CHAPTER 3
AGRICULTURAL KNOWLEDGE AND TECHNOLOGY IN LATIN AMERICA AND THE CARIBBEAN: PLAUSIBLE SCENARIOS FOR SUSTAINABLE DEVELOPMENT

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Key Messages

1) By building five scenarios, : Global Orchestration (GO), Order from Strength (OS), Life as it is, Adapting Mosaic (AM), and Technogarden (TG) future alternatives are provided to answer the question: "How can we reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially, and economically sustainable development through the generation, access to, and use of agricultural knowledge, science, and technology?"

2) These scenarios present different challenges that require complex adjustments in order to ensure the successful performance of AKST systems and productive systems. The scenarios show us that in the real world of Latin America and the Caribbean, it is not feasible to think in terms of simple technological solutions or global solutions to respond to the growing complexity and vulnerability of these systems.

3) In most of the scenarios, the AKST systems have favorable social and environmental repercussions for society as a whole. Science generates innovation and helps improve competitiveness and production efficiency, and the quality of the products in terms of safety, diversity, bromatological quality, and nutritional value for all social groups (including the most vulnerable ones, depending on the scenario), and reduces the impact of agricultural activities on the environment.

4) The existence of trade barriers of different types would increase the cost of agricultural activity and threaten the sustainability of small farms, and it would create specific demand for AKST systems. The scenarios assume different types of barriers, which would expand over time, as a result of difficulties stemming from various factors—environmental, economic, and biological—even in the scenarios depicting a highly integrated and economically open world (GO and TG). These barriers, which could lead to the loss of important markets and a reduced capacity for economic insertion on markets suitable for small-scale agricultural producers, would be eliminated with good policies and management capacity. The barriers would in turn generate demand for AKST systems to create mechanisms and protocols that would allow for adequate compliance with international laws and rules pertaining primarily to the most vulnerable productive systems.

5) The scenarios assume institutional changes of varying intensity in the region. In some scenarios, the changes would accompany the current development model, which shows trends towards greater stability and consistency among social development, environmental, food, innovation, and biosafety policies, and greater capacity to manage these policies (except for *Order from Strength*). But

deep-seated institutional changes--such as changes in the paradigms of agriculture itself, and consequently in the AKST system and in the expansion of power of various interest groups—would be required to introduce and implement successfully the *Adapting Mosaic.*

6) Losses in productivity of productive systems in response to variations in the contextual factors vary in the different scenarios. Rising temperatures, the manifestation of extreme weather events, and an increase in diseases, pests, and contamination of foods are contextual factors that have a differential impact on production systems in the different scenarios. More specifically, the greatest losses would occur in scenarios that emphasize trade or the ones that predict a limited capacity to prevent and eliminate or reduce epidemics (the case of *Order from Strength*).

7) Agribusiness in LAC would diversify and expand differentially, and small producers would face challenges. In some scenarios, new uses would be added for existing or new commodities. In various scenarios, the participation of a limited group of countries in markets of differentiated products would develop. These markets would require substantial inputs of knowledge and technology (in the case of differentiated products) or production on a large-scale (in the case of commodities). Small producers in Latin America and the Caribbean would be challenged to meet these requirements.

8) In some scenarios, there would be important interdisciplinary advances in formal knowledge, especially in relation to facilitating technologies--such as biotechnology and nanotechnology--and ecology. In others, there would be a high degree of integration between these technologies and other knowledge, such as agro-ecology and traditional knowledge. In GO and TG, there would be integration between materials engineering, food technology and biology, for instance, either to expand basic knowledge, or to generate new technologies capable of increasing quality and efficiency or reducing production costs. International progress in scientific and technological knowledge, which would demand large amounts of resources, should be followed by AKST systems in LAC, to prevent their knowledge from becoming obsolete and the consequent loss of relevance for the region. In view of the current situation of AKST investment in LAC, which is not only limited but is also extremely heterogeneous, these technological and scientific changes would pose important threats to the region's systems.

9) Traditional knowledge would be increasingly valued and incorporated into certain scenarios (AM, TG). Barriers, pests, diseases, and climate change would create needs for solutions using local knowledge, and its integration would be facilitated by institutional changes in these scenarios. In the other scenarios (GO, OS, and Life as it is), the integration of traditional knowledge would occur only occasionally, due to commercial interests and defective institutional structural arrangements.

10) In some of the scenarios (GO, OS, Life as it is) advances in formal knowledge and technological development linked to productive chains would remain in the hands of large transnational corporations. In other words, many countries in the region could lose the capacity to independently generate knowledge, which is the most important factor of development in the contemporary world. The scenarios indicate that the option of using local knowledge is not sufficient to meet the demand for food, nutrition, health, and environmental development in an increasingly complex world. This would pose a serious threat to the region.

11) Scientific activity in LAC would change in the scenarios, both in terms of relevant actors (public or private sector, NGOs, and transnationals) and in terms of the sources of resources. In some scenarios, such as GO, OS, and TG, the role of the public sector in generating knowledge and technology would be reduced, and private stakeholders would play a more active role. Since the public sector is the one that has historically been responsible for guaranteeing a similar capacity for access to knowledge and technology to the most vulnerable social groups--while the private sector has not had this function (although it may engage in acts of corporate social responsibility), and NGOs do not really have the capacity to perform it--the generation of knowledge and technology to equalize adverse economic, social, and cultural conditions would not be guaranteed in these scenarios.

12) The scenarios indicate that agricultural knowledge, and science and technology applied to agriculture are necessary but not sufficient to help in achieving the purposes of the IAASTD, namely, to reduce hunger and poverty, and ensure sustainable development and food security. AKST systems are not sufficient in and of themselves, because other factors, such as governance, legal and regulatory institutions, international trade practices, and the like, are fundamental and more inclusive than science and technology in actually achieving sustainable development, that leads to a real reduction in hunger and the eradication of poverty. Based on the results of the analysis of these scenarios, in the subsequent chapters specific innovation policies oriented to achieving these objectives are described, in addition to sustainable development policies for vulnerable groups, to supplement the action of the AKST systems.

3.1. Objectives of the Chapter

This purpose of this chapter is to help answer the following question:
"How can we reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially, and economically sustainable development through the generation of, access to, and use of agricultural knowledge, science, and technology?"
With specific reference to Latin America and the Caribbean, these future alternatives for the development of this region can be used to propose nonprescriptive recommendations as to how science and technology can best contribute to this development.[1]
To meet this objective, the chapter presents five scenarios on development of agricultural (sensu lato), agricultural production systems, and the knowledge, science and technology associated with them. The scenarios described are: (a) *Global Orchestration;* (b) *Order from Strength*; (c) *Adapting Mosaic*; (d) *TechnoGarden*; and (e) *Life as it is*.

The first four scenarios follow the Millennium Scenarios (Carpenter et al., 2005), and take the same name and broader macro-context or major premises used to analyze the relationships among the variables of the context closest to Latin America and the Caribbean and the variables that define the agricultural knowledge, science and technology systems and agricultural production systems in the region. The fifth scenario was designed as a continuation into the future of these systems, with their influences and interaction, as they are today. In other words, it portrays a world based on the premise that the future is similar to the past, whereas the other scenarios use the present as a point of departure to explore future alternatives (that are not a mere continuation of the present). Therefore, the fifth scenario is what is usually called a "trend scenario" or "business as usual".

Why use these scenarios?
The future is full of uncertainties for medium- and long-term policy makers, who need to understand what their worlds will look like in five to ten years from now, for decision-making purposes. In these times of extensive and speedy global intercommunications, the social, political, and economic contexts of societies change, and they are in turn modified with surprising speed. The task of understanding how these changes can alter the future and our societies is thus a difficult one and involves a great deal of uncertainty.
Building scenarios is a methodology used to help understand the future and, consequently to support decision-making on current policies and strategies. The scenarios are not linked to rigid mathematical formulas, unchangeable over time, but instead they offer a probable vision of the future and of the nature

[1] Proposals to this end are presented in Chapters 4 and 5.

of complex phenomena (such as those considered in this paper), and of how that situation is arrived at on the basis of the present and a behavioral model of various types of social, economic, environmental, and technological phenomena, among others, and their interaction. The scenarios make it possible to manage the uncertainty which necessarily characterizes the future, by creating *plausible* futures, or descriptions of what may occur in future, depending on the premises regarding selection of social stakeholders in relation to different macro-variables.

This vision of plausible futures is clearly subjective, but it is based on a critical analysis of existing information on the past and present and on methodologies—the scenarios—that lead to a systematic understanding of the future, or, better said, *futures.* The future *could be like this,* if it is not *like that.* This "*could be"* is reasonably credible here and now.

3.2. Conceptual framework

Some concepts are fundamental for building the scenarios presented in this chapter. These concepts include the following:

The concept of the future: In reality, the future is something that does not exist and cannot be attained, because when you think that you have arrived at the future, in truth it is actually the present. Thus, when one studies the future, what is studied are the images or perceptions that can influence present activities of persons or of the organization that is interested in them.

The concept of the future is related to several basic dimensions: 1) Time, the perception and measurement of which, in some societies, is related to the cycles of nature and natural phenomena that are repeated. This dimension leads to a concept of the future as a natural sequence of the past and present; 2) Advances in knowledge and technology. This dimension brings a perspective of evolution and change for contemporary societies, that is different from the previous idea of the future as a continuation of the past. It implies a turbulent atmosphere, in constant transformation, in which studies of the future become more difficult and at the same time more necessary.

Moreover, it is important to consider present influences, or the relationships among the phenomena that influence the present, as well as the possible emergence of new influences. Thus, to be able to understand the future, the current influences on the present must be understood, but account must also be taken of possible emerging events. This last consideration implies a degree of uncertainty, for the future or futures, to the extent that it expands the horizon of time in which the future is analyzed.

The concepts of present influences and future uncertainty are combined in the concept of the future adopted in this chapter. According to this concept, *the future is the result of the interaction between historical trends and the occurrence of hypothetical events.*

A prospective view is an attempt to understand the future that considers the dynamics of various types of influences, including scientific-technological, social, economic, and environmental factors, that act on social systems over time, in order to build plausible alternative futures on the basis of this analysis.

The systemic approach: In systems theory, the whole, or the system, is the product of its interactive parts, which must be understood and known as they relate to the operation of the whole. Among the conceptual frameworks of the systemic approach, the concepts of *system, limits, hierarchy, and systemic model* are the ones that are most useful for the prospective studies presented in this chapter.

A system is a series of interactive parts or components of interest to the researcher, according to Milsun's definition (apud Jones, 1970). What are the systems of interest in the case of this chapter?

The very question underlying this entire evaluation provides the clues for identifying these systems. The question refers to systems of agricultural knowledge, science, and technology and also systems in which sustainable development occurs, especially in the rural environment. The question also makes specific reference to the relations among these systems, in referring to the contributions of one to the results of another.

What are the limits of the systems to be analyzed? In this chapter, the limits are defined as follows:

a) For knowledge, science, and technology systems (AKST), they include the so-called systems of traditional and local knowledge, i.e., the "dynamic body of knowledge and practices accumulated by traditional communities and by agricultural production systems, based on their interaction with nature and their agricultural activities." They also include formal systems of science and technology, or, more specifically, research and development (R+D) designed to generate technology and know-how for agricultural production systems;

b) For systems where there is sustainable development, the premise contained in the question underlying this evaluation is that they must be agricultural production systems, because the contribution of R+D to sustainable development implied in the question can only occur on the basis of its action on those systems.

Moreover, these two systems not only interact with each other, but are also subject to the influence of other larger, more embracing systems, the system that could be referred to as the macro-context or, more simply, the context, which involves all of the different types of influences that are not generated in the R+D systems and in agricultural production systems.

The complexity of the systems is simplified in the models that represent them. A general model to represent the question on which this evaluation and chapter are based can be found in Figure 3.1.

Insert Figure 3.1

3.3. Methodology

The first stage in the scenario building process is to prepare a model that represents the relations among the systems of interest (the R+D systems, the agricultural production systems, and their context), in more detail than what is presented in Figure 3.1. Although consideration should be given to the model presented in Figure 3.1, it is too general to guide construction of the scenarios.

Thus we worked on the basis of a recently constructed model and variables for another study of the future. This study was undertaken in an attempt to understand the changes in the context of R+D systems that would affect the development of these systems over a period of ten years (around 2015) in six countries in Latin America (Castro et al., 2005; Lima et al, 2005; Santamaría et al, 2005).

Consequently, for the variables described by R+D systems and their context, the same variables used in that study were considered for this analysis. For the variables that describe agricultural production systems, a process of collective creation and bibliographic review made it possible to identify the relevant variables for those systems. All the variables considered in this chapter are presented in Table 3.1.

[Insert Table 3.1]

Next, the relationships among these variables were studied with the help of a crossed impact matrix. This matrix makes it possible to analyze the direct relationships between each pair of variables in terms of intensity, type, and direction of the interaction. Based on that analysis, the model of relations shown in Figure 3.2 was built.

[Insert Figure 3.2]

On the basis of this model, a selection was made of the variables considered as the critical factors for understanding the future in the scenarios. These variables are: the demands for and focus or focal point of the R+D; technologies adapted to the agricultural production systems; incorporation of knowledge into agricultural production systems; available resources for agricultural production systems, performance of agricultural production systems; income inequality; social inequality; urban food security; and, environmental sustainability in agriculture. These last four critical factors describe the results of the interactions between the context and the two (R+D and production) systems of interest. For each of the critical factors, submodels were prepared, that show the direct relationships with other variables based on the model presented in Figure 3.2. Examples of submodels for the four macrovariables of results (income inequality, social inequality, urban food security, and environmental sustainability in agriculture) are shown in Figures 3.3 to 3.6.

[Insert Figure 3.3]
[Insert Figure 3.4]
[Insert Figure 3.5]
[Insert Figure 3.6]

The scenarios were designed on the basis of these models, using the morphological analysis matrix tool. It takes into account the plausible situation of the variables for the time horizon under analysis. Then, the situation—considered as the hypothetical future development of each variable—is linked to the themes of the five scenarios: (a) *Global Orchestration*; (b) *Order from Strength*; (c) *Adapting Mosaic*; (d) *TechnoGarden*; and (e) *Life as it is.*

The first four scenarios follow the Millennium Scenarios (Carpenter et al., 2005), and take the same name and the broader macro-context or the main premises used to analyze the relationships between the variables of the context closest to Latin America and the Caribbean and the variables that define the agricultural knowledge, science and technology systems and the agricultural production systems in the region. In these scenarios, the interaction of two macrovariables (integration among countries and action related to environmental services) defines the major forces that determine the entire scenario. Table 3.2 presents these premises, both for the themes taken from the millennium scenarios and for the “business as usual” scenario.

[Insert Table 3.2]

The link between themes and descriptions of situations resulted in the matrix of scenarios and in the first version of the scenarios themselves for two time periods: 2007-2015 and 2016-2030. The authors revised these scenarios to obtain a working paper, that was submitted to around 50 specialists from Colombia and Brazil for validation on the following themes: climate change and environmental sustainability; governance and development policies; advances in know-how (biotechnology and nanotechnology); epidemics, pests, and contamination of food; economic and social development; and, traditional knowledge (appreciation of it and its inclusion in R+D).
The validation process entailed an evaluation of the plausibility of each description of these variables in the different scenarios and time periods, using a ten-point scale, with "1" representing the point of least plausibility and "10" total plausibility. For ratings of less than 5, the specialists were asked to indicate a) a reason justifying the assessment or rating, and b) a suggestion for improving the plausibility of the description.

The scenarios were adjusted on the basis of that evaluation and also on the basis of comments and suggestions by other external reviewers. These adjusted scenarios are presented below.

3.4 Scenarios: AKST and Sustainable Development in LAC in the Future (2007-2030)
Table 3.3 presents the current situation of the indicators selected for the variables considered in this study of the future. Based on this Table, it is possible to identify that there are countries at present that are more or less vulnerable in relation to these indicators. Vulnerability is defined as "*the weak capacity of an individual or group response to risks and uncertainty...; a predisposition to a drop in well-being, based on a configuration of negative attributes to achieve material and symbolic returns...; a negative predisposition to overcome adverse conditions*." (Filgueira and Peri, 2004, p. 21). All of the countries are presented with greater or less vulnerability, depending on the indicator/variable considered.

The scenarios built on the basis of the variables indicated are presented below. A summarized version of the scenarios, referring to all the variables used in their construction, is presented in Table 3.4.

Insert Table 3.3

Insert Table 3.4

3.4.1 Global Orchestration

3.4.1.1 2007-2015

3.4.1.1.1 Context of the AKST systems and agricultural production

The world and LAC are shifting toward the absence of barriers—except for health barriers—to international trade in agricultural products. This increases competition among countries, which fight for market shares on the basis of prices of differentiated products. The LAC countries already established on commodities markets (including Argentina, Brazil, Chile, Colombia, Ecuador, and Mexico) endeavor with some success to gain a place on the most dynamic markets—United States, China, and India—and on the market for differentiated products.

