing country collaborators on the basis of competitive grant submissions. Yet, it should be noted that the total amount of research funding is modest and support for developing country researchers is dependent on a collaborative match with US scientists. In Brazil, the São Paulo Research Foundation (FAPESP) is a major player in research support both within the country and externally. The Canadian International Research Centre (IRDC) supports projects on food security, on health and on other critical STI areas in LAC.

The Brazilian Agricultural Research Corporation (Embrapa) has developed very strong research programs in agriculture with substantial international links. Over the last forty years, the real cost of staple food has declined and yield (kilograms per hectare) has tripled in Brazil, owing to the effective application of STI (Vilela et al., 2017) and Brazil has become a research powerhouse in tropical agriculture. A big part of the Brazilian strategy has been focused on human capital development and this strategy has clearly paid valuable long-term dividends. Today, however, Brazil is struggling with a financial crisis, partly owing to a large fall in commodity demand and this has caused major cut backs in government research investments.

Training the scientists of the future is a critical aspect of international collaboration. There has been a long-standing practice of international exchange in graduate education for agriculture and related subjects, but the participation by the United States has declined substantially since the 1990s as costs of graduate education have been progressively shifted from public sources to students. In the past, US AID provided several thousand fellowships per year to students from developing countries for graduate studies in the United States, but beginning in the early 1990s this declined to fewer than two hundred per year. In recent years FAPESP in Brazil has launched an ambitious program of fellowship support for graduate studies and for visiting scientists from elsewhere in the Americas. Today most young scientists from the LAC countries, who aspire to training abroad, seek advanced educational opportunities in Canada, Brazil, Mexico or a number of European countries. In general, these practices are not formalized into international governmental agreements and access to infrastructure and financial support varies greatly among countries.

In general, the nations of the Americas are not very integrated with respect to trade and economic policies. Integration at the scientific level is stronger, but operates largely at the individual investigator level. Advanced training opportunities are also limited, although FAPESP's fellowship programs stands out as a welcome exception. Thus, the approach taken in this project has been, by necessity, a "bottom-up" approach of first assessing the food and nutrition security status of each country and then attempting a synthesis.

Chapter 2
Resource and ecosystem characteristics

Katherine Vammen

The modern industrial agricultural system, born around the start of the 20th century, has helped to feed a massive four-fold increase in the human population. At the same time, unsustainable practices together with large land and resource demands have generated major environmental problems. The accumulation of these problems is sending a strong signal that current systems must become more sustainable (Vandermeer, 2011). In particular climate change and its impacts, land use patterns and soil degradation all present great challenges for the food security of future generations. A better understanding of the relationship between water, energy and agricultural needs and practices, together with climate change impacts, is essential for the development of better management solutions related to food security.

As water, energy and soil are essential for food production, they are directly related to the current and future food security situation. The availability of water with adequate quality, including surface and groundwater, is one of the main problems in all countries in the Americas. "Water is also fundamental to essential biogeochemical, ecohydrological and physiological processes that determine the function of ecosystems (forests, lakes and wetlands) on which the food and nutrition security of the present and future generations depend" (Robinson et al., 2008).

In the Americas there have been massive land use changes in recent decades to accommodate the expansion of agriculture. This now threatens ecological equilibria and biodiversity as well as intensifying regional and global climate change. In this context, it may be useful to recall that perhaps the greatest ecological disaster in North America during the 20th century was caused by the over-expansion of wheat farming into dry portions of the Great Plains of the United States, thus causing the extreme dust bowl era of the 1930s (Egan, 2006).

1. Water resources and challenges over the next 50 years

Between 1900 and 2000 the global population increased four-fold, but freshwater extraction grew nine times. If this trend continues to 2030, the combined effects of a growing global population and continued growth of the global economy will increase the rate of water extraction beyond sustainable levels (World Economic Forum, 2011).

It is important to note that water has no substitutes, nor are there alternative ways to produce an adequate quantity and quality of water for the future without undertaking huge and expensive infrastructure projects associated with water transport, storage and desalination. Consequently, water is becoming a central political issue in many regional and global conflicts, as water in sufficient quantity and quality is essential for safe drinking, agricultural production and for the preparation and processing of food. Globally, agriculture accounts for approximately 3,100 billion m^3, or 71% of water withdrawals today, and without efficient water management policies this will increase to 4,500 billion m^3 by 2030 (The World Economic Forum Water Initiative. Water Security: The Water-Food-Energy-Climate Nexus 2011).

It is important to note that in most regions of the Americas, the availability of water resources is currently good, as evidenced by the Internal Renewable Water Resources (IRWR, computed by adding up surface, runoff and groundwater recharge per capita per year) which is a useful indicator of the availability of water as calculated by Aquastat (FAO, 2015, see Table 1). For example, Brazil has an IRWR of 41,505 m^3 per inhabitant per year which ranks ninth in the Americas; Brazil makes a major contribution to global environmental services through its large expanses of land and water, representing 13.2% of the world's potential arable land (FAO, 2000) and 15.2% of the world's water resources (WRI, 2008).

The Amazon watershed located between Brazil, Peru and Colombia is the largest drainage basin in the world, with an area estimated to be 7,050,000 km^2 and discharging 17% of global freshwater to the ocean. "The Amazon basin is also a key component of the global carbon cycle storing approximately 120 billion metrics tons of carbon in biomass" (Tundisi, 2014). The second largest aquifer system in the world is located between Argentina, Brazil, Paraguay and Uruguay. It is an enormously important source of freshwater and covers 1,200,000 km^2 and has a total volume of 40,000 km^3 and a total recharge rate of approximately 166 km^3/year.

There are regions in the Americas with fewer water resources and some of these could become critical soon, especially as a result of climate change. These regions include the island countries of the Caribbean, the extensive arid regions of Mexico, parts of the southwestern United States, parts of Chile, Bolivia and

Table 1 Internal renewable water resources: comparison of continents and regions in the Americas

Global Region	IRWR m^3/inhabitant per year
World	5,829
Oceania	29,225
Americas	19,725
North America	15,845
Mexico	3,220
Central America	13,922
Caribbean - Greater Antilles	2,367
Caribbean - Lesser Antilles and Bahamas	2,071
South America	30,428
Europe	8,895
Africa	3,319
Asia	2,697

Source: Data from Aquastat, FAO, 2015

Peru and the dry corridor of Central America, among other regions. All of these regions have suffered under extreme drought in recent years creating a lack of water for domestic and agricultural uses, such as occurred from 2014 to 2016. Stressed drought prone regions have recently been forced to prioritize the domestic use for potable water over agricultural irrigation.

There are also areas with high IRWR, but a lack of efficient irrigation systems. Examples include Bolivia (60,744 m^3/inhabitant per year) and Nicaragua (27,624 m^3/inhabitant per year) although both have low levels of irrigation. In Bolivia, only 7.1% of cultivated lands are irrigated, while the remaining 92.9% are entirely dependent on rainfall. "This limitation is exacerbated by climate change, expressed in different ways, such as the extreme drought experienced during the recent agricultural management period (2016–2017)" (Tejada-Vélez et al., 2017).

Another example of climate related impacts on agriculture can be seen in the Caribbean islands. There has been a significant rise in sea level leading to the intrusion of saline waters further inland in some islands which degrades the quality of water needed for food production.

In many regions of the Americas, as the result of poor regulation or inefficient management, groundwater extraction is undertaken without regard to sustainability (e.g. the Ogallala Aquifer in the US High Plains), so there will not be enough water for all economic purposes in the future. In many coastal areas such as Ica in Peru, agricultural production has increased enormously in recent decades by utilizing groundwater as the source for irrigation with the consequent gradual intrusion of saline waters into the aquifers. For example, the surface area devoted to asparagus cultivation in Ica, Peru, increased from 411 to 10,400 hectares over the past decade. However, there is an associated steady decrease in groundwater levels and an increase in saline intrusion, which will drastically impact the sustainability of this agricultural production for the future in Ica.

Canada has vast water resources (IRWR per capita per year of 83,691) and is the country with the highest number of lakes worldwide. However, in many places, unwanted contaminants in surface runoff, including pathogens, plant nutrients, pesticides, decomposed plant material, suspended sediment, as well as fuels and solvents (AAFC, 2017a) have decreased water quality. Furthermore, runoff into streams and lakes causes turbidity that is harmful to fish and adds materials that over time reduce the volumes of lakes and reservoirs (AAFC, 2017a). This is a problem in all countries; it is often associated with changes in land use and can lead to eutrophication in surface waters from the transport of agricultural inputs such as phosphorus and nitrogen. For example, 70% of phosphorus inputs into the Great Lakes have been attributed to agricultural sources (Bickis, 2016). The rapid expansion of oil sand projects is also causing strains on freshwater sources and can lead to many ecological and environmental issues.

Of 1.5 billion hectares cultivated worldwide, about 270 million are under irrigation (18% of the total), although half of the world's food production is under irrigation. In Brazil for example, about 6.0 million hectares are currently irrigated with the potential to increase to 29.6 million hectares. One of the great challenges in developing schemes for improved irrigation is to optimize the application of water with respect to the total crop output. There are numerous research efforts underway to improve irrigation technologies along with the introduction and breeding of crops that need less water in all phases of cultivation. Innovative uses of new technologies to constantly monitor soil moisture and plant development as well as determine the periodicity and the direct need for irrigation at specific times is being applied in many countries in the Americas, including the United States, Canada and Brazil, among others. New incentives for small-scale urban farming are also being introduced in some countries in the Americas. The reuse of wastewater as a more rational water management practice in agriculture is increasing (Figure 1) and is well advanced in several countries including Chile and Mexico, which have progressed the most, with Argentina and the United States following.

At the same time, wastewater reuse requires close monitoring according to the crop under irrigation, because of higher salinity and other possible contaminants.

2. Arable lands, drylands and soil resources

Arable land is defined as land being tilled and under a system of crop rotation, and in 2013 accounted for 1,407 million hectares out of a total 4,924 million hectares used for agriculture (Food and Agriculture Organization of the United Nations). Of the top 10 countries with the most arable land, four are in the Americas: the United States with 1,551 km^2, Brazil 726 km^2, Canada 459 km^2 and Argentina 392 km^2.

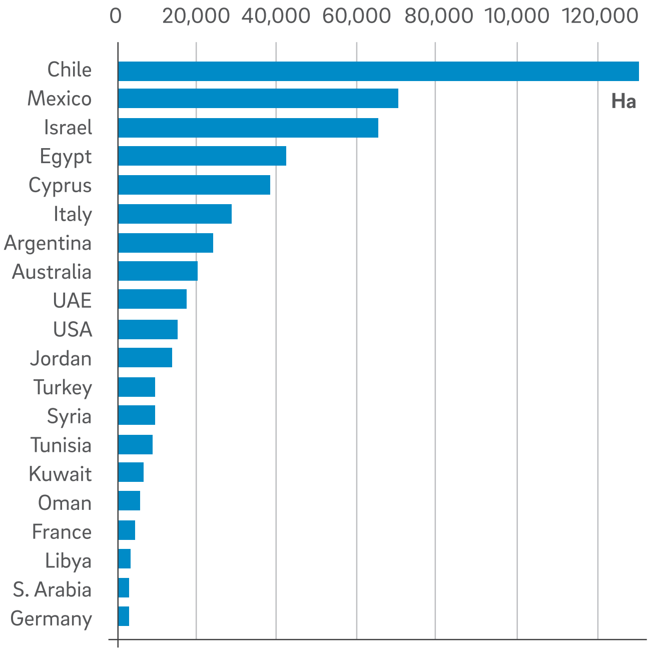


Figure 1 The 20 countries with the largest area under irrigation with treated wastewater (Jiménez, 2006).

