CHAPTER 2

AGRICULTURAL KNOWLEDGE, SCIENCE AND TECHNOLOGY (AKST) SYSTEMS IN LATIN AMERICA AND THE CARIBBEAN: THEIR EVOLUTION, EFFECTIVENESS, AND IMPACT

Lead Coordinating Authors: Hugo Cetrangolo (Argentina) [hcetrangolo@yahoo.com.ar] and Jesús Moncada (Mexico)

Authors: Hernando Bernal (Colombia), Cecilia Gelabert (Argentina), Marcelo Regúnaga (Argentina), and Mario Samper (Costa Rica)

Contributors: David E. Williams, USDA-FAS, Antonio Castro (Brazil)

Review Editor: Celia Harvey (UK)

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Key Messages

1) Latin America has a rich tradition of individual and institutional efforts in agricultural science, knowledge and technology (AKST). While these have made significant contributions to food security and the agro-exporting sector, they have not taken full advantage of the existing potential for agriculture-driven development. LAC's different sub-regions have a heterogeneous AKST System structure involving public, private, local, national, regional, and international institutions and organizations of varying sizes and capabilities, as well as major differences between countries and subregions. Recently, innovative alternatives have emerged for the management of relevant bodies with the participation of civil society. However, the way the systems are put together do not respond to this diversity and potentiality – which has impeded optimizing the use of the regional AKST System, and blocked its technical spill-over effects.

The needs that have been detected are the following: Strengthening AKST System institutions, particularly in the relatively less developed countries. Improving linkages and cooperation within the AKST System, including public- and private-sector users. Promoting the participation of civil society to ensure greater social oversight and moral, political, and economic support.

2. Priorities on the AKST System agenda in the past were food security, the production of agroindustrial commodities, and low-cost foods for local consumption and export. While these remain significant, the challenge today is to develop technologies, innovations, and systems aimed at addressing the environmental and social dimensions and the specific demands of indigenous, traditional, and agro-ecological systems. The lines of research prioritized before were directed at boosting productivity in the primary sector. Fewer efforts were made to produce technological developments geared to the competitiveness of the agrifood chains, the production of non-agricultural goods and services in rural areas, and other activities that reflected agriculture's multi-functionality.

More attention must be paid, in all three main productive areas, to social, cultural, and environmental aspects often neglected in the past. Not enough importance, moreover, has been attached to the sustainable use of the region's enormous resources with regard to biodiversity, fresh water availability, and marine resources. Not enough concern has been shown, either, for the direct impact of productive systems on water and soil resources and tree cover, or the impact of deforestation, the expansion of the agricultural frontier, and climate change.

It is to be hoped that the AKST System will manage to reconcile conflicting goals such as competitiveness, on the one hand, and environmental, economic and social sustainability on the other.

3. In response to social demands, the AKST System agenda has become more diverse and complex. In its efforts to address problems like poverty, food security, environmental degradation, deforestation, biodiversity loss, natural disasters, and global climate change, it has incorporated social, economic, and environmental considerations

as well as the notion of working with all the links in production chains, from primary production to marketing. Yet few AKST System institutions can, by themselves, respond to such diverse and complex demands in a holistic manner.

Strengthening cooperation through global, regional and national networks, with proper strategic planning, execution and follow-up, is essential. Such networks should be more systemic and incorporate more broadly the various social actors. This will put to the test the solidarity and co-responsibility between countries and institutions.

4) The AKST agenda has not paid enough attention to the problems that affect the nutrition, health, and well-being of the urban and rural poor. There is a need to design, fund, and implement an agenda in favor of the poor at the global, regional and national level.

5) **The AKST System has made significant agronomic contributions that have mostly benefited large producers and well-organized medium producers**. Traditional, indigenous, and agro-ecological producers, who share a limited availability of resources and are less organized, have not benefited as much. Their equitable participation in defining the AKST agenda has not yet been achieved. There is a need to develop a participatory innovation and development system that can meet the needs of these three groups, take into account their capabilities, and help them fulfill their potential.

6) Investment in agricultural R&D in LAC varies among countries and sub-regions but in all cases is lower than in industrialized nations, and even developing countries in other regions. There is a need to increase government funding of AKST Systems, since for developing countries it remains the best investment.

7) In spite of AKST's contributions to agricultural production and productivity, recent decades have ironically seen a decrease in public funding. Regulations governing relevant institutions, moreover, are not conducive to research. This generates uncertainty as well as the inefficient use of resources. There is a need to provide public institutions with sufficient funding and establish mechanisms to reduce uncertainty and improve the efficient use of resources.

8) Private-sector R&D focuses on the development of appropriable technologies that have benefited from patent and intellectual property legislation. It has also played an important role in the local adaptation of technologies coming from industrialized nations. However, AKST contributions by the private sector do not meet development needs, particularly among traditional and indigenous producers. LAC needs an increase in private investment on agricultural research and development. This, in turn, entails public policies that will encourage such research. In certain countries, political, economic and institutional problems have limited policies of this nature. The hope is to achieve an appropriate balance in this area between the interests of producers and society, on one hand, and on the other a fair retribution for private investment.

9) International cooperation and NGOs have also engaged in efforts to supplement the role of government bodies in AKST, mainly in the environmental, cultural and social fields. But such efforts have been scattered, insufficient, and lacking in continuity. It will be necessary to increase such investments and promote their integration into the AKST System.

10) Several factors, external to agricultural technical development, condition AKST's potential to build more productive, sustainable, and equitable systems that contribute to food supply, food security, and poverty reduction. AKST has not been taken into consideration as much as it should have when formulating macroeconomic, commercial, and financial policies and those related to access to markets, education, and information. It will be necessary to find mechanisms to better link the AKST System with policy-makers and implementers.

11) In the region, the lack of strategic plans, and the poor participation of the AKST System in their formulation, has prevented an integral response to complex rural issues. The AKST System must be an integral part of the promotion, design, and execution of strategic plans.

12) Although society has a good perception of the AKST System, there is a certain ignorance of the importance and impact of agricultural technology, hence little social support for AKST, and adverse reactions to technology that are often baseless or negatively influenced by prejudices. Improved communication on the importance and potential positive impact of agricultural technology, based on a strategy of transparency and accountability, is a must.

13) Research institutions benefiting from public funding lack balance in their human resources, in terms of the variety of disciplines and cultures represented, and in terms of gender. Moreover, their researchers and support staff are growing older and few institutions have a program to renew their personnel. Programs must be developed that contemplate the training, updating, and diversification of scientific and technical cadres through incentives that encourage research in priority fields.

14) The AKST System has contributed to improving production and productivity (with subregional differences), but mainly within the conventional or productivist system.

15) The AKST System has not interacted sufficiently with traditional or indigenous systems, nor has it taken advantage of their capabilities and potentialities.

16) The agroecological system has emerged as an option for finding solutions to environmental, economic, and socio-cultural problems. It has arisen as a result of the interaction between the AKST System and producers who share such concerns.

17) Technological development has sometimes had its environmental and social costs. The balance of agricultural, economic, social, cultural, and environmental impacts has not been studied thoroughly enough. Neither have strategies been developed to mitigate the negative impact of various technologies and production systems. There is a need to assess the results of AKST in a holistic manner, bearing in mind not only their economic and productive impact but also their environmental, social, cultural, and political implications.