Throughout the world, the diversity of consumer demand for differentiated foods increases, on the basis of flavor, appearance, nutritional value, nutraceutical properties, bromatological quality, or another such factor. In many countries, consumers demand quality certification for processed foods, referring to such matters as the absence of agrotoxins, child labor, genetically modified organizations, and animal suffering. There is also a rising demand for traceable food products. In LAC, the growing education of the people and increased availability of information lead to greater exigency on the part of consumers, although consumers are more concerned over damage to their health than over aspects related to environmental protection.

During this period of time, in most of the region the frequency or severity of epidemics is not on the rise, due to the incentive to implement good management practices in production systems, the development of appropriate research for prevention and management of epidemics and the search for safe foods, and the development of capacity and regional cooperation to prevent new epidemics.

In some parts of the region, there are major changes in land use patterns. For instance, large tracts of land are used for single crops for production of biofuels, which may encourage the manifestation of new epidemics. Similarly, in areas already highly affected by early manifestations of climate change, such as floods, droughts, heat waves, and the like, and in zones where no adaptation policies have been planned, conditions are ripe for the proliferation of epidemics or emergence of new pests.

The temperature is rising at the rate of 0.22C-0.24C per decade, and so the frequency of extreme phenomena increases. Their effects are relevant and range widely for the agriculture and production systems in the region, due primarily to the equally widely ranging capacity of adaptation and mitigation. Decision-makers and societies in general, especially in LAC, do not show much concern over these climate changes.

Some countries establish social development, innovation, environmental, and biosecurity and biosafety policies that are coherent and consistent with the major economic development objectives. Consequently, those countries increasingly improve their capacity to manage these policies. Other countries in the region still have relatively ill-defined and short-sighted policies, in addition to a weak management structure. However, as a rule, the governance situation improves considerably up to the end of the period.

Education is considered an essential factor for improving the trade competitiveness of countries. The growing generation of wealth allows governments to make large investments in formal education, from basic to graduate education. The countries with a smaller economic capacity still try to provide at least good primary and secondary education for their citizens.

Education of the stakeholders in production systems is also provided by private educational institutions, along with public schools. The former gradually improve the quality of their results. Some major agricultural enterprises also cooperate in educating stakeholders in production systems, even on a graduate level, in various countries.

The most developed countries of the region make major investments to develop new technologies, such as nanotechnology, and also biotechnology and information technology. Few LAC countries have the capacity to achieve major advances in knowledge of agricultural systems and agriculture, not to mention new technologies.

Both in other regions and in the LAC in general, the value of traditional knowledge is not recognized, yet some large private enterprises seek this knowledge to create new products, such as pharmaceutics or plant-based insecticides, to be used intensively by agricultural production systems.

3.4.1.1.2 AKST Systems

At the start of this period, the public research and development organizations define as priority technologies ones that permit: (a) an increase in agricultural productivity; (b) a reduction in production costs; (c) an improvement in the quality of agricultural products; (d) an increase in food security; (e) an improvement in the quality of processes in production chains; (f) an improvement in the income of agricultural producers; (g) an increase in competitiveness of production chains; (h) generation of exportable surpluses; (i) an improvement in the nutritional profile of the urban and rural populations; (j) environmental sustainability of agricultural systems; (k) development of mechanisms and conditions for

the preferential production of farm goods and services with a high value added; and (l) an expansion of the portfolio of basic agricultural products, including nonfood products. This last priority makes it possible to create an important autonomy of nonrenewable energy sources by developing biofuels, such as ethanol, biodiesel, biogas, and the like, particularly in countries such as Brazil, Mexico and Argentina.

In terms of the social groups to which R+D is oriented, they include first and foremost conventional large and medium-sized producers, and extend to end consumers, agroindustry, and policy-makers, and, finally, in last place, traders and merchants. Indigenous communities and subsistence farmers are not very relevant for R+D organizations.

The capacity to incorporate advances in formal knowledge into the creation of new technology varies in LAC. In most of the countries, there is a small capacity to generate such technology, and so efforts focus on the adaptation or import of technology, when possible. Argentina, Brazil, and Mexico have large investments in biotechnology which, together with equally large investments in nanotechnology, allow them to achieve some progress in applying these sciences to agriculture. Traditional knowledge is taken into account only in isolated initiatives.

Some LAC countries make an effort to set aside resources for public agricultural R+D. There are also resources available from many international sources linked to countries, communities of countries, and international institutions.

The private system is the largest investor in research for economically profitable production, and endeavors to expand its portfolio of products. In a few instances this effort is shared with the public sector.

In LAC countries with more institutionalized public R+D structures, work objectives are differentiated between the public and private sectors. This differentiation is driven by the economic profit of the investment of private companies in AKST, which is promoted by knowledge protection laws.

Most R+D systems work with the following agricultural products on a priority basis: grains, vegetables and spices, tropical fruits, and beef and fish products. Other countries focus on apiculture and development of other species of livestock, medicinal plants, and cosmetics.
The technologies generated by the public and private R+D systems are oriented more towards intensive agriculture, large and medium-sized agricultural producers and agroindustry. A few of these technologies incorporate aspects related to environmental protection and conservation, mainly in countries such as

Brazil, Peru, Ecuador, and Mexico, with a high degree of biodiversity and threats to it or in countries that have semi-arid or arid regions. The technologies generated do not take into account the most vulnerable social groups, such as small producers or subsistence farmers or indigenous communities.

3.4.1.1.3 Agricultural production systems

Conditions are favorable to incorporate more know-how in agriculture, due to greater investments in education, the availability of resources for agricultural activities, and the openness of borders and markets, as well as support by companies themselves. Know-how is basically incorporated in two ways: one is by promoting new inputs to improve productivity; and the other is by implementing and verifying a series of practices designed to ensure compliance with quality standards.

The large production systems supply the external market with commodities, but they also provide differentiated products to a broad internal LAC market. A considerable proportion of small producers become part of major production chains, such as the poultry chain, which is efficiently coordinated, even though it is highly fragmented. Other small producers manage to participate in market openings in their own country or in wealthier countries. A vast majority of vulnerable producers and subsistence farmers, however, remain isolated.

The opening of markets and borders creates a good climate for investment in agriculture. Access to natural resources, such as water and soil, is not a problem except for the most vulnerable production systems. Access to knowledge increases.

Large agricultural corporations that apply modern production and management methods operate with great efficiency and have high-quality products and processes. Consequently, they are more competitive on markets. Small producers that participate in major chains are also generally successful. The ones that participate more independently in market openings in some cases do not perform well. Efficiency is critical for them.

Nevertheless, a good part of the small production units leave the business, because they cannot meet quality requirements, such as traceability, safety, etc., imposed by marketing and consumer systems, due to the fact that technologies adapted to their conditions are relatively unavailable and to the effects of climate change, which , although incipient, are not depreciable.

3.4.1.1.4 Result of interaction between the systems

National and transnational companies consolidate their control over the supply chains and markets served. Some of the production units, with better ecological and economic conditions, manage to become organized within these chains and markets and thus improve their profitability.

For some countries, however, food imports compete with local food production systems, with a catastrophic effect on small and medium-sized production units. Displaced producers abandon agricultural activity and shift to providing small, nonspecialized services, either in the same rural areas or in nearby urban settlements. All of this exacerbates inequality in agricultural income, but this varies among the different LAC countries.

By the end of the period, there is still a considerable degree of social inequality, which is seen in differences in access to employment, food security, education, and health on the part of various social groups, such as large agricultural producers, small family producers, agricultural wage-earners, and subsistence farmers. For some of the vulnerable groups at the start of the period—small family producers and wage-earners—the unequal access is considerably reduced. This result is a continuation of a trend initiated in the last decade of the 20th century, which was also strengthened by the more widespread prosperity of that period. The situation is also heterogeneous in the case of LAC countries. In a small number of countries, thanks to public policies and to the management capacity of food regulations and standards, the urban poor also regularly have access to adequate quantities of healthy food.

For countries highly dependent on food imports and with a more reduced per capita income, the prices of these products increase, creating urban food security problems.

In the less developed countries in the region where economic efficiency is low, environmental sustainability is not a concern for production systems, except in some highly local, traditional, or indigenous production systems. Deforestation, intensive use of fertilizers and herbicides, expansion of arable land into natural ecosystems, and the consequent loss of biodiversity and neglect of soil fertility and water quality continue. In a few countries there are plans to guarantee greater productivity with environmentally friendly technologies.

3.4.1.2. 2016-2030 Time Period

3.4.1.2.1 Context of AKST systems and agricultural production

Trade barriers are still absent, with the exception of health-related ones.

The trend towards intense competition among countries increases during this period. The race to develop new agricultural products incorporating a high degree of technology is stepped up, so that commodities lose the relative importance they had in world trade. The vast majority of markets consume products with little value added, which are frequently synthetically created in laboratories or generated by micro-organisms. In many cases, commodities are only the raw material used to obtain these products. Some commodities are the principal sustenance of a few LAC communities, which preserve their identity and rituals.

In addition to concerns over quality and safety of foods prevalent in the previous period, now consumers--virtually without exception, since the entire world population is more highly educated than at the beginning of the century--demand information on genetic manipulation and nanotechnological methods incorporated in the foods. Regulations on these matters and procedures for evaluation of foods or agricultural-based nonfood products begin to be implemented by governments.

Epidemics and epizooties increase in frequency and severity, as a result of the accumulated effects of the mismanagement of ecosystems, the introduction of new pests, the lack of action to adapt and mitigate the phenomena associated with climate change, and drastic changes in the pattern of land use and technology. The quality of export products is strictly monitored, as is that of foods sold in internal markets.

Climate change remains a concern, but shows signs of increasing, in temperature and in the frequency of extreme events. In LAC there is already a greater capacity to implement adaptation and mitigation measures, and this capacity grows throughout the period.

Transnational companies have increased power over technological development. Traditional innovation polices become inadequate, since the state is no longer the main promoter of R+D activities. Moreover, problems emerge related to social development (such as job losses as a result of constant technological modernization), the environment, and excessive control over the life of the common citizen by these companies, which require governments to make institutional innovations. The situation of global climate change also requires new and vigorous policies designed to protect the environment and modify agricultural production systems.

The governments of the most developed countries in the region allocate a large part of their fiscal resources to implementing an unemployment insurance system. These governments also offer incentives to corporations not to lay off their employees as a result of technological changes, but to retrain

them instead to operate the new technologies. In 2025, governments establish a goal for gradual reduction of the work week within the next ten years.

Most of the countries in the region are in an acceptable situation from the standpoint of the their food quality standards and regulations and their enforcement. This is reflected in the reasonable efficiency of production systems, products, and services to meet the needs of their users. However, the systems are not necessarily environmentally sustainable, nor are the products, subproducts, and wastes in general, and this has a negative impact on the environment.

In general, stability and consistency among social, environmental, and foreign trade policies progress considerably for most LAC countries during this period, and various policies initiated in the course of the previous period also improve.

Education of stakeholders in production systems under the responsibility of the public education system ensures a critical mass of educated persons capable of meeting the objectives of international competition. Strategic alliances between both national and international companies and academic centers of excellence help improve the quality of public education at all levels.

The more developed countries make major advances in bio- and nanotechnology. In biotechnology, there is a much better understanding of the systemic impacts of the manipulation of genes in the second half of the period. This allows for greater efficiency in the use of these techniques and for a reduction in the negative effects on the environment. Biotechnology goes back to the technological base of genetic improvement processes, integrated into conventional processes. Nanotechnology for its part realizes its first successes with intelligent systems for monitoring crops and livestock, by using nano-electronic sensors based on DNA and other molecules. There is also integration of the two disciplines for development of environmental remediation systems, although these technologies do not develop fully. Biotechnology is also used successfully to develop plant biomass adapted to the needs of agroindustry, producers, and consumers. Moreover, other alternative forms of energy (wind, photovoltaic, hydrogen, etc.) begin to arrive on the markets. Some of them, which are more economical than biofuels, threaten to displace them from the market.

These advances are made most often by the large transnational companies that export know-how to the less developed countries.

3.4.1.2.2 AKSTA Systems

The division of labor between the public and private R+D sectors is expanded in the few countries that still have public research institutes. Public institutes focus primarily on a research agenda for the poor segments of rural producers and consumers.

For private transnationals that dominate R+D, research is centered primarily on all those technologies most directly geared to immediate application. These companies also maintain a portfolio of basic science projects oriented to new applications of biotechnology, nanotechnology, and their integration. Profitable applications based on knowledge generated by these initiatives are obtained with increasing speed, or in other words, the time between generating basic knowledge and its technological application is shortened.

Public AKST organizations still active in LAC rely increasingly on more basic knowledge generated by transnationals. In LAC, transnational companies also play the most important role in AKST. For this reason, there is no problem in incorporating advances in formal knowledge; actually, the process of obtaining advances in knowledge already has the incorporation of those advances built in, because these companies use the scientific skills of persons throughout the world.

The large companies do not save resources for AKST activities, because they need to continuously renew all the available technologies for the agricultural sector so that they will be in a better position to displace their competitors on the technology market.

Governments continue to perform the function of suppliers of financial resources for development of technologies for the poor. Transnationals also provide financing for this purpose, to enhance their corporate mage in public opinion.

There are practically no more spaces—except for marginal ones—for technological development by public organizations, which concentrate on basic and applied research. The public research that is done is directed to vulnerable social groups and “social” farm products, such as rice, yucca, and beans.

R+D is highly successful in developing products that consumers throughout the world are eager to buy. These products are extremely varied, to satisfy all tastes. Consequently they form a large mass of constantly changing products, virtually on a daily basis.

The companies also develop technology for all the components of production chains, from producers of inputs up to distributors of processed products. Although these products are developed and produced efficiently, their effectiveness is more problematical, because markets and consumers constantly want consumer products to have new attributes. In other words, the effectiveness of a product is ephemeral.

The technologies developed are adapted to large companies, that compete on markets for agriculture-based products (but not necessarily agricultural products in the traditional sense of the term). For traditional agricultural production systems, some low-intensity technologies are also developed; these technologies take into account their possible environmental impact and also serve to mitigate climate change or to adapt to it, or to do both.

3.4.1.2.3 Agricultural production systems

The process of incorporating knowledge into agriculture, initiated during the previous period, thus continues. This process occurs by incorporating new inputs into production systems or because of the need to comply with regulations or meet demands for quality. Its development is promoted by more favorable conditions for investment in education, greater availability of resources for agriculture, and more open markets and borders.

In many LAC countries, farm production is directed to external markets, especially those made up of countries with greater purchasing power and vigorous domestic markets.

A reasonable proportion of small agricultural producers manages to gain entry to markets, with the result that their improved education is reflected in improved production systems and competitive capacity. Many others, however, that do not achieve this comparative advantage of improved education, are displaced from their rural work to the cities.

The countries in the region generally have adequate resources consistent with their size, economy, and intellectual and technological capacity. Transnationals are monopolies that govern the use of natural resources, such as water and fertile soils, for agricultural activity.

The large agriculture-based corporations experience trade competition similarly to transnationals that dominate the creation of agricultural technology, because they constantly need to produce new innovative products to satisfy their markets. The products are developed on an agricultural basis, but they have strong components of bio- and nanotechnology. They include, by way of example, fiber crops with thermodynamic properties, monitored by nano-systems, plants that synthesize HIV inoculations, and micro-organisms that remedy environmental contamination. These corporations use as inputs commodities produced on huge tracts of land with highly mechanized and automated techniques.

The large corporations frequently integrate all the processes for agricultural production and production of inputs, and other times they outsource them. They build highly competitive, more regionalized production chains, that are dedicated to the integral production of specialized, differentiated products, to meet social demands for more cultural diversity and preservation of the identity of peoples. The performance of these corporations, in terms of efficiency and effectiveness, is very high, because increased trade competition requires them to make large investments, to mitigate the risk of losing markets.

3.4.1.2.4 Results of interaction among the systems

The openness of markets and borders creates a climate for investment in agriculture. National and transnational companies consolidate their control over production chains and the markets they serve. More production units manage to operate in this sphere, thereby improving their income. Nonfood imports, the monopoly over natural resources, and an intensification of the effects of climate change drive small farmers out of the circuit. These factors all exacerbate income inequality. More resources are invested in education, however, which are used to a great extent to retrain a large part of the rural population of displaced producers as skilled workers for industry. Partly as a result of these policies, the proportion of poor in the Latin American population is considerably reduced.

In this situation of growth, various social groups have greater access to education, health, and food security, although major differences persist among LAC countries in terms of social and economic development. Access to jobs is still difficult for less skilled workers. Government intervenes to provide food, housing, and transportation for the unemployed. In societies in general, the value assigned to work changes, due to the development of a market geared to recreation and leisure activities.

There is a sharp drop in urban food security problems in LAC, even in countries with a lower per capita income that rely on food imports. There is virtually no urban food security problem in LAC, or in other words food is regular, accessible, and available in the cities. As for food safety, the main sources of contamination are controlled by sophisticated health surveillance mechanisms.

At the start of this period, the environmental sustainability of production systems becomes a priority for societies, and especially in the countries most vulnerable to environmental disasters related to climate change. In addition to threats to sustainability related to poor management of agricultural systems, they are also threatened now by the consequences of climate change. During this period, the environmental sustainability of agriculture is also affected by highly intensive competition among markets, that demand more and more new products derived from exploitation of natural resources. The intensive agricultural

practices reduce the elasticity of the response of many ecosystems, and lead to various problems in maintaining the efficiency of agricultural production systems over the long run.