There is great diversity in soil type and richness both between and within the countries in the Americas, resulting in some areas with high agriculture potential and others that have limited use. The land potential also depends directly on access to water. Drylands cover approximately 40% of the world's land area and are most prevalent in Africa and Asia, with the greater proportion occurring in developing countries (72%). Latin America accounts for 15% of drylands (Figure 2). But there are increasing efforts to use these dry ecosystems where water is more limiting than land. The focus is shifting from land productivity to water productivity, which requires changes in cropping patterns, innovative irrigation approaches, crop improvement strategies, novel policies and institutions, and greater investment in research and capacity development (Garrido and Rabi, 2016)

Soil degradation is an important problem in the Americas and requires research and innovative technologies to find solutions. The use of chemical fertilizers and pesticides not only contaminates surface and groundwater resources, but may also have a negative impact on soil microbiota and thus soil quality. Excessive and inadequate irrigation practices cause salinization of soils and groundwater, thereby degrading soils and limiting future sustainable uses. In addition,

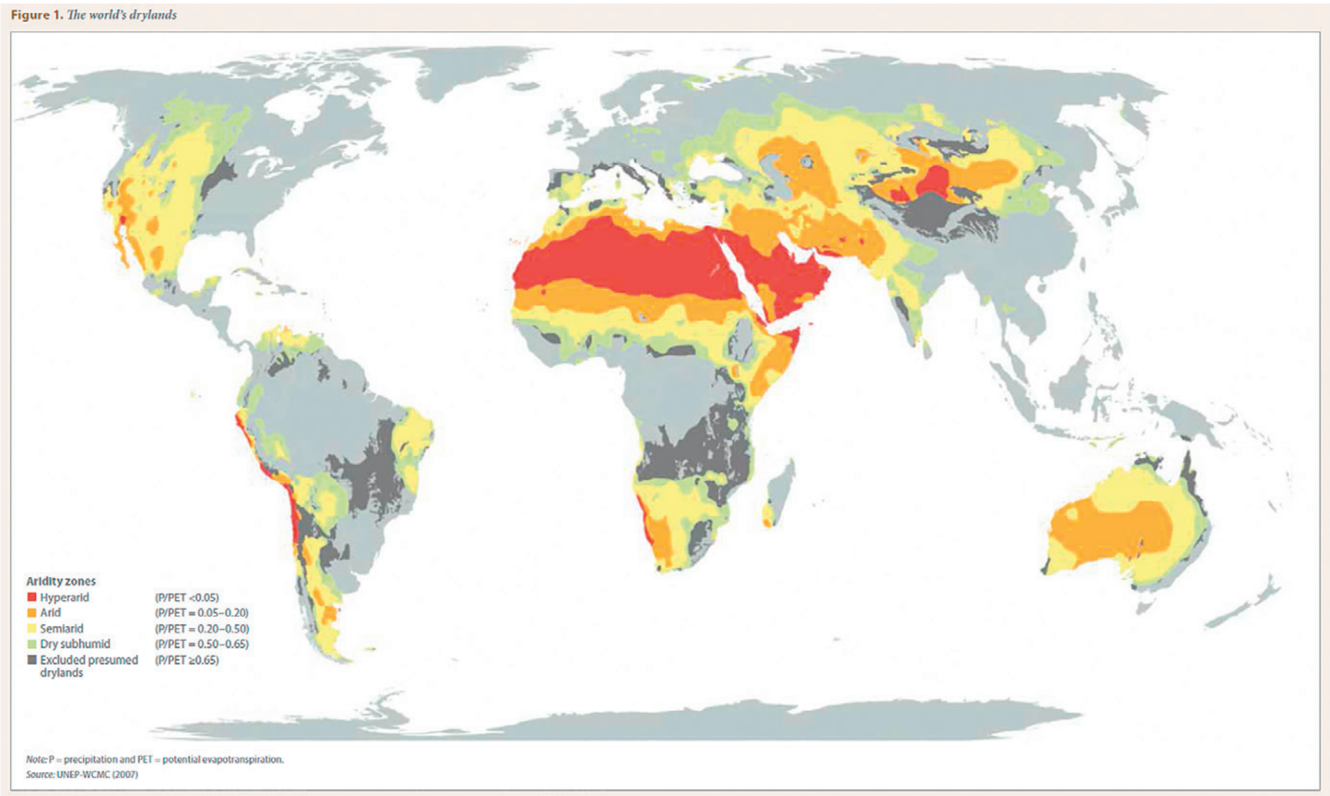


Figure 2 Drylands of the world (UNEP and WCMC, 2007).

excessive mechanization and intensive livestock farming are causing an increase in erosion and a loss of fertility, as reported in Canada (AAFC, 2017a). One approach used to reduce the impact of agriculture on soil quality is through planting without tillage. For example, there are currently more than 33 million hectares being used for cereal production in Brazil, and there have been significant gains with respect to soil protection, conservation and the improvement of the physical, chemical and biological conditions of the soil. Major efforts are also being undertaken to improve soil organic matter in Brazil (Neufeldt et al., 2002). "In the Cerrado ecosystem, a major limitation for sustainability is the low levels of organic matter in the soils. Accordingly, research designed to increase and sustain the organic matter in soil must have a high priority" (Vilela et al., 2017).

Canada recognizes that topsoil is most susceptible to erosion, which threatens soil productivity and can impact crop yields (Natural Resources Canada, 2017). The erosion of soil containing chemical fertilizers and pesticides results in increases in "eutrophication, damaged fish habitats, reduced water holding capacity and lower crop yields" (Bickis, 2016). Low temperatures, water shortage and salinity of the soils in the southern zone of Bolivia are limiting agriculture in this region. In the Caribbean region, "soil erosion coupled with major threats of urbanization, deforestation, land use, cultivation practices, pollution, saline intrusion, erosion hazards and climate change impacts are rapidly degrading and decreasing the arable areas of Caribbean soils" (Wuddivira et al., 2017).

3. Deforestation and its implications

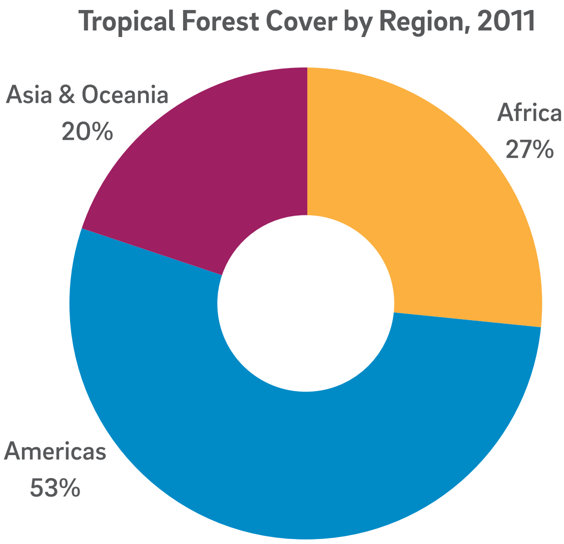
Forests provide environmental, social and economic benefits to regions and nations, so deforestation causes a loss of environmental resources, including losses of biodiversity, destabilizes hydrological systems and affects regional and global climatological conditions. The losses of environmental services can increase vulnerability to flooding and droughts, and contribute to erosion and sedimentation that flows into surface waters and impacts cities dependent on the effected waters. These downstream effects can extend to coastal areas as they may affect fisheries, causing a reduction of marine biodiversity. The specific effects vary according to climate, geology, soils and forest type.

Tropical forests, which represent 44% of all forestry globally (Figure 3), cover 6% to 8% of the Earth's surface and contain over 50% of the planet's species. The Americas possess 53% of global tropical forest areas, located between 30° north and 30° south latitude, in the Amazon basin with smaller areas in Central America and the Caribbean Islands. However, while small in total surface area, the tropical forests of the Caribbean occupy 40% of the Caribbean terrain (Wuddivira et al., 2017). Tropical forests especially contribute to regional and global rainfall. "Tropical forests control in part their own weather. Fifty per cent of the rainfall in the Amazon basin originates from evapotranspiration from plants instead of evaporation from waterbodies. Therefore, if too much forest is cleared, it is possible that rainfall will diminish to the point where tropical wet forests can no longer be supported and reforestation will be impossible." (Spray and Moran, 2006)

The 2015 report on the Millennium Development Goals concluded that deforestation had been reduced owing to a slight decrease in forest loss accompanied by an increase in reforestation. South America and Africa experienced the largest net losses of forest area in the first decade of the new millennium (MDG, 2015). Latin America continues to suffer massive deforestation, with the largest net losses occurring in South America between 2005 and 2010, where 3.6 million hectares were lost annually (MDG Monitor, 2015).

Deforestation is often associated with the expansion of agriculture. For example, in the Gran Chaco ecoregion of Brazil, deforestation has been higher than elsewhere in the Americas and exceeds world averages, following the introduction of transgenic soybean crops. Similarly, in Bolivia, forests with precious woods and high biodiversity are being burned to create pastures (Tejada-Vélez et al., 2017). In Argentina, agriculture is also expanding into native habitat for as noted "The Pampean agricultural expansion occurred at the expense of pastures and the remnants of natural pastures, while expansion toward the northeast took place at the expense of native forests." (Bianchi et al., 2017). In Nicaragua, the UNESCO Biosphere Reserve Bosawas occupies 15% of the national territory and emits 264 million tons of oxygen into the atmosphere. Furthermore, it represents a regulating force for the regional climate of Central America as it adds humidity through transpiration; yet these forests are being lost owing to deforestation at the rate of 42,000 hectares a year (Huete et al., 2017). In general, the conversion of forests to farmland increases erosive processes in all countries and has an extremely negative impact on waterbodies and riparian zones resulting in higher rates of sedimentation, eutrophication and reduction of the regulation capacity of the hydrological regime, leading to higher risks for flooding intensity.

Deforestation in many areas of the Americas has a high impact on quality of life especially for poor and rural populations. Deforestation also illustrates the complex interaction between expanded food production to meet global food needs through export markets with consequent negative impacts on GHG production and climate change. Deforestation has multiple economic and social drivers: (1) population growth, (2) land use changes (spread of the agricultural frontier), (3)



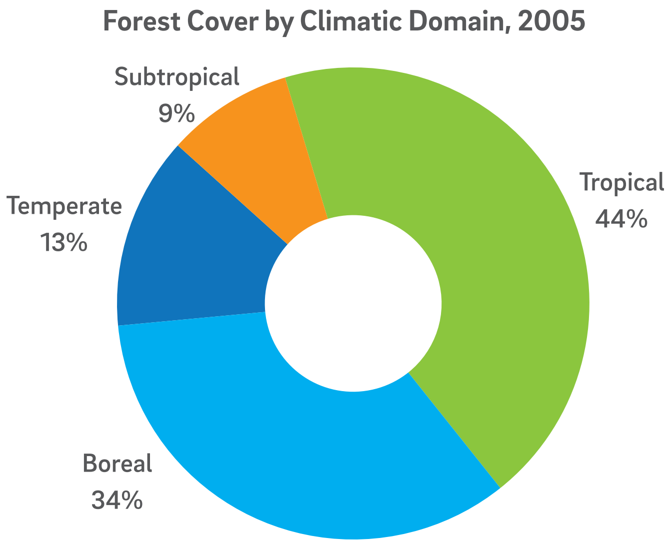


Figure 3 Tropical forest cover by region (2011) and forest cover by climatic domain (2005).

unsustainable economic expansion, (4) poverty, and (5) corruption. While the 2015 report on the Millennium Development Goals concluded that deforestation in the Americas declined slightly (accompanied by an increase in reforestation), it remains a continuing and serious problem.