2.1 Inventory, characterization and evolution of the AKST System and its interactions

Latin America has a rich tradition of individual and institutional efforts in science, technology, and knowledge regarding agriculture. They have made significant contributions to many countries in the region. LAC's different sub-regions have an abundant but heterogeneous AKST System structure, with major differences between countries involving numerous institutions and organizations — public, private, local, national, regional, and international — as well as bilateral and multilateral cooperation programs, sometimes with contrasting agendas and capabilities.

The AKST System in LAC has gradually incorporated different institutions, programs, and other cooperation mechanisms – the aim having been to provide the needed geographical and thematic coverage. It has also sought to take advantage of, coordinate, and integrate the efforts of various types of public and private stakeholders at different levels (local, national, regional, and international). As a result, it has become a complex weave of institutions, programs, and cooperation mechanisms involving i) local and third sector organizations; ii) National Agricultural Research Institutes (NARIs), universities and other national organizations; iii) regional centers; iv) cooperative programs; v) consortia and specialized networks; vi) international centers such as Consultative Group on International Agricultural Research (CGIAR) and Global Forum on Agricultural Research (GFAR); vii) Regional Fund for Agricultural Technology (FONTAGRO); and viii) Regional Forum for Agricultural Research and Technological Development (FORAGRO). The system is illustrated in *Figure 2.1*.

Insert Figure 2.1.

2.2.1 Local and third sector organizations

The complex and intricate network of local organizations, each with its own links to and interactions with the AKST System, generates opportunities but also constraints that have expressed themselves in different ways, especially in the last three decades.

There is a rich and varied experience in the creation and successful operation of civil society institutions that support publicly funded AKST System programs. In Mexico, for instance, studies have been made of "interest groups" — in this case, farmers — who have voluntarily organized themselves in *Patronatos* to provide moral, political, and economic support to research programs of interest, implemented in INIFAP's experimental fields. (Box 1.1)

Insert Box 1.1.

The main constraints on the interactions between NGOs and AKST System institutions can be attributed to regional contrasts within each country, decision-making of a political nature, and limited social participation. They also reflect a trend toward privatizing research, technical assistance, and technology transfer to small and medium producers, as a result of

administrative decentralization, structural adjustment, and market liberalization – all phenomena that have accelerated in the last two decades (Quiroz 2001 p.104).

Several countries have attempted, through public policies, to develop production systems that break the cycle of exclusion and environmental degradation, and also incorporate a gender perspective and an indigenous and Afro-American worldview. However, much remains to be done to ensure the real participation of those stakeholders in decision-making at the local level (Dirven, 2003, p. 442).

Rural societies are also becoming more complex. More interactions between different types of stakeholders blur the boundaries between the rural and the urban. New scenarios are emerging, created by the demands of the various actors and their respective local organizations.

With regard to the AKST System, local development processes pursued by communities, either independently or in partnership with universities, foundations, corporations, cooperatives, producers' associations, and both national and international non-governmental organizations, offer the possibility of reappraising traditional knowledge, developing greater negotiating power, improving territorial management, and strengthening claims for access to land. This is evident in various social movements such as the Zapatistas in Chiapas, Mexico; the Landless Peasants' Movement in Brazil; and the claims of the Mapuche indigenous people in Chile and Argentina – all of which have had local impact as well as regional and international repercussions on the design of a new paradigm regarding AKST at the Latin American level.

Most Latin American States have not yet resolved their agrarian problem, one that affects their respective societies, particularly local rural sector organizations. However, this phenomenon is no longer associated exclusively with the rural milieu, but has also spread to urban areas (Machado 2004, p.73).

In spite of some isolated experiences, new advances in AKST involving bioelectronics, bioinformatics, and biotechnology have not been widely adopted by local organizations or *campesino* farmers. Moreover, no reconciliation processes have emerged to take advantage of their positive aspects. (León et. al 2004, p.54; Amaya and Rueda, 2004.p.10.)

2.2.2 National organizations

LAC's AKST System is made up of a vast network of public, private, and third sector institutions in the various countries that have generally had a major impact, reflecting the relative importance of agriculture to the region. Within this system, the national public agricultural research institutes, generally known as NARIs (or INIAs in Spanish), have a long history – many were created more than half a century ago – and have played a significant role in generating technologies for this sector.

Just as LAC is a heterogeneous geographic area, the NARIs of the different countries also display varied characteristics. Some enjoy a high profile and receive the major share of their country's investment in agricultural science and technology as well as regional investments. These include Empresa Brasileira de Pesquisa Agropecuária, or Brazilian Agricultural Research Institute (EMBRAPA) in Brazil, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, or National Forestry, Agricultural and Livestock Research Institute (INIFAP) in Mexico, Intituto Nacional de Tecnologia Agropecuaria, or National Agricultural Technology Institute (INTA) in Argentina, Instituto Nacional de Investigaciones Agropecuarias (INIA) in Venezuela and Corporación Colombiana de Investigación Agropecuaria, or Colombian Agricultural Research Institute (Corpoica) in Colombia. In other countries, investment in AKST System has been limited and no significant institutional structure exists at the national level.

Parallel to the work carried out by NARIs, universities have played a significant role in basic and applied research, and some have made important contributions to the dissemination of technology in the region. In general, coordination between NARIs and universities has not been satisfactory and, except in some specific cases, is an aspect that deserves greater attention, since the capabilities of both types of institutions could be enhanced, as shown by some success stories.

Certain LAC countries also have national science and technology institutions of a more general nature, with additional centers specializing in topics related to agriculture and natural resources. These have made important contributions in some fields, mainly basic research. However, it should be noted that the lack of coordination between scientific research and technology development is a feature common to nearly all countries.

In the larger countries with political structures involving decentralized resources at the provincial or state level, the AKST System usually includes public institutions of a provincial or regional nature, often specializing in certain crops, production areas, or issues of local importance. Some of these have made important contributions to the development of specific activities; such is the case of the Obispo Colombres Experimental Station, in Argentina's Tucuman Province, with regard to sugarcane production and other products of local interest.

In most LAC Countries, the public AKST System developed vigorously in its initial stages and made substantive contributions during the 1960s, 1970s, and part of the 1980s. However, the situation changed in the last two decades, when their relative importance and contributions declined with regard to conventional/productivist agriculture *vis à vis* the private sector. This has resulted from two simultaneous processes: a) a gradual decline in the importance and, in many cases, in the competencies of the State, which has led to reductions in the budgets allocated to AKST, and in certain cases to the closure or merger of institutions specialized in this field; and b) economic, social and technological processes, particularly in the Southern Cone, that have affected the agricultural sector in recent decades, particularly the scale and concentration of production. Both processes have placed greater emphasis on appropriable technologies

directed at increasing productivity, with the private sector playing a key role in generating and adapting technology, mainly in fields related to plant and animal genetics, chemical fertilizers, health products, and agricultural machinery.

The scale of the R&D investments needed to obtain technology products consistent with growing demands for competitiveness in modern agriculture means that many R&D efforts are beyond the scope of national S&T bodies. In many cases such initiatives can only be undertaken by global technology firms, which obtain benefits through the sale of inputs and capital goods, and income from royalties for developments protected by intellectual-property rights.