3.4.2 Order from Strength

3.4.2.1 2007-2015 Period

3.4.2.1.1 Context of AKST systems and agricultural production

International trade in agricultural products in the region is regulated by tariff and nontariff barriers. The latter ones are designed to reduce the risk of bioterrorism. The possibility of evolving towards a free trade system is remote.

The less developed countries have increasingly less capacity to invest in agricultural innovation. As a result, they are unable to compete on markets for differentiated agricultural products, and the best that they can do is to continue exporting commodities, in more and more difficult circumstances because of the barriers imposed.

Consumers in the more developed countries both within and outside the region are increasingly demanding in terms of quality, safety, functional properties, and environmentally-friendly production methods for food and nonfood products. It is more and more difficult for less developed countries to satisfy these demands, but some of them serve special, high-value markets, such as markets for products from the jungles of the Amazon, Chaco Paraguayo, or the Bolivian salt desert, or from Patagonia –albeit on a limited scale. The domestic LAC markets are primarily made up of low-income consumers, who demand low-priced food.

Despite the massive use of pesticides throughout the region, the frequency, severity, and presence of new pests and diseases continue, and the situation in some countries is worsened by changes in land use patterns, climate changes, and the lack of remedial action.

The temperature and frequency of extreme climate events persist. Most countries in the region do not perceive the threat of climate change, and hence the need to direct agricultural R+D to that end. Social organizations that warn the public of the coming danger are not echoed by government authorities. There is also generally a low capacity to mitigate or adapt to climate change in most countries, because most of these countries give no priority to action in this area.

At the outset of the period, some LAC countries adopt highly diverse measures for technological innovation, social development, environmental protection and biosafety. By the end of the period, as a result of the relationship with developed countries outside the region and their dependence on external

resources, most of the LAC countries adopt more coherent biosecurity policies based on protocols imported from more developed countries, the implementation of which is completely subsidized by these developed countries. However, as a rule, these policies are not seen as stable in most countries, and in highly import-dependent countries, this stability is very much weakened.

Management of these policies is also precarious, but due to the developed countries' concern over bioterrorism, from midway through the period onwards, a slow transition towards establishing regulations and quality standards and enforcing compliance with them begins, to reduce the risk of terrorist acts related to the food supply or agricultural products. Early in the period governments, and by the end of the period transnationals, take responsibility for managing health standards and antiterrorist measures. Transnational corporations are only capable of exercising this control in the major cities.

Public education does not lead to good results, especially in the less developed countries. Similarly, private education often offers defective, poor-quality courses and programs.

In more developed countries, there is a major social concern that science should provide ways to avoid any biological, physical, or chemical threat from less developed countries. The developed countries invest large amounts of private and public funds to develop new technologies (nanotechnology and biotechnology) to reduce this threat. In most of the less developed countries of LAC, due to the fact that many basic needs are not met and education levels are generally low, development of science is limited. These countries as a rule do not place value in traditional knowledge as a source of agricultural innovation.

3.4.2.1.2 AKST Systems

In the few LAC countries that have the capacity for technological innovation, efforts and resources are channeled to biosafety. The larger countries, many of which are members of economic blocs, establish health barriers to food imports, but without repercussions on the focus of AKST. In view of the scarcity of economic resources in the region, R+D is mostly directed to ensuring food supplies and economic efficiency. The sustainability of products and processes and their environmental impact are not given priority by the public or private sector.

The capacity of the different LAC countries to incorporate advances in formal knowledge into agriculture varies. Some, such as Argentina, Brazil, and Mexico, even apply their advances in biotechnology and nanotechnology to agribusiness, while others are limited to adapting or importing technology. The few countries with the capacity to generate technologies do not incorporate traditional knowledge.

There is also a loss of personnel and management capacity in public R+D. Personnel migrates to other jobs either abroad or with transnationals. Public R+D institutions have difficulties in establishing policy lines, defining priorities, and especially coordinating the whole research effort. By the end of this period, there is a wide gap between the scientific and technological capacity of the LAC countries and that of the developed countries, such as Japan, Germany, and the United States. Some countries in the region begin to import technology from the developed countries, to meet needs in some areas regarded as strategic. Because of a shortage of financial resources, most governments in the region reduce public investment in education, and in science and technology. There are financial resources to use for international support in solving problems, mainly related to biological security. The protocols, patents, and genes generated in these projects are the property of the donor organizations.

Throughout LAC, public R+D institutions give way to transnational companies. In some countries, they still perform the function of generating knowledge and technology in areas relevant to production, that private research institutions are not interested in. For instance, in the genetic improvement of corn, they develop pre-technological products, i.e., intermediate products in the crop development process, as an input for processing the final technological products (Castro et al, 2006). Public AKST organizations also take on the basic research that the private sector is not interested in doing.

Due to these many limitations, public R+D institutions are unable to develop technological products adapted to the demands of their customers and users, whether private transnational or national organizations. The most vulnerable social groups are not given any consideration at all in generating technologies.

3.4.2.1.3 Agricultural production systems

The lack of investment in education, the reduction in resources for agriculture, and the lack of openness of borders and markets lead to a situation that discourages incorporation of know-how into agriculture. Fragmented knowledge on use of inputs and machinery is incorporated on a limited scale, and only among the partners of enterprises, for the purpose of improving the productivity of production systems. Exporting firms and quality standard certification companies also require implementation and verification of a series of practices to meet market requirements, and the partners of the enterprises (medium-sized and small producers) find themselves forced to incorporate complex know-how associated with these product and process standards.

Trade barriers limit agricultural markets for LAC countries. Few countries export commodities to countries with greater purchasing power, because the costs of product certification, as a prevention against any biological threat, are high. A small number of countries and organizations has an opportunity to participate in “Latin-American” or “Amazon” markets, which also demand safety guarantees for the products offered. By the end of this period, a very small specialized market begins to open up for products of traditional production systems.

The internal LAC market has two segments: 1) the segment of high-income consumers, which is constantly shrinking in size, due to the poor economic performance of countries, but which requires goods similar to those of consumers in more developed countries; and, 2) the segment of poor consumers, which is an expanding segment for which the most important factor is price. A considerable number of countries has only the segment of poorer consumers for its goods, and relies increasingly on imports (agricultural imports in general, but especially foodstuffs), to feed its people.

External markets, the high-income market, and part of the poor domestic market are supplied with products from large, technified production systems. The niche markets are supplied by small production systems that nonetheless have a high degree of biosecurity technology incorporated into them.

The poorest domestic markets are supplied by production systems with little technology incorporated, with no links to production chains, and with little concern for biosecurity. This means that a large part of the people in these countries consumes food of poor bromatological quality.

The stakeholders in the production systems are not generally organized into stable associations, and this leads to a diminished resource management capacity, a weak position on agricultural markets, and poor performance by production units.

In the more developed countries of the region, the economic losses of the more vulnerable production systems are offset by aid policies or by an insurance mechanism. As a rule, however, the most vulnerable systems--which the large agricultural corporations of some countries are not part of—do not have financial resources to protect themselves from risks related to epidemics or the impact of climate change, for instance.

The large transnational companies that do their own R+D operate at high levels of efficiency and effectiveness. In other words, they produce with a high cost-benefit ratio, as demanded by their consumer markets, while family production systems are pushed towards increasingly less profitable agriculture.

3.4.2.1.4 Results of interaction among the systems

Income inequality rises, as a result of domination of agribusiness investment in LAC by the large transnational companies, and also because of the reduction of public investment in education, science, technology, and rural development. Only a small group of producers with better ecological and economic conditions materializes partnerships with these companies, while the vast majority of small production units are left out of the playing field.

There is a general deterioration in the capacity of countries to guarantee the sustainability of their agricultural production systems—especially the most vulnerable ones—and this is dramatically reflected in a reduction in access to jobs, housing, health, and education, and a decline in food security. Many unemployed rural workers and small bankrupt landowners move to the cities, where the generalized reduction in productive activities is also felt. Governments as a rule are not able to provide social protection to a large and growing poor population in urban settlements. In many cities, there is an atmosphere conducive to social protest and vandalism. Lack of security increases both in cities and in the rural milieu. Along borders with more developed countries like the United States, and also with some Latin American countries with higher living standards, there is an increase in fatalities resulting from thwarted attempts to enter a world in which there are “greater opportunities”...

As for urban food security, the supply of food is inadequate and a fraction of it has a high contamination risk.

The status of climate change tends to be critical, because temperatures are rising, as is the frequency of extreme climatic phenomena. The primary cause of this situation has to do with the specific energy matrix of the more developed countries and also with massive imports of raw materials from poor countries, reflected in the growing exploration of their natural systems and in the exposure of their native forests. Environmental sustainability and adaptation to climate change are not concerns of governments, except in the more vulnerable countries, which are usually the less developed ones.

3.4.2.2. 2016-2030 Period

3.4.2.2.1 Context of AKST systems and agricultural production

Both the countries of the region and those outside LAC continue to use all types of barriers to agricultural trade, encounter difficulties in making their national production systems competitive, and face ongoing threats of bioterrorism. The LAC countries with a greater presence on agricultural markets have

compulsory certification systems, exert strict control over the production process, and impose patterns of technology to manage epidemics and to guarantee the quality and safety of foods.

The markets are increasingly more sharply divided, with developed countries outside LAC dominant in trade competition and on world markets. Very few LAC countries are able to supply commodities to external markets. The less developed countries and the poorest ones have little access to these markets, so most of them turn to their domestic markets. These markets have a high percentage of low-income consumers, who are more interested in low prices than in food quality.

Management of agricultural pests and diseases relies mainly on the use of expensive, specialized external services and inputs. There is a reduced capacity in most LAC countries to implement preventive health measures or measures to contain diseases, and to adapt to and mitigate climate change. For these reasons, epidemics in the region increase.

In LAC there are even greater rise in temperatures than in the preceding period, and also more frequent and intensive extreme climate events. Their strong impact on the region is largely responsible for the highly reduced capacity to adapt to and mitigate climate change.

The situation of governance is highly varied in the region. In many countries, the general situation of survival is aggravated by corrupt politicians who have joined forces with groups that engage in illegal activities, and that frequently often offer one of the few opportunities for survival for many urban dwellers. In a few countries, there are governments that endeavor to follow consistent, sustainable policies, but these efforts are hampered by the shortage of economic resources. This is seen in the inability to intervene proactively to cope with various types of problems, such as social disaggregation, epidemics, natural disasters, and the like.

With resources becoming increasingly more scarce, most countries in the region experience enormous and mounting difficulties in ensuring social order and productive capacity and in guaranteeing the supply of essential services, such as health, unemployment insurance, education, housing credits, and the like. Laws on environmental protection, trade security, the protection of knowledge, and biosecurity, among others, remain unenforceable. The more developed countries feel threatened by this state of affairs, and create funds to alleviate the situation in the countries suffering most, by sending professionals, products (such as pharmaceuticals) and equipment to help these countries. This aid, which begins around 2022, ends when the period comes to a close.

Due to the deterioration of both economic resources and governance in LAC countries, their capacity to impose regulations and quality standards on food, which they had during the previous period, is diminished. Some of them make an effort to reverse this situation, but achieve meager results. Assistance by developed countries to recover that capacity is inadequate and limited in time.

The education of stakeholders of production systems in the public system of education does not generally produce good results. Private education is usually expensive and of mixed quality, because there are relatively few schools that offer a quality education.

Developed countries make enormous scientific progress. In the sphere of biotechnology, there is a sharp increase in the understanding of the systemic repercussions of gene manipulation. This leads to greater efficiency in the use of these techniques, which in developed countries is reflected in the decrease in negative effects on the environment. Biotechnology becomes the basis for genetic improvement projects; the use of conventional improvement systems moves to second place. Nanotechnology in turn is used successfully for the first time in intelligent systems for monitoring crops and livestock and food processing systems. These systems rely on the use of electronic nano-sensors based on the characterization of DNA, which are especially designed to detect threats to biosafety or biosecurity in raw materials or processed foods.

Nanotechnology is also used to develop systems for tracing origin and preservation of identity. These systems are sold to poor countries that want to export their raw materials to rich countries and so must comply with the identity preservation requirements for exports. This technology is also used to generate strict control protocols for biosecurity and biosafety in international transactions.

Biotechnology is also used to produce plant biomass adapted to the needs of agroindustry, producers, and consumers in LAC countries in a better economic situation. Moreover, other sources of energy cheaper than biofuels begin to be developed and threaten to take over their market share.

These advances are realized in most cases by large transnationals that export their know-how to less developed countries.

3.4.2.2.2 AKST systems

Scientific activity, virtually abandoned in LAC countries, is left on its own. In many countries the scarce resources of the people encourage the formation of markets for traditional products. For instance, expensive medicines manufactured by international laboratories are replaced by active principals

obtained directly from plant biodiversity. However, since there is no interaction between formal and traditional knowledge, the systematization of the latter and its incorporation in formal systems are reduced.

The activity of generating know-how and technology is left to the developed countries outside LAC.

The capacity to incorporate advances in formal knowledge is in the hands of large transnational corporations, because there are actually no public or private research institutions or universities that perform this work effectively.

At the outset of the period there is a fleeting attempt to incorporate traditional know-how into efforts to generate agricultural products.

R+D resources come from major transnational corporations, that tend to focus on their short-term interests and the needs of markets outside the region. There are virtually no other sources of funds to sustain sizeable investments in R+D. The focus of the large corporations is on the competitiveness of commodities and biosecurity protocols. These are produced with technologies generated in other countries, that are directly applied or adapted to the conditions of LAC and exported to wealthier countries outside the region.

Almost all of the R+D produced by large corporations is directed to improving successful products, such as transgenic varieties, or to testing new products, to serve external and internal markets. For the R+D activities of these corporations, the countries in the region have a comparative advantage in that they can explore the environment without facing protests from environmentalist organizations, taxes are low, and there are generally few restrictions to such exploration. Locally important food crops, such as beans and yucca, are not the subjects of the R+D done by these corporations.

However, the technologies generated by the corporations are not the best suited to the diverse needs of the countries of the region, either in terms of sustainable development, or their culture or production conditions.

3.4.2.2.3 Agricultural production systems

The slow economic growth of the region makes it much more difficult to incorporate know-how into agriculture, and especially as required for the most vulnerable production systems. Moreover, the large corporations no longer operate as organizations dedicated to a broad sector of activity, such as

production of inputs, for example, but instead they operate as large, well coordinated production chains, ranging from production to sale of these same inputs, including technology, and including the production and sale of agricultural products. Know-how is automatically incorporated into these chains, as part of the whole process.

Production systems that do not participate in these chains do not have an adequate supply of technology to solve the problems of agricultural pests and diseases or to adapt to higher temperatures, nor do they have the resources to incorporate innovations when there are a few available.

The vast majority of LAC countries lose a great deal of their competitive capacity on external markets, due to the following factors:

a) The rich countries become increasingly closed, to guarantee the best markets to their own agricultural producers;

b) The rapid change in the technological base of economic development, increasingly more dependent on expensive technologies, such as biotechnology and nanotechnology, information sciences, geomantics, and on their incorporation, which are not affordable for all countries of the region;

c) The creation of new products with these technologies incorporated into them, that are not dependent on the use of commodities--the principal exports of LAC, which have experienced a sharp drop in international prices;

d) the limited capacity of the region to maintain agriculture free of pollutants, diseases, and pests.

Few LAC countries, especially the largest ones, sell their agricultural production on external markets. In all the LAC countries, the domestic market is an important target for agriculture. For most of the countries, that market is virtually the only market on which the large corporations participate as chains. Small vulnerable producers supply the poor on local markets, or sustain themselves. It is increasingly more difficult for small producers to become part of production chains, due to their reduced capacity to satisfy certification and biosecurity and biosafety requirements.

In view of the ongoing poverty crisis and social and productive vulnerability, the stakeholders of vulnerable production systems are reliant on assistance to mitigate social and natural emergencies.

The financial resources available for agricultural production are channeled to economic and political power groups, and not to small producers, which are generally family or traditional and indigenous farmers.

The allocation of resources to agriculture tends to diminish during this period throughout the region, and especially in the poorest countries, as a result of poor governance.

Medium-sized production systems, which are dependent on government support, are efficient, but unable to meet market demand. Consequently, they frequently lose market shares to multinational production chains, which export their products to the region. The performance of these medium-sized systems deteriorates, as they need to reduce their production costs more and more to keep their market share.

3.4.2.2.4 Results of interaction among the systems

Because of a lack of proactive measures to mitigate the effects of climate change, extensive tracts of land are increasingly vulnerable to those effects, making investments more risky. Agribusiness stakeholders wage an aggressive competition to gain access to natural resources. Investments in agriculture are dominated by transnational companies, which in many cases receive support from governments. The result is a volatile land and water market and the consolidation of natural resources in a few hands. All of this leads to an increase in income inequality.

Public resources for education decrease, which creates a mass of people without access to information and to collective organizations to defend their interests. This creates conditions that exacerbate income inequality and deepen social inequality. The income gap expands in some countries and remains stable in others, with an eventual improvement resulting from the delivery of resources, in the form of land titles for small farmers, for instance. In this way, an attempt is made to attenuate the heavy migration from rural areas to cities and other countries, which grew in the course of the previous period.