4. Biodiversity conflicts and challenges

The preservation of biodiversity is essential for the ecosystem services that are directly related to human well-being. Biodiversity plays a direct role in food security, health, clean water and energy production. Almost all countries in the Americas have high diversity relative to their climate zone and geographical characteristics. In Brazil, for example, there are approximately 55,000 plant species accounting for 25% of the world's total number, and the Cerrado Atlantic Forest and Amazon ecosystems constitute the richest plant biomes on Earth. Owing to its closed island structure and diverse ecosystems, the Caribbean region is characterized by a high proportion of endemic plants and animal species. "The exceptionally high diversity of plants includes more than 13,000 species where more than 6,500 can be considered as single-island endemics. There are 26,000 km of coral reefs representing 7% of the total world coral reef ecosystems." (Wuddivira et al., 2017). Some countries such as Brazil are making efforts to take advantage of "native and exotic genetic diversity to improve its main crops and provide choices for farmers to adapt to ecosystem changes."

Most areas of the Americas are facing great challenges related to the destruction and fragmentation of habitat caused by the expanding agricultural frontier, urbanization, tourism, other land and commercial developments, together with changing consumption habits. Natural resources such as water, inland and marine environments are overexploited. For example, in Canada, degradation of ecosystems and habitats due to pollution, climate change, wildlife disease and the introduction of alien species have endangered many species and affected the country's biodiversity (Canadian Biodiversity, 2016). Expansion needs of the agricultural sector have led to decreased intact prairies (13% of the shortgrass prairie, 19% of the mixed grass prairie and almost none of the tallgrass prairie community remains) (Natural Resources Canada, 2017); this threatens many prairie species and leads to the depletion of genetic diversity. Most countries in the Americas are in need of better functioning policies and effective enforcement to promote the sustainability of forest, marine, inland waters and all other terrestrial ecosystems and their biodiversity.

5. Climate change implications

Climate change is affecting all countries in the Americas, albeit with differences in the degree of vulnerability, independent of whether they are high or low producers of GHG emissions. As noted, "Consequently, it has been forecast that climate change will aggravate vulnerability to hunger and poverty, and accelerate environmental degradation in the poorest and most vulnerable countries that contribute the lowest levels of emissions" (Evanson, 2009).

The impacts and vulnerabilities to climate change are illustrated, for example, by Canada (the rate of warming is twice the global rate) where tundra areas are under the influence of rapid warming, and countries such as Bolivia and Peru that are suffering from extreme events ranging from droughts to floods (Tejada-Vélez et al., 2017; Klironomas et al. 2017; Gonzales et al., 2017). These extreme weather events have generated significant losses in agricultural production in all parts of the world, so strategies to cope with the impacts of climate change and assure food security are essential.

The Caribbean countries are especially vulnerable to many effects of climate change. Natural disasters cause widespread damage to agriculture and can impede efforts to enhance food security. "For the period 1990–2014, 182 major natural disasters occurred in the region, affecting 11.5 million people, and causing US $16.6 billion in damage to immovable assets and stock. These included landslides (1%), earthquakes (3%), droughts (7%), floods (30%), and storms/hurricanes (59%)" (Guha-Sapir, 2015). It has also been reported that damage and losses due to natural disasters have increased in the past 15 years. As of this writing, financial losses from hurricanes in 2017 seem to be setting an historical record.

The coastal communities in many countries are also under the threat of rising sea levels and saline intrusion, coastal flooding and infrastructural damage from storms and erosion. This creates seasonal food insecurity, which, in turn, influences trading markets, causing an increase in the importation of food products. Climate change also has indirect effects on crop production, impacting beneficial insects such as pollinators, biological control agents, mycorrhizas as well as the spread of pests and diseases of crops, observed in recent decades.

6. Building resilience to climate change

The majority of countries in the Americas are focusing on the development of new management strategies and techniques to build resilience to climate change. Implementing STI-based solutions for reducing GHGs is very important and can be a win–win by promoting reduced GHGs, while achieving economic savings at the same time. Canada, for example, has instituted management techniques that result in higher carbon sequestration on agricultural lands.

The introduction of monitoring systems and early alert programs for tracking the potential impacts resulting from climate change have been established in many countries. For example, Bolivia reported that "stepped territorialized warning monitoring models are currently being implemented in the country's five main macro-watersheds and rivers, in which monitoring points have been implemented with equipment at hydro-meteorological stations, trained personnel from the municipal RMU and the permanent, active involvement of several dozen indigenous communities, who live near the rivers in these basins" (Tejada-Vélez et al., 2017). According to the research community of Brazil an "obvious key issue for the future of agriculture in Brazil is to improve the understanding of the country's biodiversity and biome characteristics and functioning (Rech and Arber, 2013), and efficiently incorporate this knowledge into agricultural systems to achieve greater production with increasing resilience and sustainability" (Vilela et al., 2017).

The promotion of agroecological management systems to guarantee food security is increasingly being implemented in the Americas. These systems allow better adaptation in cases of extreme events and other environmental changes for highly diverse ecosystems. Changes in methodology such as decreasing tillage, using self-regenerating cover crops, using green manure and related practices are being carried out in many countries. Further improvements in agricultural production with increasing nutritional quality and the sustainable use of resources such as water, energy and soils depend on STI to create capacities and to introduce strategies needed "to mitigate the effects of extreme weather events, increase systems' resilience, and allow adaptation to new scenarios of heightened biotic and abiotic stress, as well as energy insecurity" (Vilela et al., 2017).

7. Management of the water–energy–food nexus

Water, food and energy are interdependent resources that need more integrated management. There are predictions that by 2050 demands for water, energy and agricultural food production will increase respectively by 30%, 50% and 50–70%. This presents a very complex picture and requires effective systems management approaches that will vary between countries. For example, the predicted energy demands increases are 56% for Latin America, 63% for Western Asia, 65% for Africa and 78% in the rest of Asia. Population growth and increasing standards of living play an important role in driving such changes in energy demand.

The World Economic Forum ranked the water crisis as the top global risk (World Economic Forum Water Initiative, 2011), so clearly water resources will need to be used in a more rational way. For example, the production of thermoelectric and nuclear energy requires considerably more water than hydroelectric, wind, geothermal and solar sources. Moreover, solar and wind energy production have almost no impact on water quality. Therefore, it is important to identify the energy sources that use more water and gradually replace them with forms that have the potential to reduce water extraction and use.

The case of biofuels is controversial as the water required for the production of plant material depends on the crop grown and the possible need for irrigation. For example, grain and oil seed crops are generally much more water intensive than sugar cane. "As biofuels also require water for their processing stages, the water requirements of biofuels produced from irrigated crops can be much larger than for fossil fuels. Biofuel-based subsidies that incentivize farmers to pump aquifers at unsustainable rates have led to the depletion of groundwater reserves." (UN World Water Development Report, 2014a).

Chapter 3
National agricultural research systems

Eduardo Bianchi

Introduction

Technology and innovation in agriculture have been decisive factors in economic and social development throughout modern history, which has resulted in significant substitution of capital for labor at the farm level. This increased the labor pool available for industrial development. It also underpinned the increases in agricultural productivity needed to feed a population that grew more than four-fold in the 20th century. Today, genetically modified crops, precision agriculture and advances in animal husbandry are obvious examples of the transformative potential of agricultural innovation. In a scenario of complex challenges related to food and nutrition security, agricultural research and innovation are strategic components essential to driving the transformations that are needed in the future and it is estimated that the rate of return on agricultural research is between 20- and 40-fold (Beachy, 2014).

The wide heterogeneity that exists between the economic structures of the various countries in the Americas translates into a substantial diversity of their national agricultural research systems, infrastructure, human capital, financing and the roles of public and private sectors in the provision of STI.

1. Institutional context, areas of research and infrastructure

Several countries in the Americas began the construction of their national agricultural research systems in the late 19th century, while others did so in the early decades of the 20th century. In all countries, their agricultural research systems were designed to cope with unique national circumstances, while taking advantage of the advances being made in agricultural sciences. A common feature in almost all countries was the creation of public agencies specializing in agricultural research based on a pattern of decentralization and broad territorial coverage. Furthermore, all countries in the Americas have, to a greater or lesser extent, the essential components of a national agricultural research system: government, universities, research centers, private companies, although the degree of interaction among these sectors varies. Within this framework, almost all countries in the region have one or more public agri-food research institutions, either within a Ministry of Agriculture or in a specific government agency that represent the agri-food research capacities in most countries. Although private sector research now plays a larger role in only a few developed countries (such as the United States and Canada), it is low in most countries and this is deemed a major deficit, since for the efficient use of agri-food research it is crucial to include those facets that are largely a private sector activity.

Although universities and public research centers are still by far the dominant STI providers in most countries, there has been a significant growth in the role of non-governmental organizations in recent years. For the efficient use of research in the agri-food area, it is crucial to link capacities with implementation needs that are largely a private sector activity.

In most countries in the Americas, the public sector constitutes the central nucleus of national systems for technology generation and transfer, and, especially for smaller countries, the role of the public sector is essential for technological support to family agriculture, as well as for regional production and the conservation of natural resources. In most countries, the pursuit of food and nutrition security and its linkage with the national agricultural research system is institutionalized through legal instruments such as special laws or is even covered by national constitutions.

On the other hand, research endeavors cover a wide spectrum, with different degrees of sophistication that reflect the enormous heterogeneity of the countries in the Americas. Some countries are world leaders in cutting-edge technologies, such as the implementation of molecular genetic markers for genetic improvement, phytochemistry, bioinformatics, development of new crops and control of diseases and pests. In turn, these have led to important results such as the sequencing and characterization of maize, bean and avocado genomes and the development of wheat varieties. In contrast, other countries, with lower human and material resources, focus their research primarily on a set of products that are essential components of their food basket. The CGIAR centers such as CIAT (International Center for Tropical Agriculture, Colombia), CIMMYT (International Maize and Wheat Improvement Center in Mexico) and IICA (Inter-American Institute for Cooperation on Agriculture, Costa Rica) provide a vital link connecting agricultural research throughout Latin America and the world. For example, the work that formed the Green Revolution began in CIMMYT and has had a global impact.