In some countries, private mechanisms for generating and disseminating technology have eclipsed the work of public institutions, whose efforts have focused on addressing the needs of small and medium-sized farmers — groups that are seldom of interest to firms that supply inputs, particularly when the potential customers are not able to purchase them in significant quantities.

Beyond the role of the private companies specialized in generating innovations and technology for the agricultural sector, private or public-private partnerships based on production chains have emerged in recent years that, in some countries of the region, implement research programs on topics they themselves have identified. Such innovative, albeit incipient, activities are carried out in close association with science and technology institutions and universities, and are good examples of identifying demands and engaging in planning and coordination to resolve technological problems.

Many significant advances in technology have been achieved by “catching up” with technologies generated in developed countries and adapting them to local or regional conditions in different countries. This has led to some very competitive developments in certain crops and regions — especially in temperate zones — with relatively little effort or investment in science and technology at the national level, by simply adapting the technology of other countries with similar agroecological conditions. However, it should be noted that certain LAC countries with fewer resources, particularly those in tropical and subtropical zones, have been unable to address specific local needs due to the lack of basic and applied research, and because they have not developed sufficient capacity in the field.[1]

National public institutions has focused R&D mainly on the most relevant ways of improving farmers’ livelihoods and incomes, while social and environmental aspects have traditionally

[1] It should be noted that in developed countries, technology for temperate zone crops is more readily available than for tropical ones; consequently, there are fewer possibilities of using foreign technology and adapting it to the tropical climate of LAC Countries.

received less attention. It is only in the last two decades that these issues have become more important in NARIs' activities.

The region's public AKST System has also placed greater emphasis on generating "hard" production technologies than on "soft" organizational technologies, due to the characteristics of its own member institutions. This has hindered their linkages with production models – a situation aggravated by the fact that technology products are often generated from the supply side, without considering the needs and capabilities of their recipients. As a result, support is growing for a line of thought that holds that the management of technological development should involve a greater participation by end users.

Demand-side requirements are becoming increasingly important in determining the types of technologies needed. Consumers and more concentrated distribution channels require new services like product traceability, certifications of origin and processes, respect for the environment, and "natural" products. This, in turn, has placed new demands on the AKST System.

Given that technology is both an economic and a social good, and given the negative social and economic trends in many Latin American and Caribbean countries in recent years, public AKST institutions have begun to incorporate social issues, such as subsistence agriculture and urban agriculture, in their agendas. However, S&T institutions are still a long way from being able to respond to specific demands in terms of developing appropriate technologies for the most disadvantaged sectors.

In some countries, extension and technology transfer systems have undergone major changes in the last two decades as a result of public institutions assigning greater importance to social issues and to small farmers due to the aforementioned emergence of the private sector as the main provider of appropriable technologies to larger producers, toward whom agricultural extension and technology transfer is generally directed. For specific types of farmers, independent professionals — both agronomists and veterinarians — are an important factor in technological development.

It should be noted that in some cases there is an important *spillover* effect, with the technology used by larger producers being adopted by small farmers, especially when they are not prevented from doing so by economic or cultural constraints.

2.2.3 Regional organizations, international centers and other regional cooperation mechanisms

LAC has had a long experience — more than half a century — of regional cooperation between countries and institutions on agricultural research and education. The existence of common problems in different regional and sub-regional spheres and in some fields of interest, as well as the constraints encountered in attempting to develop significant independent agricultural research programs, especially in the smaller countries, led to the implementation of various

initiatives. In some cases, these efforts were consolidated in new regional institutional structures: In others, they resulted in joint or cooperative research projects and programs and a growing exchange of knowledge among the region's national institutes, and between these and various regional and international institutions.

Some **regional organizations** are of long standing and in some countries even predate the creation of the national institutes (NARIs). One example is Inter-American Institute of Agricultural Sciences, currently known as the Inter-American Institute for Cooperation on Agriculture (IICA), an institution created in 1942 in Turrialba, Costa Rica, where an experimental station and postgraduate education center was established that subsequently led to the creation of Tropical Agriculture Research and Higher Education Center (CATIE)[2] in 1973. In that year, the research and training activities were separated from more comprehensive efforts of hemispheric scope undertaken by IICA, which established its headquarters in the canton of Coronado, also in Costa Rica but in the outskirts of the country's capital.

Also In the mid-1970s, the twelve members of the Caribbean Community (CARICOM) [3], a trade and integration initiative, created Caribbean Agricultural Research and Development Institute (CARDI) with the aim of strengthening agricultural research and development activities and supporting the agricultural sectors of member countries. These functions had previously been carried out by a regional Research Center, created in 1955 by the English-speaking Caribbean countries to meet the growing and increasingly complex challenges of agriculture.

In addition to the sub-regional centers mentioned above, in the 1970s and 1980s the NARIs and other public and private institutions of LAC countries gradually established *cooperative agricultural research programs* (known as PROCIs), which have grown notably and continue to function today. These programs evolved, from initial exchanges of knowledge among participating institutions, to the execution of joint research activities and the implementation of regional research projects and informal training efforts. Nowadays there are various cooperative programs for several topics and for all the sub-regions of the Americas.[4] The majority of these initiatives received support from IICA and the IDB during their initial stages. Such cooperative mechanisms, which do not require new institutional structures, have had a positive impact in

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[2] Currently with 14 members: IICA, Belize, Bolivia, Colombia, Costa Rica, Dominican Republic, El Salvador, Honduras, Mexico, Nicaragua, Panama, Paraguay and Venezuela.

[3] Antigua & Barbuda, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St Kitts-Nevis, St Lucia, St Vincent & the Grenadines and Trinidad & Tobago).

[4] The Cooperative Research and Technology Transfer Program for the Northern Region, involving Canada, Mexico, and the U.S. (PROCINORTE); the Caribbean Agricultural Science and Technology Networking System for the CARDI countries plus Suriname (PROCICARIBE); the Central American Cooperative Program for the Improvement of Crops and Animals (PCCMCA); the regional Cooperative Program for the Technological Development and Modernization of Coffee Cultivation in Central America and the Dominican Republic (PROMECAFE); the Central American Agricultural Technology Integration System, involving the Central American countries and Panama (SICTA); the Cooperative Research and Technology Transfer Program for the Andean Subregion, which includes Bolivia, Peru, Ecuador, Colombia and Venezuela (PROCIANDINO); the Cooperative Research and Technology Transfer Program for the South American Tropics, covering Brazil and the countries of the Amazon Basin – Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela (PROCITROPICOS); and the Cooperative Program for the Development of Agricultural Technology in the Southern Cone, which includes Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay (PROCISUR).

promoting technological development in the countries involved, as shown by various impact assessments.

There are also *consortia and specialized networks* for different topics, products, and sub-regions that have received support from FAO's national and regional offices and other international institutions. Some of the most important include the regional Cooperative Potato Program; the regional Cooperative Program on Beans for Central America, Mexico and the Caribbean; the regional Maize Program, coordinated by the International Maize and Wheat Improvement Center (CIMMYT); the Latin American Agricultural Conservation Network; the Consortium for the Sustainable Development of the Andean Ecoregion; the International Network of Farming Systems Research Methodology; the Technical Cooperation Network on Plant Biotechnology; and various cooperative research programs funded by the United States Agency for International Development (USAID) and administered by US universities.