As a rule, for a growing number of persons, access to health, employment, education, and food security becomes more difficult. A segment of persons employed by the major corporations is created, as compared with persons who work for national organizations, the government, or independently. The middle class loses its status, since it becomes more impoverished. The situation of social disaggregation, violence, and insecurity worsens considerably.

Although the bromatological quality of foods accessible to the urban poor is maintained by the standards of the previous period, the quantity of food for the poor in large urban centers decreases, mainly for the

following reasons: (a) the number of urban poor is on the rise, as a result of the lack of opportunities and jobs; and (b) there is a strong internal migration from rural areas to cities. The wealthiest countries, even in LAC, institute drastic measures to contain this migratory movement.

The resilience[2] of ecosystems diminishes considerably, especially in poor countries. In these countries, natural resources are exploited virtually without restrictions. There is no capacity to adopt measures to recover degraded land or to mitigate and adapt to climate change, which is not a priority for the governments.

3.4.3 Life as it is

3.4.3.1 2007 – 2015 Period

3.4.3.1.1 Context of the AKST systems and agricultural production

Trade barriers are used by developed countries as a mechanism to defend the competitiveness of their agricultural products. Minor victories in reducing barriers by agricultural commodity-producing countries are offset by new social or environmental barriers.

The LAC countries already established on commodity markets (Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, etc.) try to gain access to more dynamic markets (United States, China, India) and the market for differentiated products. However, these countries still cannot compete on markets for differentiated agricultural products, because of their increasingly limited capacity to invest in technological innovation for agricultural production systems. These countries continue to export commodities and diversify the portfolio of products by including biofuels, such as alcohol and biodiesel.

Consumers in the richer countries both within and outside the region demand more and more quality, safety, functional properties, and environmentally-friendly production methods for food and nonfood products, but they are not yet prepared to pay the cost associated with these demands. There are market openings for some differentiated products, such as products of the Amazon jungles, or the Chaco Paraguayo, or the salt desert of Bolivia, or from Patagonia. The internal LAC markets primarily consist of consumers with few resources, who demand low-priced foods, and of niches for high-income consumers, with their demand for differentiated products.

In most of the region, there is an increase in either the frequency or the severity of agricultural diseases and pests, as a result of the lack of incentives to use good management practices in production systems

[2] Resilience is the capacity of a socio-environmental system to absorb disruptions, deal with changes, and still essentially maintain the same function and structure. Resilience depends on the variability and flexibility of the system (Carpenter et al., 2005).

and the lack of a national governmental structure with the capacity to implement regional cooperation to prevent and mitigate the impacts of new epidemics and losses in biodiversity.

In some parts of the region, there are huge changes in the pattern of land use, such as large tracts of monocultures of oleaginous crops and sugar cane for production of biofuels that lend themselves to the manifestation of new epidemics.

The temperature is rising at the rate of 0.22C-0.24C per decade, and the frequency of extreme phenomena is growing. There are relevant but highly variable effects on agriculture and the systems in the region, especially as a result of the frequency with which these phenomena affect each country, their economic consequences, and the equally variable capacity to mitigate and adapt to them.

Countries in the region with a more developed scientific research structure perceive the threat of climate change and thus the need for R+D in this area. But there are still financial and management limitations in obtaining results applicable to adaptation to and mitigation of the climate problem.

Some LAC countries adopt measures of technological innovation, social development, environmental protection and biosecurity, but due to political and budget limitations, achievements fall short of expectations. Changes in government generally lead to changes in management of public institutions, which frequently interrupt the continuity needed to obtain results. Either because of their own internal conviction (the case of countries more dependent on agribusiness) or because of their dependence on external resources, the countries of the region adopt more coherent biosecurity policies based on protocols imported from more developed countries, which fully subsidize implementation of such policies.

There is a slow transition towards implementation of food quality standards and regulations, and enforcement of them. Governments are initially responsible for management of health standards and anti-terrorism measures, but towards the end of the period, transnational companies are as well. During this period, transnational corporations are only interested in the most economical production chains, and this can lead to problems in the consumption of some types of foods produced by family farmers.

The education offered by the public school system, especially in the poorest countries, does not produce good results, even when governments give it high priority. Private education frequently offers defective and poor quality courses and teachers. There is strong social pressure to improve the educational structure of the region.

While rich countries make major investments in basic science to develop new technologies, such as biotechnology, nanotechnology and information science, Argentina, Brazil, Chile, Colombia, and Mexico make limited investments, and the other countries very limited ones. Consequently, the region moves further away from pioneering scientific development, capable of sustaining important advances in production technologies for agricultural systems and agriculture, and from the development efforts needed for product differentiation and an improvement in the competitive capacity of countries.

Few people recognize the value of traditional knowledge in LAC. It is appreciated by NGOs that advocate environmental sustainability and social inclusion, and also by a few large private companies, that are interested in this knowledge to create new products, such as pharmaceuticals or plant-based insecticides, intensively used by agricultural production systems.

3.4.3.1.2 AKST systems

As a result of scarce economic resources in LAC and the social problems of its population, R+D for the most part goes to ensure the food supply and economic efficiency, with priority given to increasing productivity in agriculture. Environmental sustainability, differentiation, and product quality are not priority items in the public or private sector, but instead are issues addressed by personal initiatives in R+D organizations.

The capacity to incorporate advances in formal knowledge into agriculture varies widely among the different LAC countries. Some, such as Argentina, Brazil, and Mexico, even apply their limited advances in biotechnology and nanotechnology to more dynamic production chains in agribusiness. The poorer countries, with limited R+D resources and infrastructure, are confined to adapting or importing technology. The few countries with the capacity to generate technologies incorporate little traditional knowledge during this period.

Public R+D organizations have problems establishing lines of action, defining priorities, and especially coordinating the entire research effort. There is also a loss of personnel and technical and management capacity in the public R+D system, in some cases because of the retirement of professionals, and in others due to a shift to other more remunerative jobs.

As a result of limited public and private investment in research and the priorities set by R+D institutions, at the end of this period there is a wide gap between the scientific and technological capacity of LAC countries and that of developed countries such as Japan, Germany, and the United States, and also among the countries in the region themselves. For some areas of application regarded as strategic, a

few countries in the region begin to import technology from rich countries, which leads to renewed interest in LAC in renovating existing public R+D structures or creating new ones.

The situation in the different countries in the region continues to be widely disparate. Brazil, Mexico, and Argentina, traditional exporters of agricultural commodities, invest more public and private monies in R+D than the other countries. However, these regional investments continue to be proportionally lower than those of other regions of the world, except for Africa. In certain export production chains and in countries where they exist and where laws to protect innovation are in force, an increase in private investment in research is observed.

Due to the scarcity of financial resources and the competition for them with other areas such as health and security, most governments of the region reduce public investment in science, technology, and education. There are financial resources to use for international support in solving problems related primarily to environmental sustainability, social inclusion, and biosecurity.

In LAC countries without relatively institutionalized public AKST structures, there are technology transfer and adaptive research programs in operation. In countries with more institutionalized public AKST structures, competition over work spaces is triggered between the public and private sectors, principally in relation to generation of technology to make production chains more dynamic. This competition between public and private institutions is driven by the economic return on AKST investment, as a result of knowledge protection laws.

In commodity exporting countries in the region, the technologies generated by public and private AKST systems are oriented more toward intensive agriculture for export, large and medium-sized agricultural producers, agroindustry, and input suppliers.

As a result of strong pressure by international and national public opinion, in countries with fragile, threatened ecosystems, such as the Amazon, or with semi-arid or arid zones, as found in Brazil, Peru, Ecuador, and Mexico, research programs include aspects related to protection and conservation of the environment. The technologies generated are therefore adapted to these conditions, but few take into consideration the most vulnerable social groups, including peasants, subsistence farmers, or indigenous communities.

3.4.3.1.3 Agricultural production systems

The limited openness of borders and markets associated with social control of certain technologies, such as transgenic technology, creates a situation that works against incorporating knowledge into certain agricultural activities. Agricultural enterprises increasingly incorporate fragmented knowledge on use of inputs and machinery to improve the efficiency of production systems, generally by reducing costs.

Export and product origin and quality certification companies also require the application and verification of a series of quality attributes to meet market requirements. Producers are required to include complex know-how associated with product and process standards.

On the internal LAC market, there are two segments: 1) high-income consumers, a small segment but one that demands quality goods similar to those of consumers in richer countries; and 2) a large segment of poor consumers, for whom the most important factor is price. A considerable number of countries only have the poor consumer segment for their goods, and increasingly need more agricultural imports in general, but especially food, because they are unable to meet the growing demand of their population.

Commodity producing systems consist primarily of large capitalist corporations that produce for the external market and for mass domestic consumption. A considerable proportion of small producers are linked to large production chains, such as the ones that participate in the poultry chain which is highly fragmented but efficiently coordinated. Others manage to find market niches for products with a high value added, either on domestic markets or on markets in wealthier countries.

The problems of inclusion of farmers displaced by production chains, and without access to factor markets (land, water, and other inputs) and product markets, persist. Conflicts over development models and among organized social groups, the absence of public policies, and the shortage of resources constrain efforts to plan and implement programs geared to these social segments.

Limited openings in markets and borders and a short supply of public resources work against a healthy climate for investment in agriculture, although this is the economic sector that contributes the most to the economies of the countries of the region.

Investment of resources in agribusiness fluctuates on the basis of the prices of export commodities, which go from boom to crisis situations based on price variations. Agribusiness is still the main source of income for many LAC countries, however.

Since the main economic activity in the region is the competitive production of commodities for the international market, production systems focus on increasing their productive efficiency on the basis of comparatively lower production costs. To achieve this objective, the major corporations frequently take over and integrate all agricultural production, agroindustrial, and input production processes. Highly competitive national and multinational production chains are strengthened, for products such as soybeans and sugarcane, driven by the demand for biofuels.

Efforts to develop systems to produce specialized and differentiated products, to meet social demands for higher quality products, are timid. There is a moderate increase in organic production systems, although it is limited by the lack of an efficient certification structure. Product differentiation is restricted by the lack of a structure and R+D capacity in technologies for processing agricultural products.

3.4.3.1.4 Results of interaction among the systems

Continued production of commodities for the external and internal market prolongs income inequality, caused by competition to reduce production costs. Thus, small producers are prevented from participating in the most dynamic sector of agribusiness. Inequality persists because of a reduction in public investment in education, science and technology, and rural development.

Social inclusion and agrarian reform programs are not successful in raising the income of most peasants and small farmers, due to widespread social conflicts and management and continuity problems. Only a small group of producers in the best ecological and economic conditions improve their income profiles, because they form partnerships with companies that are in production chains or manage to produce for market niches for differentiated products with a high value added.

There is still a considerable degree of social inequality at the end of this period, which is expressed in differences in the access to employment, food security, education, and health, by various social groups, including large producers, small family producers, agricultural wage-earners, and subsistence farmers.

The effects of climate change, the intensification of pests and diseases associated with them, and the shortfall in financial resources contribute to a slight increase in social inequality that prevails to the end of the period. This is the general situation in LAC, but in a few countries improvements are beginning to be seen, as a result of changes in and more stable development policies.

Food security problems in the region are much more the result of demand problems caused by consumers whose economic resources do not allow them access to the market, than due to the food

supply. The region has the capacity to produce sufficient quantities to supply its domestic markets and also to create an exportable surplus, especially in agricultural commodity-exporting countries, such as Brazil, Argentina, Mexico, and Colombia. For the low per capita income countries that are highly dependent on food imports, the prices of these products increase, causing urban food security problems.

Production of export commodities is generally based on the use of environmental factors, such as water and soil, and on biodiversity. There is strong pressure by organized social groups to protect the environment, but resources available to implement effect protective measures are inadequate.

Private enterprises, and mainly producers of export commodities, refuse to include environmental preservation costs in their production costs.

In both the poorest countries in the region and in peasant production, where economic efficiency is low, environmental sustainability is generally font a concern for production systems, except in some traditional or indigenous cultures.

Deforestation continues, as does the intensive use of fertilizers and herbicides and the expansion of arable land, as a result of incentives to produce biofuels.

3.4.3.2 2016-2030 Period

3.4.3.2.1 Context of AKST systems and agricultural production

After a long period of negotiations in the World Trade Organization, developed countries begin to reduce trade barriers previously used as a defense mechanism against the competition of agricultural products. Agricultural commodity-producing countries have to neutralize environmental barriers imposed out of fear of harmful environmental and climatic effects resulting from the expansion of land planted to grain crops and energy products.

The LAC countries already established on commodity markets, i.e., Argentina, Brazil, Chile, Colombia, Ecuador, and Mexico, among others, manage to gain access to the most dynamic markets (United States, China, India), and, on a smaller scale, to the market for differentiated products. The economic results obtained allow these countries to increase their capacity to invest in technological innovation for agricultural production systems and thus to compete on some differentiated agricultural product markets. These countries continue to export commodities in addition to a portfolio of bioenergy products such as alcohol and biodiesel.

Consumers in wealthier countries both within and outside the region gradually demand safer and higher quality food and nonfood products that are also have functional properties and are produced according to environmentally friendly production methods, and they are willing to pay the cost associated with this demand. Internal LAC markets are composed mostly of low-income consumers, who want low-priced food, and of a middle class capable of demanding differentiated and healthy products at higher prices. Niches for high-income consumers with differentiated demands increase.

In most of the region, an increase in the frequency or severity of pests and diseases, seen in the previous period and aggravated by rising temperatures, leads to improvements in the development and use of best practices for management of production systems, and to improvements in the national governmental structure for preventing and mitigating the impact of new pests or diseases, or even epidemics, both on a domestic level and through regional cooperation.

Major changes in the pattern of land use—for example, large tracts of land planted to a single oleaginous crop or sugarcane for production of biofuels—lead to the appearance of new pests and diseases, which in turn result in the creation of public policies and research plans to mitigate the effects of these pests and diseases. Similarly, government have planned adaptation policies in regions already highly affected by early manifestations of climate change, such as floods, droughts, heat waves, and the like, and these policies create an environment that is conducive to the proliferation of epidemics. Thus progress is made in dealing with the coexistence of agricultural production and epidemics in the region.

The temperature rises at the rate of 0.22C-0.24C every ten years and the frequency of extreme events increases. This has important but disparate effects on agriculture and production systems in the region, mainly due to the equally disparate capacity of countries to adapt to or mitigate these effects. At the same time, many countries expand their capacity to live with these phenomena.

The countries of the region that have a more developed research structure apply the results obtained from public policies designed to mitigate the impact of climate change, to guide agricultural development. Financial and management limitations still affect the ability to obtain results that can be used for adaptation to or mitigation of the climate problem, mainly in the poorest countries in the region.

Many LAC countries adopt measures of technological innovation, social development, environmental protection, and biosecurity, but in some countries political and budget restrictions cause the results to fall short of expectations. Democratic changes in government usually lead to management changes in public institutions, which in turn disrupt the continuity needed to obtain valid results. As a result of the creation

of an environmental conscience, the countries of the region implement more coherent biosecurity and environmental protection policies based on both domestic protocols and protocols imported from rich countries, which subsidize all of part of the relevant implementation costs.

The transition to establishing regulations and quality standards for food or agricultural products and their enforcement, initiated in the previous period, continues. Governments, working in partnership with transnationals producing agricultural inputs and major stakeholders in the wholesale and retail trades, are responsible for management of health and biosecurity standards. Governments take on the task of supervising and assisting family-based agricultural units, with encouraging results.

Strong social pressure to improve the structure of education in the region has a positive impact on the quality of public education, especially in the poorest countries, which obtain good results. Private education improves as well.

While developed countries far from the region make major investments in basic science to develop new technologies, such as biotechnology, nanotechnology and information science, the LAC countries also boost both investment in basic science and transfers of know-how from developed countries. Consequently, in some countries of the region and in certain fields of research, there is pioneering scientific development, that enables them to acquire the capacity to make important progress in production technologies for agricultural systems, agriculture, and product differentiation, and in improving their competitiveness.

In LAC, NGOs that defend environmental sustainability and social inclusion, large private companies, and public R+D institutions recognize to varying degrees the value of traditional knowledge, which they seek for use in creating new products (such as pharmaceuticals or plant-based insecticides), cosmetics, and nutraceuticals.

3.4.3.2.2 AKST systems

R+D resources remain scarce in LAC. As a rule, R+D is largely channeled to ensuring food supplies and economic efficiency. Priority is given to increasing productivity in agriculture or reducing production costs or both, in order to ensure that the commodities produced are competitive. In the larger countries of the region, environmental sustainability, differentiation, and the quality of products are on the public sector's research agenda.

The different LAC countries still have varying capacities to incorporate the advances in formal knowledge into agriculture. Some, like Argentina, Brazil, and Mexico, even apply their advances in biotechnology and nanotechnology to the most dynamic agribusiness production chains. Poorer countries, with limited resources and R+D infrastructure, are confined to adapting or importing technology. Countries with the capacity to generate technologies incorporate traditional knowledge in this creative process.

Public R+D organizations in the countries of the region with a long tradition in scientific research are better able to manage strategic R+D tools, because they coordinate the research effort. In these countries, a new generation of researchers replaced the former one and there was an increase in technical and management capacity in the public R+D system.