Despite the enormous disparity of research institutions among the countries of the American continent, it is possible to find some common problems that appear in most countries, especially those in LAC, such as the following.

a. Infrastructure, equipment and facilities (such as laboratories) are, in some cases, obsolete and insufficient.

b. Although, in some cases, there are numerous programs to support agricultural research, plans to integrate these programs by setting priority areas are deficient.

c. There is a need to increase the number of researchers to meet national needs and to ensure that there are qualified individuals to replace those currently in place when they retire.

d. Many countries do not have adequate databases for characterizing the status of their agricultural system and there is insufficient statistical information on the sector.

e. Interdisciplinary and transdisciplinary research is not sufficiently encouraged and, in some cases, remains marginal, where the individual disciplinary approach still prevails.

f. Collaboration between universities and research centers is not robust, making it difficult to create stable, dynamic links.

g. In a number of countries, links between research and the demands of the private sector producers are weak or completely absent, thus causing a dissociation between research results and production needs. Furthermore, in most countries technology transfer from academic institutions to the private sector is poor. One notable exception is the United States where the Bayh-Dole Act and other policies provide incentives for technology transfer from universities to the private sector.

h. In many countries, the link between scientific research and the needs of vulnerable populations in terms of food and nutrition security is weak.

The joint effect of these problems is to limit the ability of some countries in the region to capture innovative research technologies for food and nutrition security. This is compounded by insufficient funding for agricultural research. Public investment is essential for agricultural research in all the countries of the region, although in many investment it is far below the average of the most developed countries or the levels recommended by organizations such as the United Nations. This lack of funding is partly offset by development cooperation funds or external indebtedness.

International cooperation has been, and continues to be, an essential element in the development of agricultural research in the Americas, especially for those countries with less economic development. In some countries, particularly the smaller ones, international cooperation schemes represent a significant part of their agricultural research capacities. There are several international organizations that provide cooperation in different ways including the International Center for Tropical Agriculture, the Food and Agriculture Organization of the United Nations, the Inter-American Institute for Cooperation on Agriculture, the World Bank, the Inter-American Development Bank and European Country Cooperation Agencies.

2. Universities and the development of human capital

Human resources are a critical component of research systems and higher education organizations develop the skills and abilities of individuals in STI and related subjects. Thus, universities are a fundamental element of any national research and innovation system, training professionals and researchers, generating basic and applied scientific research and promoting the transfer of technology and knowledge through university extension.

Most of the countries in the Americas have important universities, both public and private, that play a fundamental role, not only in the training of researchers in the area of agri-food, but also in conducting much of the basic research that is done in this arena, although too often this is not well linked to productive systems. Several of the continent's universities and their research centers maintain collaborative networks that contribute to scientific exchange, which is essential when addressing the growing complexity of food and nutrition security. In this context, the close link between research and university teaching is relevant, since it improves the effectiveness of research and contributes to the updating and intellectual renewal of human resources.

3. Role of the private sector in agricultural research

The participation of the private sector in agri-food research is a phenomenon of increasing importance in much of the world. In the countries in the Organization for Economic Co-operation and Development (OECD), private investment in research and development accounts for approximately 60% of total investment. Although there are no precise data on the magnitude of private participation in the case of most of the LAC countries, private investment is growing, but is still at much lower levels than in more developed countries. The relationship between public institutions and private companies in the development and commercialization of certain technologies is becoming increasingly important in terms of the growth of markets for technological inputs to agriculture. This ranges from the provision of simple services (e.g. pest management services), to the generation of information for the commercialization of the technologies, to research and development contracts based on shared intellectual property. These schemes are similar to those between universities and firms in the most developed countries of the world, linking the innovation capacities that exist in the public sector with the production and marketing capacities that are required for research results to reach end users and to produce more rapid impacts. It is likely that these more integrated approaches will become increasingly important in the LAC region over the next 25 years.

The Productive sectors, as they search for greater competitiveness, are looking for ways to accelerate the incorporation of new knowledge and technologies into the production processes related to agro-food and this is a harbinger of the future. The growing importance of biotechnology and the agro-industrial stages in the innovation process reinforces these trends. However, in most countries of the LAC region there are few agriculture or agricultural biotechnology companies that have their own research programs, while in others the private sector may be relevant to research on specific products, such as coffee, sugar cane, bananas or soybeans. For these reasons the participation of scientists and technologists is necessary for the creation of new technology-based companies, in addition to promoting technological transfer from academic institutions to companies.

4. Research and innovation in the context of climate change

Agriculture is one of the main sources of GHG emissions and, consequently, one of the main drivers of climate change. It is essential to include optimal alternatives for the reduction of GHGs and strategies for adaptation to climate change in the agricultural STI agenda. In most countries of the region, the agricultural research agenda on climate change is dominated by issues related to the emission and mitigation of GHGs, such as soil management practices, land use change and biodiversity. Consequently, the research agenda in adaptation is generally weak, and there are issues of relevance that are not being addressed. Examples here are the adaptation of productive systems versus crop adaptation; innovation and technologies for adaptation; "types" of adaptation and the "paths or routes" of adaptation that offer ranges of options. Incremental, systemic and transformational adaptation are issues that are not being studied and should be strengthened throughout the region.

In most countries in the Americas, multidisciplinarity in scientific research related to agriculture and climate change is weak. This is something that needs to be addressed, including increased intra-regional collaboration.

5. Conclusions

The role of agricultural development policies has evolved over the past half century and continues to evolve. Today there is a pressing need to respond effectively to climate change and to ensure food and nutrition security for growing populations in the Americas and elsewhere. This has stimulated a growing recognition that technological development and innovation are inescapable components of any comprehensive future development strategy.

The main conclusion that emerges from the country assessments and from the account contained in the previous paragraphs is that the current situation of national agricultural research systems in the Americas is very diverse. There are a small number of large countries that represent the majority of the regional capacities, while most of the remaining countries have marked levels of underinvestment. This translates into limited capacities to impact agricultural development in many countries where a strengthening of food and nutrition security is an essential component of future development.

As discussed in the preceding paragraphs, in most countries national agricultural research systems need to be improved with respect to human resources, infrastructure and financing. These deficiencies must be addressed to generate the capacity to effectively mobilize innovation processes in the agri-food sector and to support development aimed at food and nutrition security.

The country assessments performed by IANAS, which are summarized here, reveal both institutional strengths and very significant weaknesses in the national and regional pursuit of food and nutrition security. The identification and correction of these weakness must constitute an urgent agenda that can be most efficiently pursued within an interregional cooperation framework.

Chapter 4
Opportunities for STI to increase the efficiency and competitiveness of sustainable agricultural production in the Americas

Elizabeth Hodson de Jaramillo

1. Introduction

Agriculture is one of the most important economic activities on the planet, but it can be highly polluting and environmentally unfriendly, especially when carried out on an industrial scale. To reduce impacts on natural resources and to conserve the few remaining natural ecosystems on the planet, it is imperative that all countries achieve greater efficiency in food production and utilization, without increasing the area under cultivation. To achieve the goal of food security, while advancing more sustainable agriculture, STI systems must be strengthened and applied to all stages of the production chain from large scale industrial farming to small-scale family farming, found in the different countries in the Americas.

One key step is the wider adoption of the "circular economy model" (based on the principle of materials balance) of reducing, reusing and recycling in production. The circular economy model is based on the law of conservation of matter, where the weight of residuals (e.g. pollutants) of consumption and production is approximately equal to the weight of the inputs to production and consumption. Consequently, the only two ways in which pollution can be reduced are (1) recycle the residuals back through the production and consumption transformations or (2) reduce the amount of throughput. These approaches must also be combined with the promotion of climate-smart agricultural systems (FAO, 2016b). STI has a crucial place in this strategy when adequately articulated with indigenous systems and ancestral knowledge of cultivation and the conservation of diversity. The challenge is to produce more healthy food without increasing agricultural acreage, while at the same time reducing GHG emissions and reducing wastage.

2. Achieving sustainability while increasing the efficiency of agricultural systems

There is enormous heterogeneity in the agricultural systems of the various countries in the Americas, ranging from low production subsistence agriculture to technology-dependent industrialized agricultural systems. Answers to efficiency and production challenges must necessarily be country- or region-specific as there are major differences between agroecological zones and cropping systems and practices. The challenge is to increase efficiency in agricultural productivity in all countries in the Americas while achieving sustainability.

Achieving sustainable and resilient agricultural production involves managing complex systems composed of numerous interacting factors. These include water and soil resources, variation in the incidence of pests, and migration of rural populations to the cities, among others. The application of technological advances that facilitate the rational use of resources and address the constraints of both biotic (pests and disease) and abiotic factors (availability and efficient use of water, soils, nutrients, salinity, soil recovery), together with sustainable intensification, is encouraged in many parts of the Americas. Technologies that are in wide use include biotechnologies and molecular techniques mainly in plant breeding programs, as well as conservation and utilization of genetic resources. Advances in genomics, metabolic engineering, proteomics, reproductive biology and bioinformatics are of great value in increasing agricultural productivity, efficiency and resilience.
On the other hand, the need to better integrate the research and technological development processes with the social sustainability and well-being of the rural population is an imperative. In addition, in some of the countries in the Americas (Mexico and Central America), efforts are being made to encourage technical and scientific training programs to attract young people to the agricultural field. These activities will need to provide adequate incomes and rewarding work.

It is worth noting that Latin America is a privileged area owing to its exceptional abundance of natural resources (OECD-FAO, 2015) and the region's wealth of agrobiodiversity, arable land and availability of water constitute important advantages. The Latin America region is a biodiversity superpower that includes five of the world's ten most biodiverse countries – Brazil, Colombia, Ecuador, Mexico and Peru – as well as the most biologically diverse area in the world: the Amazon rainforest. South America alone is home to more than 40% of the Earth's biodiversity and over a quarter of its forests, 30% of its freshwater and nearly 30% of its arable land, which makes it a genetic reserve and supplier for the planet. These assets also impose major conservation and sustainability responsibilities on the region.

The main producers and net food exporters in the Americas, considered key suppliers for "pantries" for the world are the United States, Canada, Mexico, Brazil, Argentina, Paraguay, Bolivia, Uruguay, Chile, Ecuador, Peru and Colombia. The net trade in agricultural products in the LAC region has increased in recent years, surpassing that of North America in 2002. This upward trend is associated with a significant increase in production, making Latin America the largest net food exporter in the world (according to a report on the State of Agricultural Commodity Markets 2015–16 – SOCO), a trend that is likely to continue into the future (FAO, 2015b). North America is the second largest net exporter, more the result of stagnation in consumption than an increase in production. Projections suggest that Latin America will maintain a surplus position in several commodities, with net exports of coarse grains, oilseeds, sugar (Brazil is responsible for more than 50% of sugar exports worldwide), as well as coffee, fruits, poultry, beef and, in recent years, ethanol. In contrast, the region has negative balances for rice and wheat. North America will continue as the main net exporter of oilseeds and poultry followed by Latin America as the second. Nevertheless, 18 LAC countries are net food importers, which is why it is necessary to strengthen technical and human capacities to promote more efficient agricultural production in the context of self-sufficiency, sustainability and resilience.

In 2015, Brazil, Bolivia, Chile, Costa Rica, Ecuador and Saint Vincent and the Grenadines created a regional network of public food supply and marketing systems for LAC to promote inclusive and efficient production and marketing and to assist the most vulnerable populations. The network seeks to strengthen food supply programs, promote the formation of food stocks, and encourage as well as promote the articulation of public purchasing programs with family agriculture, which produces about 80% of local food in some countries of the region.