LAC's institutional AKST System also has two other types of components, implemented in the 1990s in an effort to complete the region's institutional architecture and fill some of the gaps observed in its functioning: FONTAGRO and FORAGRO.

The Regional Fund for Agricultural Technology (FONTAGRO) is a consortium created to promote strategic agricultural research of regional scope with direct participation by LAC countries in setting priorities and funding research projects. It was established by a group of countries of the region[5], with sponsorship from IDB, IICA, the Rockefeller Foundation, and Canada's International Development Research Center (IDRC). Its purpose its to improve the competitiveness of the agricultural sector, ensure the sustainable management of natural resources, and work to reduce poverty through the development of technologies that qualify as international public goods. It should do this by facilitating the exchange of scientific knowledge within the region and with other regions of the world. The goal is to establish an endowment fund of 200 million dollars and use the annual dividends to provide sustained non-reimbursable financing for regional strategic research projects. Project funding is allocated through a competitive mechanism based on projects' coherence with the Fund's objectives and on technical, economic, environmental and institutional criteria established for the priority research areas defined in the Medium Term 2005-2010 Plan. The design and execution of the proposals is undertaken by different organizations in the Fund's member countries (research institutes, universities, foundations, private groups), together with regional and international research centers, in association with national technology development organizations.

Taking into account the growing importance of operating in knowledge networks, FORAGRO is a mechanism designed to facilitate discussion and support the definition of a regional agricultural technology research and development agenda. FORAGRO's general objective is to

contribute to the consolidation of the Agricultural Technology Innovation System for the Americas by facilitating dialogue, coordination, and strategic alliances between the stakeholders that comprise national, regional, and international technology research and development systems. In 1997, the Inter-American Board of Agriculture (IABA) decided to support the Forum's creation and asked IICA to set up its Technical Secretariat. In May 1998, FORAGRO held its first meeting. The Forum includes a wide range of members: national public and private agricultural research institutions, national science and technology councils, university education centers and private sector organizations, producers' associations, NGOs, public and private foundations that implement or promote technological innovation, sub-regional cooperative research programs, regional networks, CATIE and CARDI centers, CGIAR Centers located in the Americas, as well as FONTAGRO and IICA, which acts as the Forum's Technical Secretariat.[6] Although FORAGRO does not have official representation in CGIAR, it plays an important role in the design of that body's overall strategy by providing regional inputs for determining its priorities at the global level.

Finally, the regional Technology Research and Development Center of the Americas is supported by the international centers of CGIAR, the main global agricultural research network. Three of these centers are located in the LAC Region: CIMMYT, headquartered in Mexico; International Center for Tropical Agriculture (CIAT), based in Colombia; and the International Potato Center (CIP), headquartered in Peru. The Region also receives support from the rest of the network of international research centers for different activities and products with headquarters in other countries, including those specializing in policies, the International Food Policy Research Institute (IFPRI), plant genetic resources, the International Plant Genetics Resources Institute (IPGRI), livestock production International Livestock Research Institute (ILRI), and forestry and agroforestry, the Center for International Forestry Research (CIFOR) and the International Center for Research in Agroforestry ICRAF). All these institutes carry out activities in LAC and in some cases have offices in several countries in the region (Box 2.2).

Insert Box 2.2

In brief, we can say that the present AKST System in LAC consists of a complex web of institutions, programs and other cooperation mechanisms created over time with the aim of ensuring sufficient spatial and thematic coverage, and taking advantage of potential contributions from public and private stakeholders at the different levels (local, national, regional and international). (Figure 2.1.)

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[5] In 2000, its members included Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay, Venezuela and the International Development Research Center (IDRC). www.fontagro.org .

[6] FORAGRO implements biannual plans based on the interaction between the agreed political-institutional lines of action and the priority technical lines of action, consisting of 11 major research topics adopted for hemispheric cooperation (www.iicanet.org/foragro).

Nevertheless, various authors have noted that the lack of inter-institutional links has been a major weakness of AKST systems in LAC (Nickel, 1996; Eckboir *et al.* 2003; (Parellada and Eckboir, 2003; and Piñeiro *et al.* 2003).

In the *Amazon region,* the evolution of the institutional complex has been based on integrating its important contribution at the global level to the respective national economies, and reinforcing national sovereignty in the face of the possible internationalization of tropical rainforests (Becker, 2005a:72; Walschburger, 1992:359; Chaves de Brito, 2001:23). In this subregion, the key problem is the lack of an autonomous research corps and hence of regional capacity in science and technology for the agricultural sector (Aragón, 2005: 788; Franco, 2000; Aragón *et al.*, 2001:3; Domínguez, 2004:16; Becker, 2005b:624; Sicsú & Lima, 2001:25).

The advance of democracy and subsequent economic liberalization at the end of the 1980s and beginning of the 1990s redefined and energized the roles and functions of the State – all this in the context of an environmental crisis that has encouraged new ideas within the framework of sustainable development. Special reference must be made of the U.N. Conference on Environment and Development (UNCED), or Earth Summit, that was held in Rio in 1992 and promoted the development of AKST systems both by governments and non-governmental organizations.

In the 21st Century, a new AKST agenda is emerging in the region. It involves, for instance, South-South cooperation for eco-development and sustainable water management in the Amazon basin (Aragón & Clüsener, 2003: 25; Aragón, 1997: 591; Díaz, 2005), the Initiative for the Integration of Regional Infrastructure in South America (IIRSA, 2004; IIRSA, 2003) and the United States Agency for International Development's Amazon Basin Conservation Initiative (USAID, 2006).

2.2.4 Institutional and administrative constraints in national AKST Systems

Although LAC's national AKST Systems vary greatly in size, organizational structure, effectiveness, and level of support, and have very different characteristics stemming from their institutional, cultural and political context, a study carried out by Nickel[7] identified a number of common problems affecting these institutions. The most outstanding include limited inter-institutional cooperation (Table 2.1a), lack and poor allocation of resources (Table 2.1b), organizational and management weaknesses (Table 2.1c) and labor related weakness (Table 2.1d).

Insert Table 2.1a,b,c,d

National AKST leaders in LAC have acknowledged the existence of these problems and several efforts have been made to correct them, often through externally financed projects. ISNAR, for

[7] Nickel "The role of agricultural research" published by ISNAR (1996).

instance, sent specialists to various countries to assess their institutional situation and offer advice on the best measures to improve organizational structure and administration and management procedures. It also devised tools for research management and made them available to institutions through publications and training programs. This has led to a significant improvement in the effectiveness and efficiency of some national institutions. But many problems persist because certain institutions continue to operate in a policy and cultural environment that is not conducive to the changes required.

In order to overcome these problems, a variety of semi-autonomous institutions have been established, based on the assumption that they would be free from political influence in such fields as hiring and would enjoy greater flexibility in such areas as their administrative regulations.

Often, however, the institutional changes proposed could not be implemented, o were only done so partially. When examining the reasons, one or more of these factors seem to have played a role: i) the Ministry of Agriculture or its equivalent agency would not renounce control of the AKST body; ii) the new human resource policies were not all that different from those applied in Ministry departments; iii) administrative procedures and financial controls remained too complex.