By the end of this period, the gap in scientific and technological capacity existing among the LAC countries and between them and developed countries, such as Japan, Germany, and the United States, is narrowed.

Brazil, Mexico, and Argentina invest more public and private resources in R+D than the other countries, but investments in the region are proportionally lower than in the other regions of the world. In specific export production chains and in countries with legislation to protect innovation, private investment in research is comparable to public investment.

Despite the persistence of scarce financial resources and competition with other areas of government, such as health and security, governments of the region gradually increase public investment in science, technology, and education. There are financial resources for international assistance to help solve problems related primarily to environmental sustainability, social inclusion, and biosecurity.

In the few LAC countries that do not have more institutionalized public AKST structures, there are technology transfer and adaptive research programs. In countries with more institutionalized AKST public structures, there is competition for work space between the public and private sectors. This is focused mainly on generating the technology for more dynamic production chains. This competition between public and private organizations is driven by the economic return on investment in AKST, derived from knowledge protection legislation.

In the region's commodity exporting countries, the technologies generated by public and private AKST systems are oriented more to intensive export agriculture, large and medium-sized agricultural producers,

agroindustry, and input suppliers. There are programs directed to adding value to family agricultural production and developing differentiated products.

Due to continued pressure by world public opinion, in all countries, and especially in those with fragile, threatened ecosystems like the Amazon, or with water-stressed areas, such as the semi-arid or arid regions found in Brazil, Peru, Ecuador, and Mexico, research programs on environmental protection and conservation and on recovery of formerly degraded areas are developed. The technologies generated are therefore adapted to these conditions and take into consideration the most vulnerable social groups, such as peasants, subsistence farmers, or indigenous communities.

3.4.3.2.3 Agricultural production systems

Fluctuating economic growth affects the region's production chains differently. Large corporations form extensive, well-coordinated production chains, which incorporate everything from the production and sale of inputs, including technology, to the production and sale of the end products. Know-how is automatically incorporated into them, as part of the process. Competition on the international market is the determining factor for including innovation in these chains.

The most vulnerable production systems that do not participate in these chains seek diverse sources of technology to solve efficiency and quality problems, which is critical to gain market access. There are public credit resources for incorporating any innovations that are available.

Throughout the region, commodity-producing systems made up of large capitalist companies are established to produce for the external market and for mass domestic consumption.

A considerable proportion of small commercial producers is linked to large production chains, such as the ones that participate in the highly fragmented but efficiently coordinated poultry chain. Others are able to participate in market niches, producing products with a high value added in their own country or in wealthier countries.

Many of the problems related to inclusion of farmers displaced by production chains, without access to factor markets (water, land, and other inputs) and product markets, are solved by persistent efforts and an improvement in public policy results.

More open markets and borders and greater availability of public resources lead to an increase in investment in agriculture, the economic sector that contributes the most to the economies of the region.

Investment in agribusiness still fluctuates on the basis of export commodity prices, but the fluctuations smooth out due to better coordination between stocks, production management, and commodity prices. Agribusiness gains strength as the primary source of income for most LAC countries.

In the performance of productive systems, the focus is on increasing productive efficiency, based on increases in productivity and lower production costs. The large corporations integrate all the agricultural productive processes, agroindustrial processes, production of inputs and the wholesale trade, leaving to third parties only the retail trade. Highly competitive and increasingly national and multinational production chains are strengthened, driven by the demand for biofuels, such as biodiesel from soybeans and African palm and ethanol from sugarcane. Productive chains for meat and fruit become part of the economic portfolio of the region.

Efforts to develop production systems for specialized and differentiated products are stepped up to meet the demand for high quality products. There is a sharp increase in organic production systems, stimulated by implementation of a certification structure. Product differentiation begins to produce results based on the growth of an R+D structure with the capacity to develop technologies for processing agriculture products.

3.4.3.2.4 Results of interaction among the systems

Despite the fact that the consolidation of commodity production for external and internal markets exacerbates income inequality, by hampering the participation of small producers in the most dynamic sector of agribusiness, social inclusion programs and research on family agriculture and agrarian reform lead to an increase in the income of many segments of peasant farmers. In addition, an expanding group of producers forms partnerships with companies inserted in productive chains or produces differentiated products with a high value added for market niches, and so it manages to improve its income profile.

During this period, there is a considerable improvement in access by the people to health, employment, education, and food security in most of the countries. However, social exclusion and lack of access to basic services are still prevalent in many countries.

When problems of food security do occur in the region, they are caused by pests, diseases, epidemics, and climate and environmental disasters. However, the region generally, and especially commodity exporting countries like Brazil, Argentina, Mexico, and Colombia, have the capacity to produce for both their national markets and to generate exportable surpluses. All of the countries still experience urban food security problems because of a lack of access to the food market. For countries with a low per capita

income that still rely on food imports, the prices of these imports increase, causing food security problems.

Organized social groups continue to exert strong pressure for measures to protect the environment, and they receive international funds to implement effective measures to this end.

Private enterprises, and mainly export commodity producers, partially incorporate environmental conservation costs in their production cost, because they share this environmental cost with the national government.

In the poorer countries of the region, and in peasant production, an improvement in economic efficiency, outside resources, and technical and management assistance include environmental sustainability as an objective of production systems. As a result, deforestation diminishes, the use of fertilizers and pesticides improves, and use of arable land for large-scale production of biofuels stabilizes.

3.4.4 Adapting mosaic

3.4.41 2007 – 2015 Period

3.4.4.1.1 Context of AKST systems and agricultural production

The concern over climate change and environmental sustainability is reflected in changes in various policies and regulations in some LAC countries in the early part of the second decade of the millennium, and in countries with better governance capacity.

Initially, changes in regulations affect trade among countries, including LAC, through a curious combination of barriers: on the one hand, nontariff barriers hinder agricultural imports of doubtful environmental and social sustainability; and, on the other, subsidies are granted for agricultural products with environmentally-friendly characteristics.

Barriers hamper trade among countries. Moreover, as regards external markets, the LAC countries see their competitiveness in agribusiness weaken on some markets, and especially the European ones, that require guarantees on the environmental sustainability of the production process. New and differentiated products are not demanded by the “new consumers.”

Agricultural production declines in many countries, due to climate effects. Social movements in LAC in favor of greater environmental sustainability also favor consideration of ecosystems and strict development rules in each country. All of these factors further reduce the productive capacity of

agriculture, and leads it to focus more on the domestic market, and especially local markets. Thus, external markets are no longer the target of agricultural products for many countries.

Climate change contributes to the sharp rise in epidemics and the emergence of new pests, leading to considerable losses of human and animal lives and a substantial decline in crops. These losses are scattered unevenly across LAC, and also affect countries that contribute only slightly (in terms of CO2 emissions, for instance) to global warming and the severity of extreme events.

This scenario begins to take shape following major temperature increases in various regions of the world, and extreme weather events of an unprecedented intensity are observed by the end of 2010. Countries prove incapable of dealing with the crises triggered by these changes.

Governance ranges from mediocre to acceptable in the countries of the region. The profound institutional innovation required takes place under the pressure of strong mobilization of different social groups, which force governments to share all of their decisions and action with these groups.

Following the global trend, some LAC countries begin to modify their policies to create more sustainable systems, based on lessons learned from the relationship between socio-economic and environmental systems. Some of the larger countries of the region, such as Brazil, Mexico, Argentina, Peru, and Colombia, are very much affected, however, since some of their ecosystems and people have been subjected to extreme conditions for a long time, a situation aggravated by climate change. For the first three countries, it is difficult to make the transition to a new paradigm, since they have commodity export-oriented economies and agriculture. For poorer or smaller countries, where agriculture already concentrates on products for local markets or niches, such as Costa Rica for ornamentals, and Bolivia for quinoa, this transition is easier.

Agricultural development policies are designed to facilitate a change in the productive paradigm through specific R+D activities and the transfer and dissemination of the necessary traditional and conventional know-how and technologies.

Policies for the integral development of biofuels and other renewable sources of energy are established within a framework of environmental sustainability. Similarly, laws are adopted to encourage agro-ecological based agricultural production systems, and fees or taxes are imposed to limit agricultural operations that use large tracts of land or single crop techniques. In the middle of the period, policies to facilitate access to land for small landless producers are defined, as a way of minimizing the impact of the

climate on this vulnerable social group. Various conditions are facilitated, and credit, technical assistance, training, and the like are provided, so that they can produce at least the basic food they need to survive in such adverse circumstances.

Education is a key element for making the institutional changes needed by this new society. By about 2010, most LAC countries invest on average 13% of their GDP in education.

At the outset of this period, many countries see the emergence of groups of scientists who advocate more a systemic approach to agriculture. In their view, for instance, research on the biosecurity of transgenics should take into account the possible systemic repercussions of genetic manipulation on the cell and the environment. These groups argue that agriculture needs to use more environmentally friendly practices.

Advances in scientific knowledge, including biology and nanotechnology, continue. Major investments are also made in R+D on the environment and its effects on agriculture. Research in this field provides the technological basis for certification of environmental protection for agricultural products.

To reduce the risk of new environmental disasters, various international organizations, including the World Bank, UN, UNESCO, and WHO, step up efforts to organize and empower traditional communities around the world.

The knowledge of these communities begins to be more highly valued. Numerous initiatives for environmental protection and for certification of the environmental safety of products and production processes are proposed. In many Latin American countries, there are numerous initiatives to systematize traditional knowledge and elucidate its principles.

3.4.4.1.2 AKST Systems

One of the demands for R+D is development or improvement of agricultural processes such as the following ones: (a) biological control of pests and diseases; (b) control of the application of nutrients and residues to soils in the productive system; (c) elimination or reduction of agricultural and agro-industrial residues or waste; (d) identification and use of natural sources of soil fertilizer; (e) supervision of safety and quality in processing foods; and (f) generation of productive processes with a lower environmental impact. Processes for increasing productivity continue to be given importance, but environmental aspects are also prioritized now. The following topics linked to the environment and ecosystems are now considered as priorities: (a) on-site prospecting and conservation of germplasm; (b) economic valuation of biodiversity and natural resources; (c) sustainable economic exploitation of biodiversity; (d) traditional

knowledge of biodiversity; (e) management of fishing resources; (f) conservation-oriented agriculture, management, and zoning; (g) management of water quality and use; and (h) management of forest resources.

The existence of barriers promotes research on certification of origin systems and ecological labeling of foods. A large part of R+D is channeled to research on adaptation to climate change. In defining R+D priorities, consideration must be given first and foremost to the need to adapt to and mitigate climate change and environmental sustainability.

Added to the social groups that have been the traditional users of agriculture research are now small producers, subsistence farmers, and indigenous communities, as high priority groups for R+D.

In LAC, all countries are interested in and share efforts to ensure that R+D is used to offer responses to the demands of these social groups. However, only a few countries have the infrastructure, trained scientists, and financial resources to achieve advances in this area. Incorporation of know-how is partly limited by these resources. It occurs only after an evaluation of its potential repercussions on socio-economic and environmental systems. Everyone involved in scientific work makes major efforts to incorporate traditional knowledge into formal AKST systems, while guaranteeing the rights of traditional/indigenous communities.

In some LAC countries there are sufficient but not optimum R+D resources. In allocating these resources, priority is given to major environmental protection objectives, sustainable agricultural practices, and the safety of the consumer. These resources are for the most part national government monies or social funds, but a small portion comes from regional sources.

Strict biosecurity protocols are defined for research in biotechnology and nanotechnology. Research in these sciences is uninterrupted, but progresses slowly.

R+D management is important, so that it is channeled correctly to meet environmental protection objectives. Various social groups gain full participation in the integral process of agricultural R+D.

R+D is concentrated in research institutes and public universities, that work in a highly participatory way with users and other organizations interested in R+D and its social repercussions. Private firms cooperate to some extent with these organizations, but their sphere of action is more restricted by laws limiting their concentration (i.e., to prevent a few firms from controlling the entire market). They are

oriented more towards solving problems related to productivity and reduction of production costs in productive systems and their environmental externalities. Towards the end of 2015, the vast majority of private R+D firms become aware of the existence of important environment-related markets that are worth exploiting.

In a situation of scarce resources, R+D endeavor to achieve efficiency in their use. Yet effectiveness is more important than efficiency. In other words, the emphasis is on R+D products and how well they adapt to the need for a reduced environmental impact, and only secondarily on optimization of the use of financial resources to obtain them. In the beginning of the period, few technologies are available for the wide range of R+D users. By the end of the period, capacity increases, as does the understanding of the needs of these users. There is also an increase in the stock of different technologies available and adapted to different users.

By the end of the period, after several years of effort, agricultural technologies that are better suited to different production systems, crops, and social, economic, and ecological conditions are developed.

3.4.4.1.3 Productive agricultural systems

Policies that emphasize local sustainable development require a considerable input of agro-ecological knowledge, as well as the parallel development of diverse theories on the valuation of natural resources and environmental services, as an integral part of the methodology needed to estimate the economic efficiency of the new productive systems. These policies also require a high degree of social mobilization in order to be accepted. This makes the relevant technological innovation processes highly dynamic.

Networks of advisory services are established, including public or private NGOs, for multifunctional and sustainable management of production systems, dissemination of technology, and facilitation of access to resources on the part of agricultural production systems, and especially the most vulnerable ones.

The local markets served are very limited in volume and global scope. In reality, the countries of the region have imposed reciprocal trade obstacles. Agricultural production chains are encouraged to incorporate the more vulnerable productive systems and to support them in this effort. These chains also become more limited in their geographical scope, and this facilitates the insertion of small producers. The participants in these chains work to improve the productive processes and products, always with the environment as the reference point.

The pursuit of environmental sustainability as a priority objective has a strong effect on access to productive resources, for the following reasons: (a) it notably restricts the use of natural resources, such as fresh water sources, for instance; (b) it makes it easier to obtain development credits, in order to facilitate in turn the purchase of land by farmers; and (c) it demands an enormous effort to provide basic training in cultural, scientific, and technological aspects, in order to successfully rationalize and modernize production systems.

In general, the productive systems supply relatively small nearby urban groups, because they do not have the capacity to guarantee the supply of food in the amounts and with the regularity required by populous urban centers. The largest LAC cities, including Mexico City, São Paulo, Rio de Janeiro, Buenos Aires, Caracas, Santiago, and Bogota, are abandoned by thousands of citizens without employment options or food. Many people loot supermarkets or urban stores. Others go to the countryside, and try to sustain themselves directly with certain crops that are resistant to natural disasters, and especially food crops such as rice, beans, corn, and yucca. This is another source of agricultural losses.

3.4.4.1.4 Results of interaction among the systems

Following the serious effects of climate change, a drastic change in agricultural production systems occurs. Many of the major single-crop commodity systems do not survive these changes. However, smaller integrated production systems manage to remain in operation and become stronger in this scenario. Thus, in rural milieus, the rich and the poor—at least as regards the owners of the land--trade their positions of relative wealth. In many cases, the percentage of rich and poor also changes. The most vulnerable groups, i.e., subsistence farmers, rural wage-earners, or communities that produce for their own consumption, especially in areas that were subjected to climatic stress such as frequent floods or droughts, are the most affected by climate change. Many leave their homes and seek refuge in the cities, where there is generally not enough food and jobs for everyone.

Moreover, the effects of climate change and the failure of many large-scale enterprises also displace unskilled workers, who previously worked in sugarcane production in Brazil, for example, or in oil palm production in Ecuador or Colombia.

With regard to income inequality, results are mixed. However, when we look at small, medium-sized, and large landholders in agricultural production systems, we see that ownership of the land changes hands. Many rich owners leave the business and become poor, while small owners growing crops and crops systems with a lower environmental impact become stronger and grow. Rural workers, however, are frequently left without employment and need assistance to meet their basic needs. Their situation

improves with policies that facilitate their access to land, water, credit, and know-how. But the employment issue is not totally resolved, because economic fragmentation causes a sharp drop in agricultural production and job creation.
Access to basic education, health, employment, housing, and food security are objectives pursued in a heterogeneous way by the countries of the region. In the fields of education, health, and housing, the countries pioneering in social and political change begin to reap their first successes towards the end of the period.

Access to food in the quantities and with the regularity needed in the cities becomes a major problem, because the number of persons without regular access to sufficient quantities of food to meet their basic needs increases. This access is even more difficult for the poor, because the reduced supply of food leads to increased prices.

During this period, agriculture undergoes a major change of objectives: it shifts from a strongly productivist approach to a profound environmentalist conviction. The quantity of chemical products applied to agriculture, such as fertilizers and pesticides, is reduced. Environmentally-friendly practices and biodiversity gain ground, and although they do not always lead to greater productivity or a higher yield in the short run, they guarantee a continued supply of agricultural products in the exploited ecosystems. There is also more control over health standards, and products are required to be free of contaminants related to production technologies. These changes in agriculture mean that environmental sustainability begins to show signs of improving towards the end of this period, after a profound crisis during a good part of the previous years.

3.4.4.2 2016-2030 Period

3.4.4.2.1 Context of AKST systems and agricultural production

International trade barriers, and especially nontariff barriers, continue in place, but countries agree not to impose restrictions on the exchange of information. The methods and procedures developed in the previous period for ecological labeling of foods are perfected and extended.