3. Role of technologies in agricultural production systems

Most of the countries in the Americas support agricultural practices focused on the achievement of environmental goals such as the promotion of low-carbon agricultural production initiatives and the encouragement of renewable energy associated with second- and third-generation biofuels. It is important to note that progress is already being made towards sustainability; for example, the 2016 Food Sustainability Index ranked 25 countries globally which included several in the Americas among those ranked: Colombia 10, United States 11, Argentina 14, Mexico 15, and Brazil 20. (The Food Sustainability Index ranks countries on food system sustainability on the basis of three pillars: food loss and waste, sustainable agriculture, and nutritional challenges; FAO, http://www.fao.org/fsnforum/resources/fsn-resources/food-sustainability-index.)

For most countries, STI associated with the adoption of advanced technologies is essential for creating improvements in productive capacity, international competitiveness, and the development of an eco-efficient agriculture. STI is even more critical for countries that are not self-sufficient in food production and rely heavily on food imports. To varying degrees, all countries in the Americas have set up national breeding programs (employing conventional, biotechnological and molecular tools) to address the challenges of temperature change, climate extremes (desertification, droughts, floods, landslides, storms, erosion, salinity), variation in precipitation, yield stability, nutritional quality and protection from pests and diseases, which are emerging as a result of changes in climate conditions. An increasing incidence of pest and disease attacks is one of the threats of climate change. The conservation of genetic resources in "in situ" and "ex situ" germplasm banks is part of an insurance strategy in most countries. Physical and mechanical technologies such as precision agriculture (the use of drones or sensors that convey information on soil fertility, water requirements, climatic conditions) are increasingly important contributors to sustainable agricultural production, through more efficient soil and water use, and pest and disease control.

It is interesting to note that major crop producing and exporting countries in the region (United States, Brazil, Argentina, Canada) use genetically modified crops (mainly soybean, maize, cotton and canola – rapeseed). These countries account for about 88.5% of global land devoted to genetically modified crop production (https://www.statista.com/statistics/263294/acreage-of-genetically-modified-crops-by-country-since-2003/). The main advantages are reductions in chemical pesticide use, adoption of soil conserving techniques – such as no tilling – and reduced use of fossil fuels. Other advantages include increased average productivity and reduced conversion of non-agricultural lands to agriculture and less pressure on natural ecosystems. Genetically modified crops also lead to increases in farm incomes, improvements in food security, and reduction of poverty among small farmers in developing countries (Brookes and Barfoot, 2017).

For much of the past 50 years, there has been a relatively rapid rate of growth in crop yields (kilograms per hectare), especially for major commodities, owing in large part to the broad adoption of the technologies of the Green Revolution. This rate of increase is now declining or even stagnating in some regions, especially in the middle latitudes of the Southern Hemisphere (Iizumi et al., 2014). The causes of the decline are not fully understood, but may involve the incidence of climate extremes and the fact that the technologies of the Green Revolution have now been fully exploited. This highlights the critical importance of new technologies in meeting the demand increases anticipated over the next 50 years. Fortunately, there are a wealth of basic science developments that promise to translate into increased agricultural efficiency, including the discovery of genomics, protein engineering, gene editing and a wealth of other tools. Moreover, the world is experiencing a revolution in data-based information technology applications that are already affecting almost all aspects of agriculture, from better, more timely weather information, to precision agriculture and supply chain management.

4. Prospects for new products

In addition to conventional and molecular-marker-assisted breeding programs, several countries are developing their own genetically modified crops. Brazil has made important developments with respect to beans (virus resistant), sugar cane and eucalyptus, as well as potato, papaya, rice and citrus. In Mexico City, CINVESTAV has developed drought-tolerant maize plants, and the Irapuato group of CINVESTAV is developing plants engineered to solubilize and take up phosphorus from the soil, a system that has the additional benefits of providing a weed control system (since weeds require phosphorus) and reducing herbicide use. Additionally, INIFAP (Mexico) is developing citrus fruits with resistance to fruit greening and fungus-protected beans. CIAT in Colombia is employing CRISPR–Cas9 in search of resistance or tolerance to factors limiting production. Costa Rica, in partnership with a private company, is developing a pink pineapple with a high lycopene content, while international centers such as CIMYT in Mexico are developing drought-resistant plants.

5. Animal production systems

Among the technologies most widely used to make animal production more efficient are those related to animal health, especially the prevention and timely treatment of diseases through vaccine production systems and systems for early molecular diagnoses. There is also an emphasis on the conservation and utilization of landraces, where locally domesticated varieties provide a source of traits and have value in selection programs. Moreover, there is substantial interest in the development of animal feed including techniques for the storage, preservation and processing of local raw material as well as additives, for nutritional improvement.

6. Marine systems

A few countries in the Americas have significant technological or innovation activities linked to marine resources, mostly on the basis of already established practices for genetically improving animals including selection and manipulation of reproduction systems. Aquaculture has emerged as a major industry in countries such as Canada, Chile, Mexico, Peru, Argentina and Ecuador. In countries with extensive coastlines, industrial fishing (generally for processing and export) and artisanal fishing (usually for direct consumption or local markets) are important. Environmental regulations relating to the conservation of biodiversity have been put in place in some countries and have moderated overexploitation to some extent.

The development of intensive aquaculture in Chile is based on significant investments in technology and has great similarities with the development of agriculture, especially livestock production. Chile, with an aquaculture industry using introduced species, is now the second largest producer of salmon in the world. It is noteworthy that rainbow trout was introduced into South America and is now used in 50% of the countries ranging from the Venezuelan Andes to the southern areas of Argentina and Chile.

7. Increase in the efficiency and competitiveness of food systems: prospects for increases in agricultural production based on STI

Agrobiotechnologies provide powerful tools for micropropagation or clonal multiplication, biopesticides, virus cleaning, biofertilizers (nitrogen fixation, mycorrhizae and plant-growth-promoting bacteria), marker-assisted selection breeding, genetic transformation or transgenesis (genetically modified crops). The new gene editing technologies (such as the CRISPR–Cas9 technology, among others) have elicited enormous interest because of their potential for meeting various regulatory constraints, developing new crops, improving the nutritional quality of products, obtaining resistance or tolerance to pests and diseases, as well as the capacity to exploit mechanisms of tolerance to abiotic factors (drought, flood, salinity) related to climate change. The gene editing approach has several advantages compared with other molecular improvement systems, including relative simplicity, lower cost, high accuracy and specificity in the modification of genes in plant, animal and microbial cells. Importantly, gene editing techniques may potentially avoid some regulatory barriers, because these products may be considered non-genetically modified as they do not contain foreign genes, which would certainly facilitate widespread application. (It is important to note that regulatory costs constitute a major barrier to the transgenic improvement of all but a few crops with very large market potential.) Although the potential of gene editing technologies to suppress or improve certain characters is enormous, a fundamental knowledge of the relationship between gene and phenotype is still essential.

To meet the social and environmental imperative of minimizing waste by increasing the efficiency of value chains, it is important to adopt the bioeconomy approach, where the by-products of a given process are used as raw material for another process, thus generating new products and services in multiple sectors. This model of bioeconomics promotes greater efficiency in the sustainable use of land and other resources, while taking advantage of the region's enormous natural wealth and local particularities. Furthermore, it facilitates the introduction of new products and sustainable services into the world economy. Adding value to production systems based on knowledge and innovation is essential to increasing profits for producers. The addition of knowledge and technology to obtain processed or semi-processed products is crucial to improving producers' incomes. Improvements of the economic returns to the agricultural sector should focus on value-added products such as processed foods, probiotics, prebiotics, nutraceuticals, bioenergies and biomaterials.

8. Obstacles to the application of new technologies

Among the main obstacles to the development and application of new technologies are the requirements of physical infrastructure (laboratories, equipment, timely access to inputs) and scientific capacity in the case of agrobiotechnologies. Moreover, the level of acceptance of innovations by society can limit the rate of adoption of novel products. The spread of certain innovations may be delayed, owing to negative perceptions associated with perceived risks, excessive regulatory requirements in some countries, or the absence of regulation in others. In the case of physical and mechanical technologies, one limitation is the access of farmers, especially small farmers, to the capital required to purchase equipment and machinery.

Major constraints on infrastructure are common to all countries in the Americas. These include the need for the development of adequate irrigation systems, adequate water and food storage capacity, sufficient transport and road systems, and adequate investment in STI-producing institutions. Strengthening the technologies for processing, packaging and marketing of processed products, as well as access to markets, is also crucial to guarantee a better income for primary producers. This must be complemented with good agricultural practices (GAP) and knowledge of international requirements and standards for markets to assist small- and medium-sized enterprises and innovative entrepreneurs.

In addition, effective collaboration networks between research centers and private companies are crucial, so that efforts in science and technology focus on solving problems related to the needs of the productive sector. It is also essential to strengthen and provide sources of financing that facilitate the incorporation of technologies.

9. Conservation of genetic resources and prospects for underutilized crops as an asset

Owing to the rich biodiversity of the Americas, numerous species have long been used by local indigenous communities and offer enormous potential for food production and food security. This subject has elicited interest in the scientific world and there are several academic compilations on these crops, such as the US National Academy of Sciences "Lost Crops of the Incas: Little Known Plants of the Andes with Promise for Worldwide Cultivation" published in 1989. There is also the "Promising Plant Species of the Andrés Bello Agreement countries" Manual (1989–1998), a collection of 12 volumes with complete information on promising plant species from the Latin American member countries of the CAB, that are fundamentally native, underutilized and little known. These publications contain abundant information on the potential uses of numerous plants which are adapted to regional conditions, including roots and tubers (achira, arracacha, maca, oca, ulluco, mashua and cubio), grains (quinua, cañahua, quiuicha and amaranth), legumes (chachafruto, balú, lupino and tarwi), fruits (chirimoya, mora de Castilla, lulo o naranjilla, lúcuma, passifloras/maracuyá, granadilla, curuba, uchuva), vegetables (Chilli and sweet peppers, pumpkins and the like) and nuts (palma Quito, Brazil nut and walnuts).

Most countries make efforts to preserve their valuable germplasm and seek to strengthen their use in efficient value chains with social, environmental and economic sustainability so that their use can benefit everyone. Examples include the export of quinoa from Peru and Bolivia and walnuts from Brazil and Bolivia. Export trade in tropical fruits is also potentially important. These materials adapted to different conditions also serve as material for the selection of characters of interest for breeding programs.

10. Reduction of food waste and loss

Food waste is a widespread problem and while levels vary among countries, it is close to 30–35% globally. It is essential to develop suitable systems to reduce this waste, and to modify unsustainable patterns of production and consumption. One way to address this problem is the establishment of food banks, which reduce loss due to deterioration and provide food for distribution among vulnerable populations. Food banks are a practical response to the problem of food waste in the world, since they focus not only on access, but also on the use of what is produced and commercialized. The causes of waste can be located throughout the production and supply chain, owing to lack of certifications, lack of quality standards, inefficient management, poor practices, inadequate packaging systems, transportation, distribution and storage infrastructure or lack of training. In addition, the consumer is partly responsible for waste, owing to excessive purchases or improper handling of products.

This challenge can be addressed through the design of strategies for the preservation, storage and distribution of food susceptible to deterioration or, alternatively, to give perishable food products added value through their use as raw material for other processes. In many countries, it is important to strengthen transport infrastructure by connecting trunk distribution hubs and strengthening port capacity. Reducing food waste and loss is a joint task for all participants: producers, distributors, retailers, consumers, research institutions and governments must all intervene decisively.