Human resource issues cannot be attributed to the quality of researchers, who are often cited as among the most capable and productive scientists in the field, but rather to the working atmosphere and the resources available to those centers. It should also be noted that simply improving salaries to attract and retain competent personnel does not automatically increase productivity nor the quality of research unless, at the same time, more attention is paid to the processes whereby staff is hired, evaluated, and provided with incentives.

Sometimes, particularly in traditional government systems, annual salary increases and promotions are based on seniority, not on productivity. The reason such systems were adopted was to discourage “favoritism”. This is undoubtedly a consideration. However, it has become a crutch for a majority of the personnel of these institutions, aggravated in some countries by the existence of labor laws that make it almost impossible to sanction or fire unproductive employees. Productivity is thus rarely valued or rewarded, a severe weakness of national institutions that, unless corrected, will condemn them to mediocrity.

In addition, LAC’s oldest publicly funded research institutions such as EMBRAPA, INTA, INIA and INIFAP of Brazil, Argentina, Chile and Mexico respectively are faced with a problem of ageing researchers and support staff. Few of these institutions have adopted plans to renew or replace human resources due for retirement. In some countries, such as Mexico, this has resulted from a government policy of “indiscriminately downsizing the state apparatus” – an issue that merits critical assessment with a view to designing rational, efficient and effective policies.

Few AKST institutions have programs for training their scientific and technical staff and keeping them up to speed on current developments in their field, nor do they offer incentives to attract talented young people into cutting-edge research in new, highly promising fields like biotechnology or nanotechnology. Even less attention has been paid to other fields of knowledge — economic, social, anthropological — that are not so new or popular, but are very valuable when it comes to explaining and encouraging individual and collective attitudes and actions in order to generate and implement innovations leading to productive, sustainable and equitable development.

The abovementioned challenges justify efforts to promote a greater and more effective interaction between research centers and advanced training and education institutions, and to promote their participation in projects of interest to their respective countries and societies involving is known as Participatory Innovation Development.

In the administrative field, it is clear that senior managers of AKST institutions feel more comfortable with bureaucratic procedures than with more flexible systems for administering financial resources and purchasing inputs, since the former protect them from being accused of mismanagement. Safeguards or controls are necessary to prevent abuses, but it is also essential to adopt more flexible and effective administration and financing systems. This is particularly crucial in AKST System institutions, where significant delays in making funds available, or in purchasing equipment and inputs, can negatively impact the effectiveness of research.

However, either because of the nature of their legal constitutions or because of subsequent administrative decisions by the Central Government, most NARIs have operated within the administrative restrictions and political interference that characterize Latin America's public sector (Bisang, 2003).

Piñeiro, (2003) cites Argentina's National Agricultural Technology Institute (INTA) as an example of the progressive erosion of their autonomy. Created in 1958, INTA's charter granted it financial and administrative autarchy. However, over the years, the political authorities gradually curtailed this independence, converting it *de facto* into an institution with the same restrictions as the rest of the central administration. (Recently, this situation was reversed when INTA recovered its budgetary autonomy.)

A similar situation occurred with Mexico's National Agricultural Research Institute (NARI), which was widely recognized for its effectiveness, efficiency and productivity. Legally, it was a deconcentrated body of the central administration; from the beginning it was endowed with a trust fund that allowed for flexible and timely financing and operational autonomy. This mechanism was canceled in 1982, as part of a general government instruction to cancel public trust funds, and thereafter the Institute became subject to the regulations of the central administration, which were not very suitable to research functions. However, national public

research centers like INIFAP currently enjoy once again a trust fund that contributes to the flexible and timely financing of their research activities.

At present, the effectiveness and relevance of AKST System institutions is in doubt. The lack of consistent political support, the ensuing weakness and randomness of public funding, and institutional "obsolescence" in the face of the growing complexity of science and extraordinary changes in the economic context, all call for AKST institutions in LAC countries to embrace modernization (Piñeiro and Trigo, 1983), including modifications to their management processes and their links with users.

To be more efficient and effective, changes to AKST System institutions must be approved, implemented, and audited. External political pressures must ensure that these changes are approved by higher-level government authorities. That will not be easy. This external political pressure may be exerted more naturally and efficiently by society through the social oversight of stakeholders, who will ensure that AKST institutions implement the approved changes. In other words, the advancement of AKST Systems in LAC depends in large measure on their capacity to monitor the risks and opportunities posed by their external context and their capacity to communicate with their users and obtain their feedback.

Such a legal framework would allow for a responsive and flexible management style, essential for achieving greater efficiency – including salary levels and promotion system for scientific personnel, flexible recruitment policies, links and associations with the private sector, royalty contracts, and/or a share in income derived from intellectual property. Examples of this trend in the region include Chile's INIA and the Colombian Agrarian Research Corporation (CORPOICA) (Piñeiro, 2003). In response to this problem, Mexican lawmakers took the initiative of creating a new definition for public research institutions.

There has also been a growing tendency among NARIs to include representatives of leading private sector trade organizations on their governing bodies at the national and regional levels. Argentina's INTA has enjoyed a long history in this regard; half the members of its Board of Directors have been representatives of producers' organizations since it was established in 1956. Among the more interesting examples of this trend one can mention Uruguay's INIA, CORPOICA, and INIFAP. However, sometimes the composition or actions of the governing body could be improved, as in the case of INIFAP in Mexico (Piñeiro *et al.* 2003).

2.2.5 The evolution of the AKST System

Technology generation in LAC dates back to pre-Columbian times. Notable contributions have been made throughout history, for instance in the Andes and the Amazon basin.[8] Towards the

[8] Among other significant innovations that have been documented as part of Inca civilization, one can mention drainage systems, as well as anthropic soils and other recent archaeological findings in the greater Amazonian basin. The diversity of genetic resources to be found in Peru is an achievement of its indigenous peoples who, over at least 10,000 years, domesticated native plants, selected them, and adapted them to ecological niches of varying altitudes. Thanks to

end of the nineteenth century and the beginning of the twentieth century, the AKST System was institutionalized; that is to say, the first stage of organized agricultural research began in universities or specialized national institutions sponsored by the State. In those early stages, these institutions were organized into departments, that is, by branches of knowledge. Their researchers interacted very little with each other, and their sphere of action was the Experimental Station.

In the second half of the twentieth century, farming system research was incorporated, forcing researchers to interact directly with the rural milieu. From the relatively simple environment of the Experimental Station, the move was made to the more complex and multifaceted context of farms and production systems, leading to an acknowledgement of the need for interdisciplinary work. By working with "cooperant producers", researchers adopted an informal but highly effective role as extension workers that were broadly appreciated by producers. Some LAC countries have pursued such a researcher/extension-worker strategy as an effective means for the transfer of technology.[9]

In many LAC countries, however, extension services have not been integrated with agricultural research efforts, often separate agencies of Agriculture Ministries. The question of how to improve the effectiveness and efficiency of technical outreach and technology transfer has been, and remains, a highly significant and relevant issue.

Some LAC Countries have pursued a participatory strategy involving farmers and extension researchers as an effective means of experimentation and transfer of technology (Piñeiro *et al.* 2003). These participatory systems have not only become important in technology transfer and training projects with low-income farmers and women but are also being used for such purposes as the genetic improvement of plants or the characterization and management of natural resources (Araya and Hernández, 2006).