Continuing the trend of the previous period, competition among countries virtually comes to a halt. Countries produce primarily for their domestic markets, without large surpluses. In a few cases, especially when a country afflicted by natural disasters or social crises needs assistance, food is exported and imported. In a few cases, there is also specialization of agricultural production by country, based on its tradition, culture, and agro-ecological capacity. Consumers, both within and outside LAC, increasingly

value products with certification of origin and environmental protection. There is also a growing demand by consumers for nutritional and safe foods.

In certain countries or regions, pests and diseases, as well as epidemics, are almost permanently reduced by improved socio-environmental management, use of appropriate technologies, mitigation of the loss of biodiversity, and improvement of soils. The results are: (a) an increase in production and marketing of healthy, higher-quality products; and (b) a greater added value in these products.

The status of climate change is still worrisome throughout the period. Many countries encourage agricultural R+D on adaptation to climate change, and implement production systems specifically designed for that purpose. There is a more robust capacity to adapt to and mitigate climate change.

Optimum governance conditions are consolidated in most of the region towards the end of the period. Agricultural development policies are pursued. Laws are adopted to limit the size of large corporations, applicable to both existing ones and new corporations that may be established, by restricting their acquisitions of and mergers with other companies. The purpose of this legislation is to guarantee a better balance of power among the different social stakeholders. A considerable portion of the fiscal resources obtained are used to implement initiatives for designing and establishing a new society. Many countries adopt regulations pertaining to the “Local Commerce Regionalization Initiative (Carpenter et al., 2005), permitting cooperation among transnational companies if they use local products and if the value added is appropriate for all the partners.

Strict standards and regulations on the composition, origin, and environmental safety of foods are applied both domestically and to erect trade barriers.

A concern over the environment leads to restrictions on the participation of biofuels in the energy matrix of countries, to prevent the expansion of agricultural land. Alternatives, such as nuclear energy and solar energy captured and powered by nanotubes, emerge in the middle of the period, as clean, mastered alternatives to meet the energy requirements of a growing world population. An extensive debate begins on meeting energy needs by using these alternative sources of energy instead of biofuels and the consequent expansion of agricultural land.

The processes and activities initiated in the previous period to improve education are pursued. Local educational systems achieve good results, after overcoming problems related to financing and teacher training.

In LAC many cooperative work arrangements are consolidated, in view of the realization that R+D is increasingly more expensive but essential for the development of the countries of the region. These arrangements even include the foundation of regional R+D institutions, to achieve a critical mass of researchers and increase the probability of important progress in the new technologies (biotechnology and nanotechnology). They are also a way to considerably reduce operating costs.

There are many projects shared among countries, that were designed to obtain the scientific support of this guarantee of the production and supply of healthy, quality food. Biotechnology and nanotechnology are used to generate knowledge on the reaction and resilience of ecosystems (Carpenter et al., 2005), but the interaction between them is not yet fully understood. This is reflected in the scant attention given to the impact of this interaction that results in episodes of contamination of many natural resources found in different countries. In other words, there is generally no awareness that waste products thrown into a river that runs through many countries is going to cause the contamination of drinking water in other communities, for instance.

By the end of the past decade, indigenous and local communities begin to reap substantial benefits from the appropriation of formal knowledge in the most widely varied areas. As a result of this and the fact that they are highly organized, they receive monetary income from various products derived from agriculture or biodiversity obtained on the basis of this knowledge.

The failure to care for common resources, such as oceans, cross-border rivers, the atmosphere, wildlife, etc., enhances the value attached to traditional knowledge. It is increasingly more systematized and its principles are elucidated by scientists from the communities themselves, who use formal knowledge in this effort. These situations that are so favorable to traditional knowledge are not found uniformly throughout the world or even throughout LAC.

3.4.4.2.2 AKST systems

The existence of barriers promotes R+D on origin certification systems and ecological labeling of foods, and the relationship between environmental services and climate change, and its reciprocal effect on agriculture and ecosystems. There is also a greater interest in (a) conservation and management of pollinating insects; (b) prospecting for and the sustainable management of plants; (c) identification and study of current and potential exotic invasive species; (d) the use of genetically modified organisms and their impact on agro-biodiversity; and (e) the impact of agricultural nanotechnology on human health and the environment. An important concern for R+D during this period is the development of sustainable productive systems capable of large-scale food production.

R+D systems are directed to all social groups, but focus especially on the most vulnerable groups.

The free exchange of information and scientists among countries, and the growing value attached to science guarantee the technical capacity of the R+D system in many of the LAC countries.

Biotechnology and nanotechnology are disciplines that play an important role in R+D projects. The incorporation of traditional knowledge increases.

Society's confidence in science mounts. The control of social stakeholders over R+D activities implemented in the previous period slackens in this period, so that advances in basic disciplines may be incorporated, thereby contributing to the understanding of the environment and its friendly use.

Resources available for R+D continue to be adequate but not abundant. There are some additional resources derived from accreditation services and certification of products by some R+D institutions. There are difficulties in obtaining outside resources for R+D. Social participation in generating know-how and technology for productive systems expands. The coordination of efforts among the various stakeholders with different interests and the need for a focal point for similar programs and projects are sources of considerable inefficiency in the use of financial resources, infrastructure, and capacity.

At the outset of this period, private R+D organizations, greatly reduced in size and power, begin to participate more actively in R+D, in cooperation with public organizations.

R+D achieves important progress in understanding and managing ecosystems. Environmental services improve as a result of the better understanding of their repercussions on the environment. The efficiency and effectiveness of scientific activity have gained considerable ground in comparison with the previous period: efficiency, because it is necessary to rationalize the use of scarce resources; and effectiveness, because the competition of many stakeholders, including users, in defining and obtaining a technological solution makes it possible to build transdisciplinary structures that are better adapted to the needs of these users. The time between creation and implementation of a project, however, becomes longer, due to the application of rules of collective participation in this implementation. There are cases where the result is delayed so much that it is no longer relevant for users. There are also many cases of duplication of efforts, caused by the fact that the local and decentralized systems do not have adequate communication and integration mechanisms.

The participation of so many stakeholders in developing know-how and technologies is also a factor that has a positive influence on obtaining appropriate technologies, but at times they are not applied to the interested systems, either because of delays in obtaining them, or because the information on their existence is not adequately communicated.

3.4.4.2.3 Agricultural production systems

The incorporation of knowledge into agriculture is actively pursued by all stakeholders that can benefit from it. Decision-makers are also moving in this direction, to reduce the negative impact of the transition that occurred in the previous period and to stimulate grater agricultural production. Policies emphasizing local sustainable development allow for more agro-ecological knowledge to be included.

The markets served are essentially domestic. A few specialized markets are established as a result of the gradual specialization of countries in a few agricultural products, which have comparative advantages in terms of culture, tradition, agro-ecological conditions, and the like.

Most stakeholders in vulnerable production systems are highly organized, as a result of decentralization of rural development planning and the greater weight given local proposals. The development of community organizations incorporates social organizations promoted by production chains or cooperative movements in the communities.

There are resources to support agriculture, with a view to protecting it from natural disasters. But these resources are not abundant, since there are many social demands and economic resources for this purpose are limited. During the last decade of the period, both agricultural production systems and cities suffer from limited access to water, especially in the semi-arid zones of Latin America, in Brazil, Mexico, Argentina, Peru, and Colombia. This reduced access displaces subsistence farmers and reduces agricultural production in many countries.

The products and processes of practically all agricultural systems are healthier and more environmentally friendly. As in the previous period, there are problems in obtaining food in the quantities and with the regularity needed to feed the entire population.

3.4.4.2.4 Results of interaction among the systems

Agricultural income does not increase very much, as a result of the dynamics of the local markets themselves. The policies designed by countries to reduce the gap in agrarian income in the previous period are improved and show promising results. The narrowing of the income gap indirectly induces

many who had migrated to urban centers to return to the rural milieu, thereby partially alleviating the problem of food supply to the urban poor.

With regard to education, health, and housing, countries improve access to these sectors towards the end of the period. Access to employment is somewhat better than in the previous period, because agricultural systems acquire greater capacity and experience, and thus are more efficient that in the previous period. Many of these systems also achieve economic sustainability by the end of the period.

Healthy food is guaranteed for the urban poor, who have the means to acquire it in the cities, but the total food supply is not guaranteed, in the quantity and with the regularity needed during this period. The increased population and demand for food causes major social conflicts, causing many countries to include in their constitutions the guarantee of available food. This only partially solves the problem of a shortage of food, which is democratically distributed among the poor.

The result in terms of environmental sustainability is an improvement in the protection of ecosystems locally. However, common natural resources shared by various countries frequently suffer from the impact of different management systems, and also at times from neglect, which has a repercussion on other societies.

3.4.5 TechnoGarden

3.4.5.1 2007-2015 Period

3.4.5.1.1 Context of AKST systems and agricultural production

The governments of various European countries begin to eliminate agricultural subsidies and tariff barriers, as a result of pressure exerted on the WTO and other international organizations by poorer agricultural countries. This liberalization produces a strong flow of imported foods and the consequent expansion of supermarkets in some LAC countries.

Throughout this period, the nontariff barriers of biosecurity and environmental protection are implemented and strengthened. These include certification of sustainable production processes in the country of origin of agricultural products and of low environmental impact, as a result of their use.

Although the diversification of agriculture, which occurs initially in the rich countries, leads to greater environmental sustainability, it also discourages them from food production, which becomes even more concentrated in the poorer countries. The poorer countries in turn, which were already dedicated to agriculture, but as commodity producers, now shift to producing differentiated products with a greater

value added, and also begin to diversify their agriculture. This latter movement is seen especially in the countries with greater biodiversity, as in the case of the countries that share the Amazon biome in the region.

The free circulation of information and persons in the world enhances the diversity of consumer demand for differentiation of foods by taste, appearance, nutritional value, nutraceutical properties, healthfulness, etc. In many countries consumers require certification pertaining to the food processing method (without agro-toxins, child labor, GMOs, animal suffering, etc.). The food tradition of other cultures is now familiar to many consumers. This means that there is an increasing demand for the inputs needed to prepare this type of ethnic meal in specialized restaurants. Traceability requirements also grow. In LAC, the increased education of the people and availability of information on food also serve to augment consumers' requirements.

Despite the implementation of more controlled production systems, agricultural epidemics increase in frequency and severity, and new pests emerge, mainly due to the effects of climate change. At the outset of the period, there are few LAC countries with the capacity to prevent and adapt to epidemics and pests. This capacity increases, however, throughout the period, as a result of abundant resources, the efficiency of international biosecurity barriers, and better governance in the countries.

The status of climate change is a source of concern throughout the period. Societies are aware of the possible repercussions of climate change on production systems. A decade of droughts and floods reinforces the concern over the effects of human action on the climate and environment, enhancing the value of environmental services in those countries. A visible consequence of this growing appreciation is that agricultural production processes begin to be monitored by consumers in the richer countries, who organize to ensure that these processes comply with low environmental impact standards and procedures, and to demand compensation--for preservation of forests, for instance—for agricultural operations. This leads to strict global regulations for the preparation and import of agriculture-based products.

Many LAC countries make great strides in their institutionality throughout this period. Despite changes in government with different parties in power, in many of these countries there are more stable and coherent policies, especially in the field of development, which is now seen as a multidimensional economic, social, and political phenomenon.

Many Latin American countries implement compensatory policies for the poor at the outset of the period. In a few countries, these policies are not accompanied by employment policies, and so the improvement in the social and economic condition of these groups is ephemeral. For the majority of social groups, more consistent, successful, and lasting policies for employment, education, and health are implemented. Many countries have laws protecting investment in science, creating an incentive for that activity.

With regard to the environment, many countries move in the direction of an institutionality that allows for the managed exploitation of natural resources. This institutionality applies rules on ecosystems and segments of ecosystems that may or may not be exploited, and regulates the type of exploration possible, conditions for exploitation, and so forth. Participation in the global market leads to rapid improvement in regulations and standards and the rigorous enforcement of them, to comply with food quality standards.

In some LAC countries, little progress has been made in the field of education. But even in those cases, there is a slight improvement, a continuation of the trend observed in the previous decade. In a large part of the countries, there is fortunately a notable gains in education, and even stakeholders in the most vulnerable agricultural production systems show a considerable improvement in their level of education by the end of this period.

At the start of the period, there is still a distrust of the true intentions and uses of science, However, certain successes towards the end of the period lead to renewed enthusiasm over the benefits of scientific activity. There is progress in the world and in LAC in establishing conditions for scientific activity, especially considering the major ethical dilemmas besetting this sector in the new day and age.

R+D applied to agriculture in the global sphere develops along two lines: one is a deeper understanding of the effects of anthropogenic action on ecosystems, with a view to reducing such action; and, the other is putting a specific value on environmental services, as a way of creating policies to promote the diversified use of the land (agricultural production and environmental services). Major efforts are made to advance knowledge of biology, nanotechnology, and the information sciences, and the integration or interrelationship among them.

The rich countries, especially European Community members and the United States, pursue their course of intensive scientific and technological development oriented to technologies such as biotechnology and nanotechnology and information technologies. The development of new products is a critical factor in international trade competition. On many occasions, and even to guarantee genetic variability, research

organizations use biodiversity resources in the hands of less developed countries, especially in Latin America and the Caribbean.
Laws on biodiversity in most countries are relatively inefficient, even in those countries that have ratified relevant international conventions like the CBD. Thus, traditional knowledge is little valued, and remains isolated from formal knowledge in the vast majority of cases. The enhanced value of environmental services gradually changes this picture.

3.4.5.1.2 AKST Systems
The concern over the environment and environmental sustainability in agriculture grows throughout the period, as a result of increased temperatures and more frequent extreme climate events in the region. Consequently, R+D in LAC gives high priority to knowledge about the environment and its relationship with agriculture. This concern materializes in a heavy investment of resources for research on this. Various R+D programs initiated also specifically focus on adaptation to or reduction of the impact and mitigation or reduction of the causes of climate change. By mid-period, investment in research designed to measure and assesses the value of environmental services and biodiversity also increases.

R+D priorities include development of processes for: (a) control of residues and nutrients added to soils of productive systems; (b) treatment and recycling of agricultural and agro-industrial waste; (c) precise evaluation of the need for inputs, water, etc. for plant growth (precision agriculture); (d) safety and quality guarantees in food processing; and (f) creation of varieties and strains adapted to hostile environmental conditions. All of these processes are complementary and designed to increase productivity. The following topics linked to the environment and ecosystems are priorities: (a) the economic valuation of biodiversity and natural resources; (b) sustainable economic exploitation of biodiversity; (c) management of fishing resources; (d) management of the quality and use of water; and (e) management of forest resources.

In terms of the social groups targeted by R+D, by the end of this period an important change occurs: R+D is no longer directed preferentially to large and medium-sized traditional producers, but instead it is geared to end consumers, agro-industry, and policy makers on a priority basis, and only secondarily to merchants and subsistence farmers (Castro et al., 2005; Lima et al., 2005). Indigenous communities and small producers are not important to R+D organizations at the outset of the period, but this situation changes over time, due to the growing interaction between research institutions and these communities.

A growing awareness of the importance of science and R+D also means that LAC scientists receive greater financial and token compensation for their work. They work in close cooperation, forming multi-

institutional research networks with scientists in many LAC countries and in countries outside the region as well. In this way, advances in knowledge within LAC and the incorporation of knowledge generated in other regions of the world are facilitated.

Throughout virtually the entire period, traditional knowledge is not given serious consideration as a source of technologies for formal systems in LAC. In 2013, with the impact of climate change in LAC, many countries begin to debate the advisability of using traditional knowledge to define practices to adapt to extreme weather phenomena. Little by little traditional communities begin to be seen as sources of knowledge on the different biomes and the environmental services provided by them. This realization is confined to a few countries.

Thanks to sustained economic growth, during this period most LAC countries have financial resources for long-term investment, for instance in R+D. They also have a critical mass of internationally reputed scientists in specific fields. The R+D project management and implementation process is increasingly professionalized. It is based on detailed studies of the future and on long-term planning. This process also increasingly includes other stakeholders interested in the results of R+D activities.

Research and development activities form an arena where public and private R+D organizations compete and cooperate. These two sectors have the financial and human resources needed to perform well. They establish a division of labor according to which some of the more profitable commodities, such as corn, tobacco, melons, papaya, wood species, and cotton, in addition to most of the products with a high value added, are the purview of the private sector, while species such as rice, beans, coffee, citrus fruits, wine, yucca, mango, bananas, and cashews are of strategic importance to the public sector. The two sectors cooperate in some areas of research, such as soybeans. (Castro el al., 2006).

Research in LAC produces important results for agriculture. In food chains, there are advances in certification, traceability, and food safety in general. There are also important developments that have to do with biofuels. The successful experience of Brazil with alcohol as a replacement for gasoline is used as an example for the development of other plant-based energy sources, such as oil from oil palm, which is used as a substitute for diesel in Brazil and other LAC countries. As a result of heavy investment in the environment, by around 2015 difficult issues having to do with the economic valuation of biodiversity and natural resources in the provision of environmental services and for sustainable agricultural production begin to be resolved. Important efforts are also made in the area of management of forest resources and the quality and use of water, which becomes a source of concern on the heels of climate change effects observed in the course of the period.