Box 1 Summary of elements to increase efficiency, competitiveness and sustainability of agricultural systems in the Americas

Strengthening of international cooperation programs including international agencies such as World Bank, Food and Agriculture Organization, UN Development Program, Inter-American Institute for Cooperation on Agriculture (IICA), European Commission.

- Timely transfer of developed technologies and strengthening of scientific and technological capacities among countries.
- Search for technologies that allow better use of the current land area (saving of cultivated land), saving of water (increased yield, crop protection, minimum tillage or non-tillage, precision agriculture.
- Efficient management and conservation of soils. Efficiency in the use of fertilizer and pesticide inputs, and integrated management of soil fertility.
- Use of modern biotechnologies for breeding programs (genomics, bioinformatics, genetic improvement integrated with metabolic engineering), Gene-editing technology (CRISPR–Cas9) will have impacts with its transformer model.
- Development and use of bio-inputs to reduce production costs and ensure sustainability. Agroecology and sustainable intensification are examples of approaches that increase yields and resilience. Use of biofertilizers, biological nitrogen fixation, mycorrhizae and plant growth promoting bacteria.
- Broadening the genetic base: obtaining and introducing new genotypes. Selection and multiplication of crops/animals tolerant to unfavorable environments (high temperatures, water deficit).
- Maintain diversification and use of local species and varieties adapted to regional climatic conditions and better integration with complex ecological processes, to facilitate synergies with natural habitat. Diversification can reduce the negative effects of climate change by its wider range of possibilities.
- Promotion of bioeconomy strategies of recycling and adding value to agricultural byproducts. Applying knowledge and innovation to obtain novel products from agricultural outputs with high added value, through the application of good agricultural practices and production.
- Strengthening value chains at all levels of the process and turning them into production networks with maximum residue reduction (concept of cascade production or circular bioeconomics: every byproduct of one process is useful as raw material for another process).
- Development of capacities in processing and storage to add value in situ to the products from the site production.
- Increased efficiency of food chains to reduce GHG emissions and to augment the resilience of food systems. Additionally, adoption of measures to reduce food losses and wastage and to promote sustainable diets.
- Addressing infrastructure constraints including irrigation systems, adequate storage capacity, sufficient systems and transport routes, organizational and technical constraints on collection, storage, transportation, processing, packaging and marketing, market access.
- Stimulate integrated agrosilvopastoral systems. For example, EMBRAPA in Brazil is implementing a sustainable system of cattle production, which neutralizes GHG emissions within the production system, called "Carbon Neutral Brazilian Beef (CNBeef)". Integrate crop, livestock and tree production into some agroforestry systems

Box 2 Synopsis of systems of agricultural production in some countries in the Americas

In Canada and the United States, partnerships between universities, agricultural research centers, private enterprise and farmers are often found to improve the efficiency, sustainability and resiliency of agricultural production by accelerating the introduction and adoption of the latest advances in technology. Their scientific and technological capacity is outstanding and has had a great impact through the development of technologies such as genetically modified crops which have proven to be environmentally friendly and that contribute to sustainability through an increase of yields while reducing the use of certain chemicals (depending on the technology used and the crop in question). Modern practices have generated greater profits, reduced production costs, and in some cases increased carbon sequestration with the possibility of obtaining tradable carbon credits.

The modernization of agriculture in Brazil has been successful in terms of competitiveness and sustainability through the development and adoption of STI-based approaches for agricultural improvement. Brazil has a solid structure for agricultural R&D, widely distributed throughout the country with a large number of highly qualified researchers. EMBRAPA has made significant contributions to innovation in both the agricultural and livestock sectors. Its goal is to continue to incorporate knowledge and technology to strengthen resilience and sustainability, while at the same time protecting biomes. The bioeconomy approach makes value chains and networks more efficient on the basis of value added to food and industrial products, and increasing exports with high added value products.

Bolivia has historically prioritized a system aimed at self-sufficiency in the production of the main food consumed in the country, taking advantage of its great biodiversity, and the large number of climate conditions associated with differences in altitude. Since 2015, there have been very variable weather conditions in Bolivia, particularly irregular rainfall regimes, which have a direct impact on agricultural production and reveal the lack of productive infrastructure, especially irrigation.

The Caribbean as a whole must address the increase in natural disasters and extreme weather conditions, as well as the overexploitation of natural resources. Agriculture in the region relies mainly on inadequate and outdated technologies, resulting in low and variable productivity of plant and animal crops. Much of the food is imported from other regions. The displacement of pests and diseases in the region is one of the most severe production constraints to be faced.

Chile boasts a solid institutional, political, scientific and technical base that makes it a power in sustainable agriculture and healthy nutrition. It modernized and transformed its systems in the 1960s and has shown significant, sustained agricultural growth based on science, technology and innovation in agroexport models. The most emblematic cases are fruit and the salmonids (Chile being the world's second largest salmon producer). Its path to challenges in agriculture and nutrition continues to meet the highest international standards. It has a solid institutional framework that generates different lines of development with an emphasis on products derived from modern, innovative agriculture that regard the sustainability of natural resources and the food requirements of society as a priority.

Agriculture is a major part of the economy of Colombia and an essential factor in the transition to a post-conflict State. Efforts are being made to achieve "smart agricultural production" to enhance the resilience of production systems, and to promote innovations for adaptation to climate change, as well as to use new technologies and to harmonize them with conventional systems, in accordance with the conditions and particularities of each region and crop. With respect to biotechnological applications, there have been advances in the development of bio-inputs (biofertilizers, biopesticides) and the use of molecular techniques such as gene editing for plant breeding. The concept of bioeconomy, based on the intensive use of knowledge of the biological resources, processes and principles for the sustainable production and conversion of biomass into products and services is practiced in all sectors of the economy.

Costa Rica promotes the use of plants adapted to changing agricultural conditions and the development of products with high nutritional quality that strengthen food security and increase production without expanding the agricultural frontier. Agricultural biotechnology is the field in which more research activities are undertaken at public R&D centers and companies. At the same time, Costa Rica promotes the development of sustainable ecotourism.

Cuba maintains its agricultural production by applying STI through improved seeds and breeding new cultivars, managing inputs, phytosanitary and veterinary control, as well as agricultural management systems and practices. Since the severe economic crisis of the 1990s the government has developed and applied biotechnological advances to address the problems of sustainability in the agricultural sector. A business management model was promoted to increase yields and optimize the value chains of the main agricultural products. The priority has been to use knowledge of the physiological mechanisms of adaptation to counter the effects associated with climate change. Cuba uses biotechnological processes to produce high quality seeds and bioproducts, in vitro and in vivo production technologies for substances of pharmaceutical and industrial interest, as well as applications of genetic engineering and functional genomics to improve agricultural production.

Ecuador believes that it is important to strengthen its STI capacity to incorporate new developments into agricultural production systems. Among the requirements is the adoption of technologies such as precision farming that can significantly increase yields and promote sustainability. In addition, it is important to implement post-harvest treatments to increase the shelf life of fresh produce. Improving preservation techniques will give added value to products.

Mexico has a great cultural wealth from its indigenous peoples, who have interacted for thousands of years with the countries great biological diversity. More than 200 species of economic importance have their origins in Mexico. The country has vast natural resources, with diverse agricultural capacity, but owing to its complex terrain, Mexico has a limited arable land inventory. Mexico has excellent scientific and institutional infrastructure and high competition in STI development. In addition, it has state policies that address the main agricultural, nutritional and environmental problems in terms of sustainability and food security. In agro-biotechnologies, research focuses on obtaining bio-inputs, in the study of the microbiomes of strategic plants for Mexican agriculture such as maize and beans. Despite these advantages, Mexico is a net food importer.

Panama has worked on the conservation, evaluation and use of wild foods, as the genetic basis for the improvement of agricultural products, applying technologies that promote new products and evaluating their nutritional quality. In animal breeding, Panama has established eight nuclei for the conservation of local livestock. It has developed various systems to promote efficient and sustainable production, such as drip irrigation, micro sprinkler and ferti-irrigation systems, which save up to 95% of water, as well as vertical agriculture, with systems under controlled climatic conditions, which is being used in horticultural production.

Peru is recognized internationally for the production of "superfoods" such as quinoa, Kiwicha, cañihua, maca, yacon, sacha inchi, anchoveta, camu camu, purple corn and guanabana. Peru is among the top ten food exporters, so it aims to be a supplier of global importance.

Uruguay is a purely agricultural exporting country, with the capacity to produce food for its population and the world. It is the seventh largest exporter of beef globally and its rice exports account for 2.1% of the world market.

Venezuela has a special situation. The State, the sole supplier of certain staple foods, nationalized the distribution of inputs and seeds. At present, there is a lack of investment in infrastructure and various restrictions on access to inputs, seeds, machinery, equipment and spare parts. The Venezuelan agricultural sector has a number of competitive advantages that could be exploited through changes in macroeconomic and microeconomic policies that would enhance competitiveness, strengthen value chains, substitute imports and increase exports, and change the negative balance of the agri-food trade to guarantee the current food and nutrition security of the Venezuelan population. At present, parts of the Venezuelan population are classified as food insecure, owing to some of the issues cited above.

Several countries in the Americas aspire to strengthen their STI capacities and renew their agricultural production systems as they address the challenges of sustainability and the need to adapt to climate change and environmental extremes. STI is needed to address low levels of productivity, obsolete, inefficient technologies, degradation of natural resources, pest and disease incidence, and the impacts of natural disasters. Thus, for example, Nicaragua has the lowest yields in most of the major crops of Central America. Honduras has low levels of productivity, obsolete, inefficient technology and natural resource degradation and is vulnerable to storm-related risks due to climate change. The Honduran Foundation for Agricultural Research (FHIA) focuses on the improvement of tropical crops, mainly export fruits. Guatemala, on the other hand, has phylogenetic resources of global economic value in the wild relatives of native plants and possesses underutilized species of high nutritional value. Guatemala has made significant contributions to the conservation and sustainable use of these phylogenetic resources.

Chapter 5
Nutrition and public health: risks and opportunities for the future

M. Cristina Cabrera

1. Food insecurity: a problem in the Americas

The Americas include a significant group of large food-producing countries that account for substantial food exports to the rest of the world, but also have a number of countries that are not self-sufficient in staple food production. All countries in the Americas have a certain proportion of their population that suffers from significant food insecurity and, while this varies among countries, the burden generally falls most heavily on children who also constitute the future of the region. Successful policies have been implemented at the school level for children, sometimes supplemented by programs to assist mothers and families, that have contributed to better nutrition and to reducing nutritional deficiencies in a number of countries. However, much remains to be done to ensure food security for everyone in the Americas, where the poor and minority populations experience the highest levels of food insecurity.

At one extreme of the food insecurity spectrum are many of the island nations in the Caribbean, which import about 60% of the food consumed and where about 19.8% of the population (7.5 million people) are food insecure (Wuddivira et al., 2017). Venezuela has also seen a major increase in food insecurity with about 74.3% of the population reporting uncontrolled weight loss (8.7–9 kg in 2016), although this is largely due to policy and distribution failures (Tapia et al., 2017). According to the US Department of Agriculture, 12.7% of US households were classified as food insecure in 2015 (https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics/). Similarly, in Argentina 8.8 million people are food insecure, despite substantial agricultural exports. Accordingly, high levels of agricultural production can and do exist side-by-side with substantial food insecurity. Moreover, a production focus on export commodities can be coupled with a lack of availability of foods of high nutritional value such as animal proteins. Levels of food insecurity are also affected by environmental degradation, climatic events and disasters that can impact food production, as has been recently seen in Ecuador.