One objective of participatory research programs is to take advantage of farmers' knowledge, which obviously implies identifying their needs, their preferences, and the reasons for what they do. Although society recognizes farmers' role in managing and improving germplasm, there is little agreement on how to appraise the role of farming communities – traditional, indigenous and agroecological systems, not conventional agricultural systems – and their potential contribution to formal systems of genetic improvement.

Technical cooperation can only grow and develop if potential barriers of mistrust are discussed and addressed ethically. The key issue here is to ensure that plant breeders – both producers and scientists – have access to germplasm.

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this, and to the domestication of various species of fauna, Peru is one of the richest world centers of genetic resources, having domesticated 182 species of plants and five species of animals.

[9] For instance, in Mexico, INIFAP formally established Cattle Ranchers Groups for Technology Validation and Transfer, with initially promising results (Piñeiro *et al.* 2003), as well as Experimental Farmers for vegetable production. In both cases, small producers were targetted.

In some LAC countries, we have witnessed over the past two decades a trend toward taking advantage more integrally of existing research institutions, mostly State-sponsored, and considering them part of a research and technology transfer system whose challenge is to promote a networking synergy based on interinstitutional complementarity.

The design, establishment, and operation of more efficient and effective AKST Systems is at different stages of development in LAC countries, going from rhetorical discourse to efforts aimed at responding to specific demands from society. In the institutional discourse, it is often said that institutions have evolved from a supply-driven model to a demand-driven model. However, the weakness of AKST systems in most LAC Countries has limited their capacity to develop interinstitutional links, as reflected in a limited number of partnership-based projects.

A new current of thought proposes that the greatest challenge is to shift from existing AKST systems to Participatory Innovation and Development (PID) systems that focus on specific production chains or commodities. Another conception, wider and more inclusive, involves the application of such systems to watersheds as the natural spaces or territories in which one or more production chains operate and interact with each other and with the broader environment.

These developments have brought about new requirements regarding the attitudes and communication processes needed to facilitate dialogue and linkages between, on the one hand, those who generate technological knowledge and innovation and, on the other, those responsible for other links or factors indispensable to the development, productivity, and competitiveness of the production chain or watershed – suppliers, producers, traders, and financiers, as well as officials in charge of infrastructure, public policies, and institutions, and those in charge of information and communication mechanisms aimed at enhancing participatory development.[10]

It is also necessary to improve the efficacy and efficiency of universities and other existing research, development, and technology transfer institutions. This calls for the creation of formal and informal mechanisms for interaction, including service contracts between such institutions and private sector users. In that respect, special programs and mechanisms have already been established to promote and facilitate linkages between agricultural research bodies and farmers.[11]

For the past several decades, moreover, private enterprise has become actively involved in the AKST System and has assumed an increasingly important role in the development of certain innovations (such as genetic products, machinery, and agrochemicals) and their dissemination

[11] For example, INTA in Argentina has implemented a technology transfer program, while Brazil's EMBRAPA and Chile's INIA have special programs in their regional centers. In Mexico, INIFAP has established the Cattle Ranchers' Technology Validation and Transfer Groups, the Experimental Farmers, and the MOCAT groups. For its part, civil society has created the Patronatos and the *Produce* Foundations to support agricultural and livestock research. In Bolivia, SIBTA has moved toward a model in which a good deal of technological innovations is carried out by private foundations that obtain financial support from the Government's budget.

among producers through the sale of inputs or services. As a result, public research institutions find themselves in the dilemma of either competing, withdrawing from the field and focusing their efforts on developing other innovations, or attempting to cooperate on joint strategies. In other words, public AKST institutions face the challenge but also the opportunity of working with private AKST institutions on projects of mutual interest. This decision has strategic political implications that must be considered. It will test governments' vision and their willingness to generate new game rules, or standards, for public-private partnerships, in the interest of safeguarding the interests of society.

Another challenge facing AKST institutions in LAC is to take advantage of the enormous potential offered by new fields of knowledge such as biotechnology and nanotechnology, which are being incorporated at a different pace by the countries of the region.[12]

Although such developments may offer interesting alternatives related to people's well-being and quality of life, the level of investment required, together with patent- and copyright issues, could become insurmountable obstacles to taking advantage of their potential to benefit the region's poor. New developments are being used mostly by industry and the service sector, where users have purchasing power and the interests of investors are protected by intellectual property rights and patents. One of the greatest challenges facing small and medium-sized countries in LAC is to review, update, and reinforce mechanisms and processes for regional cooperation in this area.

Tables 2.2 and 2.3 summarize the factors that condition AKST's potential to develop more productive, sustainable, and equitable systems. They also summarize AKST's most significant impacts in Latin America.

Insert Table 2.2

Insert Table 2.3

2.2.6 Interactions between organizations and knowledge networks

In the early 1950s, formal national research organizations would transfer their technological innovations through public extension services and private agents. They did so with varying degrees of success, depending on the type of crop, type of producer, or agro-ecological area. The interaction between science, on one hand, and local technology and knowledge systems on the other, tended to be one way, frequently leading to the latter being undervalued.

[12] For example, biotechnology is not limited to the world of genetic engineering (DNA). There have been other agronomic efforts in this field, focused on integrated pest and disease management or the integrated management of agro-ecosystems. Biotechnology includes knowledge and management of soil microorganisms, different types of compost, green manures, forage crops, multiple-crop systems, biocultures, rhizosphere microbial cultures, efficient microorganisms, and bacteria that promote growth in plants and induce systemic resistance. These are just some examples that expand the horizons of biotechnology, and should be given equal consideration in government financing policies (León *et al.*, 2004).

Starting roughly around the 1980s, and varying from country to country, a reappraisal was made of the relations between organizations and knowledge networks. Two reasons accounted for this: the need to provide agile and innovative responses to the changing environment; and the redefinition of the role of public and private actors in agricultural research and technological innovation.

Although the ways in which networks have developed in the different countries display major differences, some important changes that have occurred in the last 25 years can be identified across the board:

In many countries, the relative importance of government investment in agricultural research declined, although it continued in the universities, increasingly relying on resources from the productive sector.

The role of extension services has been redefined for budgetary reasons and due to the restructuring of the State's role in agriculture. As a result, some extension tasks have been privatized and different types of civil society associations and organizations have intervened more actively in the provision of technical support.

In general, private or non-governmental actors have taken a more active role in the generation, validation, and transfer of agricultural technology, partly on the initiative of agroindustrial firms and providers of seeds and inputs, but also due to a greater role by local and international NGOs and producers' associations themselves.

There has been a revaluation of farmers' own knowledge of agro-ecosystems and production systems better suited to local conditions. This has coincided with agroecological studies that examine comprehensively the complexity of these systems from a scientific perspective.

Our understanding of the interfaces between local technological knowledge systems and the scientific-technical system has improved with experiences in cooperation or joint experimentation. Studies have begun on both the constructive and negative interactions between formal and informal networks for the dissemination of agricultural knowledge.

Formal research networks are beginning to transcend the national sphere through joint efforts at the international level, although this remains incipient.