The technologies generated by public and private R+D and by broad social participation in the research process are usually adapted to the systems served by them. These technologies also come close to an ideal of what the most appropriate technologies for sustainable development would be. This is true even in the case of more vulnerable social groups that were not given priority at the beginning of the period.

3.4.5.1.3 Agricultural production systems

The situation created by extemporaneous changes in the climate encourages the intensive incorporation of relevant knowledge into agricultural production systems. The countries of the region approach the incorporation of knowledge and nature itself with widely varying degrees of intensity.

In this scenario, the incorporation of knowledge into agriculture is a business matter, and producing enterprises do it by training their workers in the use of new techniques and inputs to improve the productivity and sustainability of the systems. The enterprises also require the implementation and verification of a series of practices to comply with market requirements. Similarly, the stakeholders of smaller production systems are organized in associations, so that they can comply with rules of efficiency and standards and certification requirements.

Genetically modified organisms are used more frequently by a growing number of producers throughout LAC. The costs of using these technologies are reduced and thus their use becomes more widespread throughout the region. At the outset of the period, the use of transgenic organisms that leads to an increase in use of environmentally harmful inputs, such as herbicides, for instance, causes conflicts with all those that defend environmental protection within and outside the region. Towards the middle of the period, some cases of contamination in units producing biopharmaceuticals cause a wave of social rejection of this type of biotechnology. However, the introduction of new agricultural varieties adapted to hostile environments and of transgenic organisms capable of acting as bio-remedials (for instance, in cases of contamination of the soil by toxic substances) or of preventing soil erosion lead to the dissemination of transgenic organisms and their acceptance by LAC and its markets.

The major production systems, which are highly technified, serve external and internal markets. These systems are an integral part of large production chains; they are highly coordinated and have an in-depth knowledge of the markets served and consumer demands. Most of the small farmers, and also some groups that in the beginning of the period practiced subsistence agriculture, manage to insert themselves in some of these chains or to participate in certain market niches, with the production of goods, such as frog legs, for a very limited public. The number of subsistence producers is sharply reduced.

Since the very beginning of the scenario, plentiful resources are allocated to promote and disseminate use of know-how in agricultural production systems. The production systems receive considerable resources to improve their economic efficiency and product quality, especially in the form of credits and know-how, rather than land. The goal is to increase the productivity of agricultural production systems. Moreover, some of these systems also provide one or several environmental services, which are encouraged in many LAC countries by the end of the period.

Due to the influence of climate change, some regions begin to experience problems in purchasing water in the quantity and with the regularity needed to ensure the effective performance of their production systems.

Large productive systems that use modern production and management methods succeed in operating with great efficiency and use advanced processes to produce high-quality products. Thus, they also become more competitive. A large component of know-how and technology is incorporated into these products and processes. Although the external market still prefers commodities to differentiated products, the latter go to the broad LAC internal market. This situation does not change until the end of the period, when a few important developed markets begin importing a greater percentage of differentiated products from LAC.

The production systems of small farmers are inserted in the major chains by private national or transnational corporations as suppliers of inputs. They are also inserted as producers of raw materials in other chains (or in other words, as independent components that are not coordinated by another component, as is the case in the first situation described). These small systems are dedicated to producing commodities or a few differentiated products.

The vast majority of these independent production systems inserted in production chains are also successful overall. However, this is not the case in situations in which unforeseen factors, such as rising temperature, natural disasters, or epidemics, threaten the performance of these systems.

3.4.5.1.4 Results of interaction among the systems

The improved performance of productive activities, especially in terms of economic efficiency, begins to have a positive effect on income inequality. The need to substantially improve the quality of products and services and to pay more attention to their environmental consequences generally has a good effect on market prices.

During this period, there is generally a considerable increase in the indicators of greater social equality. Access to education, employment, health, and food security improve. In a few LAC countries, this progress is more limited.

Positive changes are recorded in urban food security and safety indicators, because there is a better understanding and monitoring of the handling, packaging, and processing of foods. The incorporation of environmental adaptability in many varieties and strains leads to a widespread increase in the availability of food, and thus to a decrease in prices for urban consumers.

In the beginning of the period, agriculture in both rich and poor countries is heavily based on exploitation of ecosystems to produce processed foods or raw materials. In other words, the products generated are commodities or differentiated products and always derived from human action on nature. Little by little, starting in Europe and then in the United States, global agriculture is diversified and begins to include environmental services as one of its functions. These services range from protection of water sources, carbon sequestration, and protection of habitats for pollinators, such as birds and bees, to the reduction of pollution generated in agriculture and simple conservation of plant and animal species. As a result, there is an improvement in indicators for environment sustainability in agriculture.

3.4.5.2 2016-2030 Period

3.4.5.2.1 Context of AKST systems and agricultural production

Free global markets are consolidated. Biosecurity and environmental protection barriers are further strengthened.

Competition for markets gives priority to product differentiation obtained by incorporating environmentally-friendly technologies. LAC increases its participation in these markets. Consumers throughout the world are willing to pay higher prices for products linked in some way to environmental protection initiatives. Thus, certification that products are developed by organizations that provide an environmental service of some kind is a factor adding to the value of the product.

LAC still participates in commodity markets, especially food commodity markets, where rich countries are major importers, since in some of those countries agriculture has disappeared. This group of countries continue to use, when necessary, the raw materials produced by less developed countries, to produce new products by chemical and/or molecular manipulation.

Consumers worldwide, including LAC consumers, are on the alert to prevent any environmental threats, because there are a few severe natural disasters that occur about midway through the period that cause devastation in various parts of the globe. Thus consumers value any products made with a concern for environmental and ecosystem conservation, whether it has to do with the production processes used or the fact that the systems producing such goods offer environmental services. But consumers also demand new and original types of foods, while at the same time they are attentive to issues related to health and contamination, and issues involving new genetic or molecular manipulation.

Thanks to the implementation of prevention and monitoring technologies and more sustainable practices, epidemics caused by known agents are more controlled and the time between successive outbreaks is longer. However, epidemics caused by unknown vectors are particularly intensive and difficult to control, although technological development as a rule allows for a prompt solution to these pests as well.

The status of climate change is worrisome until the end of the period, when the rate of increase in temperatures begins to decline. This reverse is the result of a major effort to develop sustainable technologies that are intensively used by production sectors in countries.

In most countries, governance is nearly optimal, with stability and consistence in policies, regardless of the government in power.

The concern over environmental services and the environment and its protection leads many countries to issue laws to guarantee an economic return for entities that can prove that they provide a specific environmental service to the country and the world. In addition to environmental protection, these laws provide work for many unemployed workers, who would otherwise move to the cities.

When LAC governments observe this unforeseen consequence of their environmental protection policies, they pass laws to allocate land for the sole purpose of environmental preservation and ecosystems. These lands, owned by the government, are managed by persons selected from the poor, based on proposals that these managers make for the sustainable use of these properties.

In LAC, there are policies to encourage tourism that promise a return to nature, with farms that function in the same way as they did in the mid 1900s and that resemble large entertainment parks, where tourists interact with persons and not machines. Activities involving visual arts or the culture of body esthetics are also strongly promoted, as an ideal way to prevent the deterioration of health or to reduce the mortality rate.

The economic return on investment in R+D is guaranteed by sustainable policies for protection of knowledge and by good management of these policies. Education is increasingly guaranteed and valued. It is offered partly by the state and partly by corporations, that employ highly qualified professionals. They must have increasingly complex advanced degrees to meet the performance standards required by systems that apply knowledge at increasing rates of intensity.

Improvements in regulations and standards and their enforcement are completed.

Unemployment grows as a result of the intensive incorporation of technology in all activities. However, this growth is offset to some extent by policies providing incentives for new economic pursuits. Large properties are taxed heavily, so that governments will have the resources to establish and maintain unemployment insurance for those out of work in such a technified world. There are also incentives to discourage corporations from laying off employees as a result of the incorporation or modification of technology.

R+D provides the basis for the valuation of environmental services based on research that uses biotechnology and nanotechnology. Public institutions in some LAC countries participate in this research.

There are enormous advances in virtually all areas of application of biology—animal and plant production, processing of quality, healthy foods, biomanufacturers of industrial raw materials, the environment, production and use of the biomass, and new nonfood products—and also of nanotechnology—animal and plant monitoring and therapies, monitoring of food processing, detection of pathogens, virus, GMOs in raw materials and processed goods, identity preservation systems, and environmental treatment and monitoring systems.

Biotechnology, nanotechnology, and soil science are integrated and produce spectacular results in the area of environmental remediation.

Varieties and strains adapted to hostile environmental conditions, such as plants resistant to drought and salinity, are developed for agriculture by genetic manipulation. These are a few examples of the advances that take place in LAC.

Concern over the handling of environmental services increases in all countries, and gradually leads to an enhanced appreciation for traditional and local knowledge. To better guarantee the continuity of these

services, many practices of indigenous and traditional communities are appropriated. Many of these communities receive economic benefits from this knowledge, because there are stronger laws that guarantee this. Conservation of biodiversity is also regarded as an environmental service. It includes preservation of river basins and the reduction of environmental contamination, because the importance of living in harmony with different animal and plant species for the preservation of many ecosystems is a matter of common knowledge. In various LAC countries traditional knowledge is also highly relevant, especially in relation to its interaction with formal science, to enhance the understanding of biodiversity and its uses.

Enormous advances in science once again bring out global fears regarding the ethical limits of scientific activity and technological innovation. Innovation of products and processes generates a debate among various social groups regarding the use of nature, as known and appreciated. Advances in science and its applications also give rise to more practical problems, because the latest technology is almost completely autonomous and no longer requires as much labor as before, especially relatively unskilled labor. During this period, however, the average skill level is high, at the level of secondary education. Thus there is social pressure to reduce the pace of scientific development, and LAC is not exempt.

3.4.5.2.2 AKST systems

R+D priorities for LAC are as follows: (a) application of recent advances in valuation of environmental services, to define protocols that make environmental protection an activity that supplements agriculture; (b) application of advanced biology and nanotechnology to production of food and new materials, that can be used in many productive areas, such as health, pharmaceutics, agriculture, industry, etc.; (c) use of micro-organisms for environmental remediation; and (d) improvement of nanosystems for monitoring diseases and for application of therapies to animal or plant groups, identity preservations systems, and tracing and monitoring and environmental recovery systems. Priority is also given to developing alternative technologies that allow for the continuity of agriculture even under the impact of climate change and that prevent increases in the frequency and intensity of these effects by reducing the factors that contribute to climate change today.

All social groups are focused on R+D in LAC.

The capacity of professionals in science and technology in LAC is growing day by day, as a result of their daily participation in the global development of science and technology, through publications, attending congresses, and joint projects. The time lag between an advance in one area of knowledge and its application to productive activities is considerably shortened.

There is a keen interest in systematizing traditional knowledge, which is massively explored by formal science under the protection of national, regional, and international laws or agreements that guarantee the rights of traditional/ indigenous peoples and the harmonious interaction between these two types of knowledge. This interaction is strongly driven by a common concern for the environment.

All productive and economic activities depend on the continued progress of R+D. Governments and corporations give priority to investment in know-how and technology. There are abundant resources available for this purpose. Management of R+D is regarded as a strategic factor in the competitiveness of companies that develop agricultural technology. This has to do with the fact that the time span between the design of a new product and its entry on the market becomes shorter and shorter.

Society participates more in research, since private R+D organizations feel the growing pressure of public opinion that is concerned over their power. This participation is mainly in management processes, but it is limited in the case of technological development projects, due to the specialized knowledge required.

Public and private organizations still work in cooperation, but the role of the private sector in R+D becomes more pronounced. In terms of products and services developed, this means that now there are few species of plants and animals that the private sector is not interested in, and that are left for public research. Interest of the private sector in basic science also increases, because of its capacity to generate knowledge that serves as a basis for future practical applications. There is a huge number of plant and animal species with sequenced genomes. Functional and structural genetics also make great strides in understanding gene functions. These advances are achieved to a great extent as a result of the cooperation between public and private science.

Research is increasingly more effective, i.e., capable of generating the innovative products or services demanded to address equally novel problems in production systems, ecosystems, and their interface in brief time periods. But the plentiful resources lead to a lack of concern with the efficiency of R+D, which becomes increasingly more expensive, even in situations that lend themselves to a more rational use of resources to obtain a certain outcome.

As for products and services obtained from R+D, they are now virtually problem-specific or demand-specific, because they are designed to solve a specific problem or to meet a specific demand of a social group. This extensive portfolio of products and services is also one of the reasons for the low efficiency of R+D activities in certain circumstances.

There is a sharp improvement in the understanding of social, economic, biological, and ecological systems. Technologies are increasingly better adapted to the systems where they are to be applied, although this adaptation is not yet perfect. New problems arise periodically in these systems, as a result of the unforeseen interaction of new technologies and their repercussions on the emerging properties of these systems.

3.4.5.2.3 Agricultural production systems

Throughout this period, new knowledge was intensively incorporated into production systems. Various other human activities considerably mitigate climate change. Relevant technological changes introduced in production systems contribute to this mitigation. There are also important advances in adaptation to climate change effects.

In this scenario, companies manage the incorporation of know-how into agricultural by training their workers in the use of inputs and new techniques, to improve the productivity and sustainability of the systems. Companies also require their employees to use and check a series of practices to comply with market requirements. Company employees or partners are required to incorporate a pool of complex knowledge associated with the standards applicable to products and production processes.

The large, highly tecnified production systems serve the external and internal markets. These systems are part of major production chains, which are highly coordinated and have an in-depth knowledge of the markets served and the consumer demand that influences those markets. Processors of basic agricultural products participate as suppliers of pre-treated raw materials (in other words, products that are subjected to some processing following primary production) for these major production chains. Virtually all the systems include new activities not in the agricultural sector, such as environmental services, tourist operations, or operation of rest homes, to give a few examples. These activities are integrated into the agriculture-based activities and serve both internal and external markets.

The major production systems and independent producers are well organized to defend their interests, with strong professional support.

Most of the independent producers manage to insert themselves into the chains and markets, but there is still a displacement of small producers to the cities.

The policies of abundant resources available for incorporating knowledge into production systems remain in effect. The region tends to become standardized in its technological efforts, and plentiful resources prevail throughout most of the region. Problems of access to water are solved by new technologies to

reprocess wastewaters and by desalinization of salt or brackish waters. Land as a resource and environmental protection are ensured through the successful use of degraded environments considered as hostile to life in the past.

The major production systems, which use modern production and management methods, operate with great efficiency and produce high-quality products using advanced processes; this enhances their capacity to compete on markets. A large component of knowledge and technology are incorporated into these products and processes, thereby generating countless differentiated products.

Smaller-scale production systems (no longer called “small producers”) participate as suppliers of preprocessed raw materials for large production chains. The vast majority of the production systems are successful.

3.4.5.2.4 Results of interaction among the systems

If only agriculture-based productive activities are considered, income inequality is sharply reduced in this period, as a result of the insertion of many producers, considered as small producers in the previous period, into powerful production chains and transnationals. Thus all the social groups participating in this activity obtain higher incomes. However, wage-earners who were working in the fields before the work was completely technified lose their jobs and migrate to the cities, which are now faced with an increased demand for food and basic services.

Access to education, housing, and food security are guaranteed by governments in different ways. Employment, however, is not guaranteed, although the diversification of agriculture has contributed to its increase and governments have implemented powerful mechanisms to create alternative labor markets and provide compensation for the unemployed.

Urban food security is supported by abundant, cheap, diversified food that meets high health standards. The sustainability of agricultural production systems gradually increases throughout the period, as a result of the application of more sustainable technologies, but also because agriculture has another paradigm, since environmental services are almost always provided along with the conventional production systems. Another important reason for this growing, yet incomplete sustainability is the use of regulatory procedures and standards in the technified countries of the region. There are also isolated cases of newly emerging environmental problems, resulting from technological solutions to previously existing problems.

3.5 Implications of the scenarios for innovation and development policies

The purpose of this chapter is to help answer the following question, with specific reference to Latin America and the Caribbean and alternatives for the future development of the region:

"How can we reduce hunger and poverty, improve rural livelihoods, and facilitate equitable and environmentally, socially, and economically sustainable development through the generation, access to, and use of agricultural knowledge, science, and technology?"

On the basis of these alternatives, it is possible to propose nonprescriptive recommendations as to how science and technology can best contribute to this development.

The five scenarios constructed to answer this question show that knowledge, science, and technology can contribute to the changes suggested in the question, but in different ways, depending on each alternative scenario considered.

The scenarios also make it clear that this contribution will be more likely and facilitated in situations in which other political, economic, and social conditions are also present. In each scenario, the direct influence of these conditions, and the interaction among them, will guide the action of formal AKST systems, and the use of traditional knowledge, and hence determine their contribution to sustainable development, as proposed in the question that generated this critical evaluation (IAASTD).

According to the *Global Orchestration* scenario, society has abundant resources, it is guided by market forces and is highly interconnected, but is concerned only on a reactive basis with the impact of human action on the environment. Formal AKST systems are characterized by uncontrolled generation of new products, which increasingly incorporate more technology to meet ever more sophisticated demand. Little if any use is made of traditional knowledge. As a result of the high degree of technology incorporated into the system, there are unemployment problems. Due to the careless exploitation of natural resources, the impact of human action intensifies, generally leading to highly negative consequences for agriculture and human life.