2. Micronutrient deficiencies

Food insecurity, whether transitory or chronic, may result in micronutrient deficiencies, particularly iron and heme iron. This has resulted in an increase in anemia, especially in young children, adolescent girls and very young mothers, which compromises the development of the future intellectual capacity, work performance and physical abilities of the individuals affected. Considerable progress has been made in many parts of the Americas to address problems of micronutrient deficiencies through widespread fortification programs. The high level of urbanization in the Americas makes these programs especially effective as a large proportion of the population can be easily reached. There has also been excellent progress in addressing problems of iodine deficiency, which can cause goitre, impair reproductive health and lower IQ, through the fortification of table salt (Pretell et al., 2017). On the other hand, the growing availability of ultra-processed foods among urban populations can present special problems as a cause of increasing obesity and associated chronic health conditions (see below).

Important deficiencies in iron, vitamin A and zinc as well as general malnutrition affect 10.9% of the LAC population. Moreover, these problems are difficult to assess for people living in distant and geographically inaccessible areas, far from distribution centers for fresh food such as fruits and vegetables. In several countries, such as Chile, Uruguay and Ecuador, poverty has been reduced by almost 50% in recent years, as have associated diet-linked deficiencies, but the problem still persists and there is now a deceleration of the rate of poverty reduction.

3. Foodborne diseases: a problem common to all the Americas

Foodborne diseases are present throughout the Americas, with varying severity according to the country. As an example, in Canada, more than 4 million people suffer from food poisoning each year (out of a total population of 36.3 million) resulting in 11,600 hospitalizations and 238 deaths. Of this total, 2.4 million are due to unknown causes and 1.6 million are associated with known bacteria, viruses and parasites. In the subset of cases where the causal agent of food poisoning has been identified, 1 million were due to norovirus, causing just under 1,200 people to be hospitalized with 21 deaths. These figures indicate both the scope of the problem in a wealthy country such as Canada and highlight the deficiencies in public health and regulatory systems intended to protect the public from foodborne diseases. In the Caribbean region in 2015, approximately 135,000 people in Trinidad and Tobago (approximately 1 out of 104 people) each year suffer from diarrhea probably because of consumption of a contaminated food or drink. Dehydration associated with diarrhea is especially dangerous for small children and can be a major source of childhood mortality.

Industrial-scale food production and long transport networks can contribute to serious foodborne disease outbreaks. For example, an increased incidence in foodborne disease outbreaks in the United States has been traced in some cases to new practices in farm and agricultural production where waste from large animal feed lots is transported via water to nearby large-scale vegetable processing facilities (Allen et al., 2017). Increased time in transport may also be associated with the emergence of food pathogens, such as *Escherichia coli* O157, *Campylobacter jejuni*, *Salmonella enteritidis*, *Listeria* and *Vibrio cholerae*. These changes may also increase the risk of food exposure to antibiotic resistant pathogens such as *Salmonella typhimurium* DT104, various noroviruses and rotavirus, and agents that cause transmissible encephalopathies (prions). Moreover, exposure to chemical residues and contaminants originating from the environment and/or agricultural and industrial practices (mycotoxins, persistent organic pollutants, heavy metals) may increase as a result of longer transportation times. Prepared foods based on ingredients originating in different parts of the world and requiring more time from preparation to consumption may also present a higher risk of contamination. But, poor food preparation infrastructure, particularly the lack of clean water, is the main cause of foodborne illness in the poorer areas of the Americas, regardless of the country in question.

4. Obesity in the Americas: a growing nutritional problem

The Americas present a paradoxical situation, where food and nutrition insecurity coexists with a high incidence of obesity, a growing situation that affects a high proportion of children and women. Countries with high agricultural production, such as the United States and Argentina, have the highest rates of obesity, 36% and 23.6% respectively. The most worrying problem is the increasing obesity in school children, with frequencies among children under 6 at 10% in Chile, 13% in Canada, and at 7.3% among children under 10 in Argentina. In other countries, malnutrition, food insecurity and obesity coexist to a greater or lesser extent, correlating with an increased incidence of chronic diseases related to obesity.

The causes of the obesity epidemic are varied and sometimes controversial, but the incidence of obesity appears to be related to the wide availability and consumption of highly processed foods. Some studies have concluded that there is a direct relationship between the consumption of excess carbohydrates, sugar, salt, processed meats and dairy products, with weight gain and an associated loss of fitness (Marino. 2017). Highly processed foods tend to be rich in flours and sugars with a high concentration of calories (Bove and Cerrutti, 2008), but since they are cheaper than healthy foods, it is the poor who are especially vulnerable to this perverse form of malnutrition. Highly processed foods tend to be rich in flours and sugars with a high concentration of calories (Bove and Cerrutti, 2008). Men consume fewer fruits and vegetables than adult women, a trend that is also seen in school age children which further complicates the nutritional situation (Cabella, et al., 2015). Changes in eating habits have been shown to parallel more sedentary lifestyles where exercise is infrequent, exacerbating chronic health problems and increasing the burden on public health systems. Obesity and micronutrient deficiencies can co-occur, as found in a study in Ecuador, where in over 13% of households, an overweight mother lives with a child with stunted growth, and a third of women of reproductive age suffer from overweight and zinc deficiency (Aguirre et al., 2017). This study suggests that the "double burden" of obesity and nutrient deficiencies results from excessive carbohydrate (rice) consumption combined with a low intake of fruits and vegetables. Finally, in several countries in the Americas, a reduction in poverty and malnutrition over the last 10 years has been associated with an increase in obesity. Thus, poverty reduction is necessary, but must also strive to include adequate, healthy diets.

5. Nutrition, lifestyles, and loss of healthy eating habits: a challenge for the future

In most countries in the Americas, over-consumption of high-calorie foods, especially when associated with low physical activity, increases the risk of chronic non-communicable diseases such as obesity, metabolic syndrome, cardiovascular disease, type 2 diabetes and certain types of cancer. These diseases are generally characterized by an excessive intake of macronutrients or an insufficient supply of micronutrients. It has been documented in several countries in the Americas that overconsumption of food often coexists with deficiencies of vitamins and minerals, and with low ingestion of bioactive components of healthy food protectors (FAO, IFAD, UNICEF, WFP, and WHO, 2017). Non-communicable diseases represent the main cause of morbidity and mortality in the United States, Argentina, Uruguay and Chile (IANAS, 2017). Overall, hypertension in adults is of the order of 40% in men and 30% in women, but is less than 10% in 15- to 24-year-olds and exceeds 60% among 55- to 64-year-old adults. The prevalence of hypertension in the adult population in the Americas has increased more than 5% in the past decade and hypertension is now emerging as a worrying public health problem in children.

The food and nutritional status of the Americas threatens to compromise the health of future generations. Accordingly, science-based improvements in food regulations are essential to both control foodborne diseases and to promote the consumption of healthy foods. It is crucial to educate children on food issues and to facilitate access to healthy foods. As always, lower-income populations are more vulnerable, but vulnerability extends to all segments of the population.

More behavioral research on how food choices are made and how these decisions can be modified is needed along with a more rapid assimilation of science-based best practices into the food production system. In this context, it is especially important to recognize the crucial role of women in selecting and preparing foods in family households (Henry et al., 2017). Strong, effective public policies are required in all countries in the Americas to achieve sustainable changes that shift consumption away from harmful foods and promote healthy diets.

Chapter 6
Science and policy context

Eduardo Bianchi

Introduction

As illustrated by the country assessments in the IANAS book on food and nutrition security, countries in the Americas are characterized by a high diversity of ecoregions, landscapes, soil resources, biomass and species. While there are large regional variations in physical, chemical and biological characteristics, the region as a whole is endowed with significant reserves of arable land, in relation to its current population. The region is also rich in water, possessing a large share of the world's renewable water resources, giving it an advantage in relation to other regions of the world. Likewise, countries in the Americas harbor very high biodiversity at genetic, species and ecosystem levels. For these reasons, the region of the Americas has substantial potential for increasing food production.

Moving from the hemispheric scale to a national scale, there are significant differences between countries and geographic areas as regards levels of economic development and resource distribution. These differences result in an unequal distribution of capacities, meaning that there are disadvantaged areas, both within and between countries, in infrastructure development and the availability of natural resources. Accordingly, we must have a vision in the Americas that is not only global but also local. Thus, one objective of this chapter is to better align the perception of opportunities and challenges in food and nutrition security with the current realities; a fundamental step in developing a policy vision that better serves the Americas.

The heterogeneity of the distribution of natural resources and the disparity in levels of economic development within the region make it difficult to construct a public policy agenda that is valid for the entire region. Country-specific policies are presented in each chapter of the IANAS assessment report, so in this section we focus on policies that are clearly common to all countries, together with some reflections and suggestions intended to better frame a public policy agenda that can advance food and nutrition security for all the populations in the Americas. There is therefore a need for coordination and cooperation among the countries of the region on the basis of (1) the role of STI in the repositioning of agriculture; (2) the importance of overweight and obesity in our populations; (3) the relationship between poverty and food security; and (4) the role of international trade.

1. Institutional framework

All the countries in the Americas have, to a greater or lesser extent, normative frameworks that promote the FNS of their populations. Despite the wealth of natural resources in most of the countries of the region and the advances of the past two decades, food and nutrition insecurity is present in all countries. At the same time, food and nutrition insecurity is clearly linked to high levels of poverty and the poor are among the most vulnerable in all countries.

It is important to note that there are no supranational agencies that establish policies for food and nutrition security in the Americas, unlike certain other world regions. Thus, in most cases, policies are established at the national level, with little or no coordination and cooperation among countries. This situation stands in sharp contrast to more modern conceptions of FNS that adopt a holistic approach and see FNS as embedded in a set of interrelated national and global problems with multifaceted and multidimensional aspects, where effective solutions require stronger international integration. Many of these interrelated aspects, such as climate change, obviously require cooperative solutions between countries, so a first conclusion of public policy is that it is necessary to build an enlarged framework for cooperation and coordination among the countries in the Americas for the discussion and implementation of FNS proposals. In this regard, the potential for more effectively involving the Organization of American States in FNS issues needs to be explored along with the role of non-governmental organizations present in most countries that work in FNS areas. There is also a need for deeper engagement by major donors, for example US AID, which, while heavily engaged in programs to enhance food security, tends to work through country missions while relegating integrative and regional issues to a lower priority (Clegg et al., 2017). Lastly, IANAS can be effective in advocating for evidence-based approaches to FNS, because IANAS has a significant presence in most countries in the Americas, through their national science academies.

2. Research, innovation and the repositioning of agriculture

At present, several factors point to an "epochal change" in the role of agriculture in society in the Americas. The long period of low incentives for agricultural development seems to be coming to an end and there are signs of a repositioning of the role of agriculture in development strategies. Agriculture is increasingly seen as a dynamic sector and an agent for the transformation for national economies. There is frequent mention of a new bioeconomy, where, in addition to the traditional function of producing food and fiber, agriculture is also seen as playing a strategic role in building a society less dependent on fossil fuel resources, through the production of more environmentally friendly energy and industrial raw materials. This epochal change anticipates a period of innovation and a range of new agricultural research opportunities.