The development of such interactions differs greatly, especially between relatively small countries and larger ones where the size of the agricultural sector itself, and public and private investment, have made it possible to establish institutions with more significant human and financial resources and their work has developed on a larger scale and with a more long-term projection, as in the case of Brazil, Argentina, Mexico, Colombia, and Venezuela.

In Central America, by contrast, the economic problems and policies of the 1980s, together with structural adjustment and state reform, led to a weakening of public agricultural research institutions and their links with international organizations and local universities, where a good

part of formal agricultural and livestock studies continued to be carried out. Some undergraduate and post-graduate education centers with international projection, however, continued to promote concerted research efforts and served to link researchers within and outside their respective countries – such as the Tropical Agriculture Research and Higher Education Center (CATIE), the Zamorano Pan-American Agricultural School, in Honduras, and *the Escuela Agricola de la Region del Tropico Humedo* (EARTH University).

At the same time, the "Farmer to Farmer" movement and analogous experiences supported by producers' organizations and non-governmental cooperation agencies encouraged smallholder (*campesino*) experimentation, reconfigured the relations between technicians, scientists and farmers, and promoted alternative technological approaches in pursuit of a greater agroecological and social sustainability.

In the 1990s, efforts began to develop more participatory relations between public and private stakeholders engaged in producing and transferring technological knowledge. Such efforts involved exploring more participatory forms of research and extension, setting agendas through consultations and negotiations, and testing different forms of participation by farmers and their organizations in the various phases of the research process as well as in the assessment and dissemination of results. Different positions have been taken on the effectiveness of these activities, albeit at a very preliminary stage. But it is clear that consensus mechanisms are required in public-private agricultural and livestock research that may take a variety of forms and follow different paths.

2.2.7 Society's perception of AKST Systems

The *public perception of science and technology* may be defined as a set of factors that have to do with the general public's understanding, knowledge, and attitudes towards scientific and technological activities (Albornoz *et al.*, 2003).

It is important to note that society has a positive perception of science in general, and technology in particular. This attitude is associated with the notions of modernity that prevailed over recent decades. However, negative views of technology, usually associated with concerns over environmental and social crises, also exist. (Casanovas, 2006, Albornoz *et al.* 2003, Piñeiro *et al.*, 2003).

The lack of response to environmental problems linked to agricultural production techniques – like the contamination of water, ,soil and food with agrochemicals, the loss of biodiversity, and the clear-cutting of forests to expand the agricultural frontier – has often provoked determinist postures among certain sectors of society, especially social movements and NGOs linked to the rural sector. Much of the debate around these issues is based on a lack of information, or incomplete or biased information. This underscores the importance of promoting an effective liaison with the mass media (Albornoz 2003).

A greater participation by society in the social oversight of AKST System institutions, both in terms of their work agenda and their performance, is also needed – among other reasons, to provide moral and political support through "positive external political pressure" on AKST System institutions, as well as on the Government itself. (RICYT/CYTED 2003, SENCYT, 2005.) *(Box 2.3.)*

Insert Box 2.3

2.3 Research approach, agenda, and processes

2.3.1 The AKST System agenda

From 1945 onwards, the AKST System agenda in Latin America and the Caribbean (LAC) had a strong biological orientation and was driven by agricultural export activities based on the premises of modernization and import substitution (Méndez 2006:74; Ballarin 2002:107; Kalmanovitz & López 2006:112; Dixon 2001). These lent special weight to economies of scale.

The current agenda and processes for generating knowledge and technological innovation in AKST institutions in LAC have become more diverse and complex. Nowadays, AKST System institutions are expected to address issues related to all the links in the agricultural production chain.

At the national level, AKST institutions face growing challenges in their efforts to address a wide range of diverse research agendas. These are aimed at generating:

Technological innovations for specific production systems of strategic interest to a particular country and/or watershed.

Innovations to explore and develop new agricultural products with high export value.

Technological innovations aimed at benefiting the poor and designed to meet their needs.

The design, application and financing of some of these research agendas has been, is, and will remain the responsibility of the State, since the goal is to generate public goods for society as a whole but mainly for the poorest sectors.

Due to their implications, other efforts regarding the AKST System agenda, such as the development of new agricultural products with high export value, will have to be financed mainly by the private sector. However, government support should not ruled out, given the interest by any country in improving its balance of trade.

A wide range of issues, such as post-harvest handling, food safety, nutraceuticals, and organic products, also form part of society's new and growing demands. For this reason, it is said that today's AKST System agenda is driven more by consumers than producers.

Such considerations, together with a growing environmental awareness, means that some sectors of society expect AKST institutions to address and reconcile seemingly conflicting objectives, like productivity and environmental sustainability (Moncada and Muñoz, 1999).

Countries also face the challenge of responding to subregional AKST agendas (in Central America, the Caribbean, the Southern Cone, and the Andean countries) that are directed at generating knowledge and technological innovations and providing relevant subregional public goods for local application in fields such as:

Climate change

Diseases

Biodiversity

Water availability and quality

Land degradation

Management of persistent organic residues

Air pollution

Traditional government institutions have little capacity to meet such a broad array of demands. As a result, others have begun to emerge. They specialize in specific areas, such as post-harvest handling, food quality and safety, and certain promising cutting-edge fields such as biotechnology and genetic engineering.

We are just beginning to witness the emergence of institutions in a front-line scientific field – nanotechnology[13]. As what might be considered an unprecedented preventive action, governments, industry and the world's research organizations have started to study ways to take advantage of its potential benefits while minimizing its potential risks. However, despite commitments to that effect, many opportunities have been missed to establish cooperative research programs.

The following question, however, remains unanswered: who will finance research projects aimed at using the potential of nanotechnology in areas of interest to the poor, such as health, nutrition, or energy?

Reducing poverty has been a secondary concern for the AKST System agenda in LAC. The primary goal has been to boost productivity in order to increase the food supply and reduce food prices. Implementing a research agenda aimed at helping the poor has been discussed by Hazell and Haddad (2001). More recently, in 2005, the International Food Policy Research Institute organized a meeting to explore poverty-related issues that might be of interest for public-private financing of pro-poor research projects.

Particularly noteworthy are certain research initiatives regarding the poorest social groups *(see Box 2.4).* The initiative by the Mexico-based International Maize and Wheat Improvement

13 Nanotechnology has been defined as the capacity to see and manipulate microscopically small structures – including atoms and molecules – and use them to create a new generation of materials and substances useful to humanity.

Center (CIMMYT) to promote the use of QPM (Quality Protein Maize) in several Central American and South American countries could be mentioned. Another example is INIFAP's adaptation of genetic material produced by CIMMYT to areas with a high concentration of poverty in the states of Oaxaca and Guerrero. In combination with the National Institute of Nutrition, INIFAP has already gathered statistical evidence to show the nutrition benefits offered by these types of maize to indigenous children in Oaxaca.

Insert Box 2.4

2.3.2 Clients of the AKST System

Different socio-economic segments strive to determine the focus of research in relation to their own needs and aspirations. Assessments have been carried out of the importance to the public agricultural R&D sector of a variety of economic-social segments as target groups or beneficiaries of research in the field.