In the *Order from Strength* scenario, society is fragmented, and there is a pervasive distrust of the rich, and generally developed countries on the part of the poor and generally undeveloped countries; highly restrictive governance conditions and largely inadequate policies prevail in LAC, and there is a strong trend towards aggressive exploitation of the natural resources of the poor countries by the richer countries. The region even loses its capacity to generate technology independently, and becomes

increasingly dependent on other regions. The incorporation of traditional knowledge in this scenario is only peripheral and marginal. As a result, LAC becomes a mere supplier of inputs for the rich countries. There is an enormous social and economic crisis, and the environment is subjected to unprecedented impacts.

The "Life as it Is" scenario presents a world in which countries are integrated, but not to a great extent. The course of action is defined by the market, but not fully, and a division among countries persists, but it is still possible to conceive of change in the long run. There is both a proactive and a reactive approach to interaction between man and nature. In other words, it is a pluralistic world, in which none of the variables considered dominates others in its influence on the scenario. In these circumstances, the AKST system also obtains relatively mediocre results in its efforts to achieve any of the major sustainable development objectives referred to in the initial question that the chapter endeavors to answer, although the results are positive in the area of social development and environmental sustainability. Application of traditional knowledge improves towards the end of this scenario

The *Adapting Mosaic* presents a world in which immense institutional changes occur, including asymmetries of power among social stakeholders, paradigms for exploration of natural resources, generation of socio-political agreements, and distribution of wealth among social segments. All of these key elements for social and economic life are transformed. It is also a fragmented world, as in the *Order from Strength* scenario, but this fragmentation is not oriented towards domination of a fragment—or a region or river basin—over others. Each fragment seeks its own ways and places to deal with the environment, to reduce the impact on it. This entire transformation generates major crises and difficulties, affecting even urban food security in this scenario. There is also duplication of efforts, with a weak capacity to learn from imitation in many fragments, and delays in arriving at solutions. But there are also improvements in some indicators, and especially in the environmental impact. According to this scenario, formal AKST systems are initially viewed with distrust, but they clearly make an important contribution to achieving the objectives pursued by social groups, and so this distrust diminishes towards the end of the period. The empowerment of all of the more vulnerable social groups enhances the value of traditional knowledge, which is used in the *Adapting Mosaic* world.

The *TechnoGarden* scenario depicts a world in which countries are highly interconnected and motivated by a strong concern for the environment--with a pro-active approach, to prevent impacts on the environment. It is a world in which the actual concept of agriculture is transformed to include protection for environmental services. Environmental problems are solved and prevented by incorporating a high degree of technology. However, as in the *Adapting Mosaic*, there is also an interest in improving the

quality of life of all segments of society and AKST institutionalizes this concern in its practices. Thus, new technologies are adapted to the different social groups, but also to different environmental conditions. Traditional knowledge is valued, and is used and systematized to a great extent in this scenario. Consequently, many sustainable development indicators improve, although in this world an optimum solution to the environmental problem is never found.

What are the implications of these scenarios for AKST and sustainable development policies, that could prevent the negative situations described in them, and what possibility is there for facilitating such action and ensuring interaction that would foster sustainable development?

In the following section there is a brief presentation of the implications for innovation policies and social development policies in support of vulnerable social groups under each scenario. It is important to point out that although each scenario is described in the present tense, these scenarios should not be regarded as predictions, but rather as possible future situations.

The policy implications were devised on the basis of the different scenarios, but also in consideration of the current situation of vulnerability in each country with respect to the different variables involved in them (this situation was described at the beginning of the scenarios, in Table 3). The line of reasoning followed is that even though we cannot accurately say that the most vulnerable countries today will have the same degree of vulnerability in future, this comparison makes it possible to indicate which countries have a greater or lesser probability of overcoming risks or taking advantage of future opportunities.

3.5.1. Global Orchestration

3.5.1.1. Implications for innovation policies:

The absence of barriers could lead to a reduction in product prices, and so productive efficiency would be very important in this scenario. However, competition is also based on quality differentiation. According to this scenario, there is a great diversification in the demands of end consumers, who, like the major corporations that govern this scenario, are generally relatively unconcerned about the environment.

This is a scenario where there is tremendous competition among countries, based on the constant development of new, differentiated products through the use of technology. On the one hand, this involves risks, even for the countries with the greatest current capacity to generate knowledge, such as Brazil, Argentina, Chile, and Mexico, because the gap between these countries and the developed world widens, especially in terms of investment in new technologies. The demand for product differentiation cannot be met at the level specified in the scenario, with the current capacity of the LAC countries. To

maintain this capacity at the required levels, there would have to be a heavy investment in R+D. For those countries that have a very limited capacity to generate know-how today, it is important to make an effort to achieve independence in generating know-how and technology in this scenario.

There is also a greater risk of epidemics, of the effects of climate change and of negative impacts on environmental sustainability, in comparison with the *Life as it is* scenario*,* for the reasons set forth below.

With regard to epidemics, the countries of Central America and the Caribbean are more vulnerable (in view of their current capacity to prevent known and newly emerging pests). They could damage agriculture and human health, and cause important losses. The research agenda should include development of technologies to prevent and eliminate these epidemics, or to find ways to adapt to or live with them.

Policies that guarantee inclusion of environmental problems on the research agenda for the region—especially for the megadiverse countries, such as Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Peru, and Venezuela--should be implemented over time, and mechanisms to inform end consumers and make them aware of the risks to the environment involved in this scenario should be established.

Requirements pertaining to quality, traceability, and safety of foods entail costs that may be too high for small enterprises to bear. It is important to build policies and strategies to guarantee access to low-cost technologies that enable producers to meet these requirements.

3.5.1.2. Implications for sustainable development policies

Global Orchestration describes a world in which knowledge and its constant accumulation is the key factor of development. This involves a risk for more vulnerable segments of the population in the poorest countries of the region, that are importers of food and agricultural products and/or that have a reduced capacity to offer quality education.

Policies to reduce the vulnerability of these countries and their people by reducing their dependence, primarily on food, are extremely important. A short-term, but less recommended alternative would be to guarantee food security in the most vulnerable countries, which are the current food importers.

An effort to guarantee quality education for the people in these countries in a consistent and lasting way would be another way of reducing risks. It is important to also bear in mind that this effort would be

facilitated in the world described by this scenario, in which education and knowledge are the basis for the development model.

There is a large migration from rural areas, that will increase urban poverty. Policies to offset this phenomenon would have to be implemented, primarily in the poorest countries.

3.5.2. Order from Strength

3.5.2.1. Implications for innovation policies:

In this scenario, the key element is the existence of barriers and the division between groups of countries. This division causes an increase in all the types of vulnerability found in LAC countries today.

In a scenario of scarce resources like this one, the R+D agenda focuses on efficiency and is governed by a businesslike approach, and the safety of commodities. At risk of disappearing in this scenario, generation of technologies must find creative forms in terms of implementation, but also to ensure the conditions, i.e., financial resources and capacity, needed to develop them.

In view of the weakness of R+D in the public sector, policies are needed to ensure that it is adequately maintained/ restructured, in order to generate capacity in line with national and international demand. This applies even to countries that currently have a greater capacity to generate technology, such as Argentina, Brazil, Chile, and Mexico.

The poorer countries need policies for innovation and coordination of research with extension services and technology transfer, which make it possible to generate, adapt, and adopt technologies suitable for the most vulnerable sectors.

In the case of technology transfer and extension services, greater financing as well as a restructuring of capacities, infrastructure, procedures and focal points are required. In this scenario, the system is in a very weak condition today in most countries. Even the few countries that invest most in these activities, i.e., Cuba, Brazil, Paraguay, and Peru, need some assistance to remain efficient.

The research agenda for a weakened R+D system in which demand is diversified and problems are acute requires a major effort to establish priorities for the allocation of scarce resources. Epidemics, the impact of climate change, and food security are competing for these resources. This means that R+D must receive and act on strong, precise, leading strategic proposals on the areas of research to pursue.

3.5.2.2. Implications for sustainable development policies

According to this scenario, international trade restrictions are one of the principal factors determining the sharp decline in virtually all conditions in the LAC countries. Consequently, policies to reduce barriers to Latin American agriculture are needed. On a global level, policies promoting multilateral relations would be important, as a way of avoiding such a negative scenario, especially for the most vulnerable countries.

The division among countries and regions in this scenario calls for regional cooperation to overcome intra-regional weaknesses in capacity and infrastructure, among other things; thus governments should give consideration and priority to this.

In view of the greater risk of epidemics, the effects of climate change, and environmental deterioration, special policies are also required to train and assist the most vulnerable groups to overcome the vulnerabilities prevalent in this scenario. The Central American and Caribbean countries are most affected by these negative influences. There are also losses in South America, due to climate change.

As for food security, which is highly compromised in this scenario in virtually every country, food importing countries have the option of planning and implementing policies to overcome their dependence or, if this objective cannot be attained, to establish mechanisms to assist their most vulnerable population segments.

Education policies to facilitate access by the most vulnerable sectors also need to be implemented, as do policies to compensate for the impact of migration and food security, mainly in the poorest countries.

3.5.3. Life as it is

3.5.3.1. Implications for innovation policies:

In view of trade restrictions and to make agricultural products more competitive, product differentiation is needed based on innovation, but this is only presented as a strategy towards the end of this scenario.

In view of the heterogeneity of the region, R+D must also focus on increasing efficiency, by reducing production costs and increasing productivity, or both, and on producing low-cost foods for domestic consumers and low-income countries.

Moreover, it is important to meet the technological needs related to improvements in the quality of products produced by the most vulnerable groups in response to the more exacting demands of better educated consumers.

Research is needed to adapt to and mitigate the effects of climate change and to prevent and manage pests and diseases, while preventing environmental deterioration, so that production efficiency and productivity will not decline. Since the scenario is based on the current reality, the South American countries are the ones with the greatest capacity to deal with these impacts in this area and in the future.

Countries that have the greatest capacity to generate knowledge today—in South America: Argentina, Brazil, Chile, and in the Andes, Venezuela; in Central America: Mexico and Panama; and in the Caribbean: Cuba and Trinidad and Tobago—also are most likely to generate the knowledge demanded by this scenario.

In this scenario, many countries in the region are limited to importing technology, in a world where productive processes and trade are integrated. This means that these countries have a limited capacity to cope with unforeseen risks, and are therefore more vulnerable. It is important to plan and implement mechanisms to improve their capacity to produce know-how and technology, through specific programs or well-defined objectives, and to consider alternatives for sharing the scarce available resources.

Environmental and social issues are not adequately taken into account by all countries in their research activities. At the outset of the first period, a few countries include this concern in their portfolio of R+D projects. However, this effort needs to be stepped up to enhance knowledge of ecosystems and of the impact of agriculture on them and on environmental services.

The application of traditional knowledge is only just beginning to be seen towards the end of the period. R+D should therefore be guided by proactive policies to incorporate this knowledge in generating know-how and technology.

Specific funds and project portfolios geared to more vulnerable population groups would be important alternatives to consider, to ensure that R+D pays attention to these groups. Research organizations should also acquire more expertise than they have today regarding the technological demands of the neediest social groups whose livelihood is agriculture.

Transnational companies become a relevant stakeholder in R+D, and the public sector loses ground. Integral management and investment policies in public R+D need to be implemented, to ensure that not only short-term economic demands are considered in this research. Moreover, it is important to implement proactive mechanisms to increase participation of private organizations in generating know-

how and technology in strategic economic and social areas, when the countries do not have the capacity to do so. The technology produced must be accompanied by a transfer of the capacity and knowledge needed to continue this process.

3.5.3.2. Implications for sustainable development policies

In view of persistent management instability, as a result of changes in administration without policy continuity, stability mechanisms are needed in government management, to ensure the continuity of long-term policies. This is particularly important to ensure quality education, which requires consistent and sustainable policies, especially in certain countries that are weak in this area.

As a result of climate change and the increase in food prices, some countries must implement policies to ensure access to quality food.

For poor countries and peasant production, specific policies are needed to assist them in incorporating sustainable practices in their production processes.

3.5.4. Adaptive Mosaic

3.5.4.1. Implications for innovation policies:

This scenario is based on huge climate changes and social crises, which governments are unable to manage without the assistance and empowerment of various social groups. These changes will probably have a greater effect on South America, because of its larger size and environmental restrictions on production of crops without irrigation, and on Central America, due to its smaller production capacity, which will also have repercussions on food security in the countries of this subregion.

The environmental issue and the reduction of the effects of climate change are critical to this scenario, which seeks to achieve these objectives by using all types of available knowledge, including biotechnology and nanotechnology, agro-ecology, and traditional knowledge. Thus the R+D agenda should already be oriented to these objectives. There is also a need to find ways to promote interaction and synergy among the different types of knowledge that can presumably bring benefits to all, in the form of reduced environmental risks. In LAC, countries that already have the capacity to generate technology today (Brazil, Venezuela, Trinidad and Tobago, Cuba, Chile, Argentina, Mexico, and Panama) and technology transfers (Cuba, Brazil, Paraguay, Peru) will possibly be in a better position to engage in this interaction and achieve this synergy.

R+D should be directed to understanding and solving environmental and climate change problems. This requires an understanding of the interaction among ecosystems, and between them and the new technologies, and of the possible international effects on shared natural resources.

In view of the longer time required to obtain results, in a scenario which requires that R+D consider all affected groups, where the environment imposes restrictions on the independent development of science, and where there is a need for more efficient use of resources, it is imperative to focus on improving management of R+D, with the integration of all stakeholders.

3.5.4.2. Implications for sustainable development policies

Adapting Mosaic is a scenario that requires many institutional changes, which is strongly reflected in governance and development policies in countries. While some countries that are generally less vulnerable today, such as Argentina, Brazil, Chile, and Mexico, will have major difficulties in adapting their laws, regulations, and practices to the new times, other countries will have similar problems because they do not have political stability and efficient governments. These are the countries with the worst problems of governance and integrated development policies at the present time. All of these countries should consider the possibility of designing stable policies aimed at improving environmental protection, providing greater access to quality education, and increasing the capacity to guarantee food security to their people in future.

Food security and the common environmental issue are the two major sources of concern in this scenario. For the first, it is important to identify alternatives that will not jeopardize environmental protection but will provide the growing, increasingly educated, hence more demanding population to have access to quality foods.

The scenario offers conditions for public support to facilitate initiatives to protect common natural resources, as part of the same environmental protection approach it favors.

3.5.5 Technogarden

3.5.5.1. Implications for innovation policies:

This scenario is triggered by a strong impact on climate change, together with social movements initiated in European countries in favor of diversification of agriculture, and geared to protecting the environmental services of ecosystems. Societies cope with their problems by anticipating and identifying specific technological solutions.

Agricultural diversification is already beginning in the megadiverse LAC countries (Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Peru, and Venezuela. But not all of these countries initially have

the capacity to conduct the research needed to obtain an adequate economic return from different environmental services. Brazil, Colombia, Mexico, and Venezuela are in the best position to do so.

Environmental protection, an understanding of ecosystems and the environmental services they provide, the correction of anthropogenic aggression against nature, interaction among the different socio-economic, cultural, and environmental systems, and the creation of differentiated products by technological innovation (always with a low environmental impact), and new processes for diversification of agriculture constitute the main items on the technological agenda in this scenario.

This is a scenario that gives preference to the growing integration of knowledge of all kinds, whether formal or traditional. Thus, more than in any other scenario, this world is governed by knowledge, which at the same time strongly drives it, leading to the development of a new understanding of the systems and their integration.

It is also a world in which all social groups are covered by R+D, while at the same time the development of new products and processes intensifies, as does the anticipation of problems, especially in relation to the environment. Consequently, a large capacity for management and planning of the development of know-how and technologies is also needed. Here the scenario differs from *Adapting Mosaic,* where the issue of the speed of technological development is not as important.

3.5.5.2. Implications for sustainable development policies

In the world of *Technogarden,* agriculture is only one part of the agro-industrial complexes that offer differentiated products based on technology as well as environmental protection processes. There are no more small producers, as they were displaced to the cities.

This means that new institutions and institutional arrangements need to be created to support this new paradigm, but they are also required to monitor its benefits and risks for society. Countries that already have the capacity to generate technology and megadiverse countries, which are encountering environmental protection pressures and already have laws on this, will find it easier to adapt to this new paradigm.

Unemployment is one of the major problems in this scenario. It will have a greater impact on countries whose current population is characterized by low levels of education, such as Peru, Bolivia, Honduras, and the Dominican Republic. In these countries especially, policies that will lead to the creation of new

job opportunities can be implemented, in areas such as diversification of agriculture, enterprises related to the new agriculture-based products, or reductions in workload.

Despite the concern over the environment, new environmental problems emerge, as a result of the technological solutions tried out in this scenario. R+D needs to be oriented to achieving a systemic, in-depth understanding of ecosystems, biological systems, and their interaction, and also to adequate monitoring of these ecosystems and the impact of technologies on them, which is already included in this scenario as a way of solving these problems.