Agriculture has a critical and irreplaceable role in ensuring poverty reduction, food security and environmental sustainability. Moreover, agriculture is strongly integrated into industrial processes through, for example, the production of renewable raw materials from plant biomass and energy production from microbial-based photosynthetic processes. These provide material and energy for all kinds uses, thereby generating a wide range of opportunities for economic and social development. In this context, science, technology and agricultural innovation play a key role, not only in achieving food and nutrition security, but also in eradicating poverty, protecting the environment, and supporting and accelerating the diversification and transformation of economic conditions.

STI is essential to address the multidimensional nature of food security. For example, genetic modification and irrigation technologies can improve agricultural productivity, bio-enrichment can contribute to more nutritious food, and climate-smart solutions (including precision farming and early warning systems) can mitigate certain factors that cause food instability. In addition, new and emerging technologies, such as synthetic biology, artificial intelligence and tissue engineering, can have major consequences for the future of crop and livestock production. To take advantage of the transformative potential of technology, it is essential to develop national/regional innovation ecosystems, with the support mechanisms and necessary infrastructure to promote the high levels of agricultural innovation that will be required for the future through the promotion of regional and international cooperation. Finally, agricultural research and innovation are central to adaptation and mitigation in the context of climate change and the goal of sustainability.

3. Policy issues associated with excess weight and obesity

As the IANAS assessment report shows, all countries have a high incidence of overweight and obesity both in children and in adults, with an associated significant increase in non-communicable diseases. The most advanced policies available include clearer and more comprehensive information to consumers about the nutritional content of food through labeling, regulations for advertising to children under 14 and for the sale of food in educational establishments, as well as higher taxes on unhealthy food and drink.

Progress also requires better procedures for the collection of high-quality statistical data for risk assessments and for policy formation. It is important to encourage systematic data collection on the nutritional and health status of populations and behavioral habits that influence food choices through carefully designed consumer surveys. It is necessary to promote the development of new foods with improved nutritional profiles and to instill healthy lifestyles in the population, tailored to different age groups and to people requiring special regimes. It is also crucial to promote public policies that encourage the incorporation of new technologies into the food system (such as processing, functional foods and nanotechnology). Lastly, attention should be paid to the fact that in many cases unhealthy foods are priced lower than healthy foods. This makes the population in poverty especially vulnerable to problems of malnutrition, and specific policies to address this vulnerability should be considered.

4. Poverty and food and nutrition security

Agricultural research and innovation is essential to increase the availability of healthy food, but the "access" dimension of food security must not be left out of the public policy agenda, as it is closely linked to poverty. As documented in the IANAS assessment report, a significant fraction of the populations of the Americas lives in poverty. No progress can be made in achieving food and nutrition security if, in parallel with the increased availability of healthy food, no progress is made in creating and implementing policies to eradicate poverty. Great strides have been made in poverty eradication in the Americas, mainly owing to government income transfer programs through, for example, social plans. However, there is no doubt that these policies are a second-best alternative and that strengthening the labor market is the best option. This requires a context for appropriate macroeconomic policies that encourage sustained economic growth and minimize the variability that has historically occurred in several countries in the region.

5. The role of international trade

Projections on world food production and consumption indicate that the geographic divergence between production and consumption will increase. Therefore, international trade will become increasingly important as a mechanism to balance needs and availability. Accordingly, there is and will be a growing linkage between food security in many countries, particularly those that are net food importers, with the trade policies of other countries, which are generally net food exporting countries.

Trade in agricultural products has historically been distorted by subsidies and barriers to market access. In addition, in the context of the sharp increase in food prices in 2007–2008 and 2011–2012, there was a proliferation of policies aimed at improving or preventing a worsening of food security in many countries. Several of these policies were defensive and some of them had negative impacts on international trade, further damaging food security problems, mainly in net food importing countries, by amplifying price increases and volatility. Examples of these policies include domestic production support, export taxes and quantitative restrictions, including bans on exports. For their part, net food importers also contribute to this vicious circle by reducing border measures.

In this way, a "prisoner's dilemma" was generated by the intervention of both exporters and food importers, in which all countries lose. The way to get out of this situation is not through individual actions by countries, but by agreed multilateral actions such as, for example, the World Trade Organization (WTO) agreements. In this way, confidence in international trade as a reliable source of food products can be restored, even in periods of increases and price volatility. In periods of increasing food prices, countries can resort to non-commercial measures to protect vulnerable populations. Stable food prices in a globalized world is a global public good that requires a cooperative approach on the part of the countries.

6. Other specific policies

In addition to the policies listed above, which must constitute an agenda of priorities for the countries of the region, the following should also be taken into account.

It is important to strengthen policies for the education and training of human resources working in different aspects of food systems as well as in in agro-food research and innovation. In several countries in the Americas, there are insufficient skilled human resources and the number of qualified people has even decreased in recent years, partly because of population aging.

The secondary effects of agricultural policies should be taken into account, such as migration of the rural population to urban centers and land use and conservation practices.

All countries should develop policies that promote best practices in the use of natural resources: soil, water, forests, biodiversity.

Regulations are inadequate in several areas, such as pesticide use, overuse of antibiotics, organic agriculture and the reduction of food waste, among others.

7. Conclusions

In the near future, it will be necessary to meet the demands of a global population that is expected to reach nearly ten billion by 2050. It is predicted that, owing to population increase, combined with changing dietary demands, there will be an up to 70% increase in food demand over current levels. At the same time, it is crucial to significantly reduce the number of people (>700,000,000) currently living in extreme poverty. Lastly, the problem of failed states has continued to be a major source of instability in recent history and international mechanisms to ensure some level of food security to populations in jeopardy is essential to minimize the risks associated with uncontrolled migration, terrorism and wars.

The region of the Americas has immense wealth in land, water and biodiversity resources, which are of great strategic value to the world of the future. The region may be called on to play a critical role in the construction of a new global equilibrium, in terms of food supply. However, the innumerable problems of food and nutrition security, which are currently present within the countries that make up the Americas, must also be addressed as a larger global role is assumed.

Chapter 7
The Way Forward

Michael T. Clegg

Some areas of science are explicitly about predicting the future. For example, demography uses well-defined models of population growth to predict future population, climate science employs complex computer models to explore and evaluate future climate scenarios, and astrophysics tries to predict the future of the universe. So, what can be said about future food and nutrition security in the Americas? To begin with, we can use the models of demography and climate science to help envision plausible futures and ask how productive capacities and environmental constraints fit into these scenarios.

Considering demography, the predictions for population growth in the Americas are probably manageable. Birth rates have declined and public health outcomes have improved. The population of the Americas is projected to grow by roughly 250 million by 2050, compared with a global growth of about 2 billion. Demand is predicted to grow at approximately twice the population rate as people shift to more protein-rich diets. This seems manageable given the wealth of natural and human resources in the region and the rapid technological advances.

Climate change is more difficult, both because fine-grained models that make predictions at regional and national levels are still being refined and because there is a strong interaction between food production and the production of GHGs. Some regions of the Americas are likely to be negatively affected, including the Caribbean and Central American regions together with the deserts of northern Mexico and the southwestern United States. Extreme northern and southern latitudes (Canada, Alaska) will be strongly affected, but whether this will be a net negative or positive effect is as yet unclear. Large storm events will be more disruptive of agriculture, variation in weather will increase and periodic droughts are likely to be more intense. There is clearly room for much more scientific research on problems of mitigation and adaptation. There is also a strong need for more research on sustainability choices so that we and our descendants can preserve the productivity capacity of the Earth. Finally, there is a great need for evidence-based policy designed to prevent the worst outcomes of climate change.

Beyond making these general predictions we must focus on potential: in other words, what can be achieved with the right policy environment and with the continued strong inputs from STI? What are the key decision points that will help ensure the goal of food and nutrition security? Ultimately, these represent collective choices, so we have the power to determine our future. In the bullet points below, we identify some of the elements that must be addressed to ensure future food and nutrition security.

The region of the Americas has major potential for growth in food production. The challenge is the realization of this potential while preventing further environmental degradation and meeting the needs of vulnerable populations. This challenge can only be met through fully exploiting STI-based knowledge in all countries in the Americas.

- Future progress in providing an adequate and nutritious food supply will partly depend on greater regional and global STI cooperation, and on the development of more uniform policy frameworks. It will be important to generate an enlarged framework for STI cooperation and coordination to accelerate the spread of best practices and to gain economic efficiencies.

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

- New technological innovations show great promise for the future. It will be important to accelerate the rate at which promise is turned into practice. We live in a period driven by revolutionary changes in data acquisition and analysis that affects all aspects of the food and nutrition system. These technologies should enhance efficiency in food production and utilization and provide powerful tools for managing environmental and sustainability challenges. But an essential first step for many countries is enhancing data collection and statistical tools to better assess and respond to FNS challenges.

- There is a need for expanded STI training opportunities to build the human capacities required to secure FNS in the future. There also is a need for access to sophisticated equipment and infrastructure to support advanced STI opportunities. This is especially true for the smaller countries in the Americas.

- More needs to be done to assure a healthy, nutritious food supply and to combat the current obesity epidemic. This will require research on behavioral choices and improved public education regarding food choices.

Water is a major limiting resource for food production and for sanitation, food preparation and numerous other essential functions.

- STI-based improvements for water management, especially with respect to optimizing irrigation efficiency, are essential to meeting the food producing potential of the region. The focus is shifting from land productivity to water productivity, which requires changes in cropping patterns, innovative irrigation approaches, crop improvement strategies, novel policies and greater investment in research and capacity development.

- It is vital to identify the energy forms that use large quantities of water and to gradually replace them with ones that have the potential to reduce water use. Biofuel-based subsidies that incentivize farmers to pump aquifers at unsustainable rates have led to the depletion of groundwater reserves and such practices must be discouraged.

- Most countries in the Americas are in need of better functioning policies and more effective enforcement to promote the sustainability of forest, marine, inland and groundwaters, and all other terrestrial ecosystems and their biodiversity.

As with all regions of the world, climate change poses a major threat to FNS in the Americas. More precise models for the prediction of impacts are essential as is research on mitigation and adaptation strategies.

- The Caribbean and Central America are particularly vulnerable to environmental degradation and are in greatest jeopardy with respect to climate related disasters. The Caribbean is also the most vulnerable region for FNS, because it is heavily dependent on imports and suffers from a weak and undiversified economy. More attention needs to be focused on the special needs of the Caribbean region.

The agricultural economy of the world is likely to become further globalized. Countries with ample resources will need to help solve the problems of countries which lack these capacities. The biggest threat to FNS is political instability and failed states. Uncontrolled migration, wars and political instability all flow from inadequate resources and productive capacity, and the spill-over of these problems to other better endowed countries is well documented. Resource shortages and climate change can accelerate these kinds of disruption and STI must play a major role in understanding, analyzing and mitigating these threats.

If the recent past is prologue, then we have every reason to expect that the Americas will continue to reap the benefits of science-based advances to meet the needs of an expanding human population, while also reducing environmental degradation.

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