Castro *et al.* (2005) analyzed the situation in six Latin American countries (Brazil, Cuba, Mexico, Panama, Venezuela and Peru). Their study revealed general agreement among researchers in the region regarding the relatively low importance of social segments such as subsistence farmers and small family producers vis-à-vis medium- and large-scale producers. This work offers at best a partial perspective – only researchers were consulted. It therefore does not reflect the points of view of other sectors of society. Trigo and Kaimowitz's research (1994) on Latin America and the Caribbean, however, confirms that the benefits derived from the agricultural research undertaken by NARIs were mainly directed towards the larger, market-oriented farmers located in favorable ecological zones (Schuh 1992 and De Janvry 1991, cited by Trigo and Kaimowitz 1994).

This view of agricultural research is much more closely linked to economic development and agribusiness, and less to the social development of underprivileged segments like subsistence farmers and indigenous communities in agro-ecosystems, (Castro *et al.* 2005; Santamaria *et al.* 2006; Lima *et al.* 2006; Trigo and Kaimowitz 1994).

A study by Castro *et al.* (2005) also found that non-governmental organizations were considered of little importance as agricultural research clients in Venezuela and Peru; of medium importance in Panama, Mexico and Brazil; and of high importance only in Cuba – even though Trigo and Kaimowitz (1994) noted the importance of NGOs with regard to the development of sustainable technologies, which involves highlighting local demands difficult to identify through the traditional approach to technology transfer.

Decentralizing research activities through the training of local non-governmental organizations, extension agencies, and farmers, in order to carry out simple adaptive research, would appear to be in order (Chambers *et al.* 1989, cited by Trigo and Kaimowitz, 1994).

New priority clients also mentioned in studies on the subject include public policy-makers and agroindustry. This takes into account recent advances in scholars' concept of agricultural research as not only directed at rural producers but at society as a whole – in this case, represented by consumers.

The greater importance of agroindustry as a client suggests a conception of agricultural research as linked to production chains and the development of processes technology capable of adding value to primary agricultural production, as well as competitiveness to those chains. This concept, more recent in the region, replaces the view of agricultural research as linked exclusively to primary production that prevailed until the 1980s. Trends governing demand imply greater specialization and a call for technology products aimed at a broader typology of producers (Castro *et al.* 2005; Trigo and Kaimowitz 1994, Lindarte 1990).

Finally, a notion emerged in the 1990s that attaches greater importance to clients such as policymakers, input providers, wholesalers, and retailers: It suggests a more politically influenced organization of research and a search for partners to resolve the shortage of financial resources (Castro *et al.* 2005; Trigo and Kaimowitz, 1994, Cetrangolo 1993). Table 2.4 summarizes the AKST agenda in Latin America and the Caribbean over the past 50 years.

Insert Table 2.4

Historically, agricultural research organizations have found it difficult to determine the focus of research for each socioeconomic segment, involving as it does many complex dimensions – political, scientific, technological, environmental, economic, and administrative. To make matters worse, scientific progress has been uneven throughout the region. (Castro *et al.* 2005.).

While knowledge regarding the demands of medium- and large producers is ample, research organizations know little about the demands of other segments, such as subsistence farmers, indigenous communities, and small family farmers linked to production chains, and do not much value them.

2.3.3 Research styles

Research activities may be geared to different purposes. These purposes are commonly associated with the different types of research: basic, applied, adaptive, and strategic.

Studies that assess current research efforts by the public and private sectors regarding agricultural research of each type show that organizations involved in these activities are strongly oriented toward applied research, followed by adaptive research. Strategic research is the least important at present, but will become more important in the future, along with basic research.

During the 1950s, the dominant approach was adaptive research, based on the belief among policymakers that sufficient technology existed for the modernization of agriculture. This view

prompted the establishment of agricultural extension systems in nearly all Latin American countries (Rice 1971, cited by Trigo and Kaimowitz 1994).

The role of the private sector was limited to supplying seeds and agrochemicals. The food processing industry was still in its early stages, strongly dependent on public sector support. Except in the case of a few export products, private research was virtually non-existent. (Malan 1984 and Moura 1990, cited in Chor 2005:121.)

An analysis of historical trends suggests a gradual decline of applied and adaptive research in the public sector in favor of increasing efforts in basic and strategic research (Castro *et al.* 2005).

The development of biotechnology has prompted a change of emphasis towards basic research, which is evident in the growing importance of laboratory work with regard to fieldwork. Greater importance is attached to research institutions involved in basic science. For their part, Trigo and Kaimowitz (1994) note the importance of restrictions in the free flow of information, with a greater exclusion of research results from the public domain given their increased market value.

The private sector plays an active role in developing biotechnologies. Its interest grew with the advent of deregulation, economic liberalization, regional economic integration processes, and the growing recognition of intellectual property rights related to genetic material and other agricultural inputs (Trigo 1981, Trigo and Kaimowitz 1994). This will have major implications for the region stemming from the wide dissemination of new biotechnologies, increased use of intellectual protection mechanisms, and support to regional industries, and will impact the interactions between the different public research institutions.

With regard to strategic research initiatives, according to Trigo and Kaimowitz (1994), efforts that do not have short-term commercial application require direct participation by the public sector. At present, according to Castro *et al.* (2005), strategic research only represents about 10% of public research in the six countries analyzed.

2.3.4 Priority research processes

Castro *et al.* (2005) point to the high historical importance of research on factors that affect production efficiency and, at the same time, the low importance assigned to research approaches more focused on scientific topics and social and environmental aspects. This shows that agricultural research finds itself at a crossroads, where the well-trodden paths towards the search for efficiency in production that have sustained research in the last fifty years have been exhausted but new paths are not yet known and research organizations do not have sufficient capacity to pursue them.

To identify the technology demands of users and define their research priorities accordingly, the national institutes have taken several steps, among the most outstanding ones decentralizing

and regionalizing their activities. To this end, they have taken advantage of their experimental stations located in different areas of each country, which tend to specialize in specific commodities according to local characteristics. (Piñeiro, 2003)

It has also been pointed out (by Castro *et al.* 2005) that the selection of priority lines of research requires:

a) A strategic institutional planning mechanism to help develop a prospective approach to long-term needs that can provide a framework and nourish discussion by the scientists themselves regarding the relative importance and likelihood of success of various lines of research;

b) Institutional mechanisms to facilitate effective linkages with technology users and ensure that these users can exert the necessary social oversight over decisions regarding priorities and resource allocation; and

c) A financial structure to align research initiatives with the needs that have been identified.

However, national AKST System institutes are implementing these types of mechanisms to varying degrees and at different paces (Castro *et al.* 2005).

2.3.5 Monitoring and assessment of institutional performance regarding AKST

The follow-up and assessment of institutional performance has not been sufficiently attended to by most AKST institutions in LAC. In general, assessment occurs as an isolated action that is seldom used to improve organizational performance due, among other reasons, to a lack of the information needed to identify structural, organizational, or administrative and managerial problems.

Efforts to assess the results achieved by S&T institutions overall, and not just specific projects, only began in the 1980s and 1990s, and the issue has still not been addressed with the dynamism, energy, and depth needed to ensure a better use of resources and improve the planning and general efficiency of these bodies.

The complexity and scale of NARIs has produced vertical organizations with many hierarchical levels and a bureaucratic management style, because they were established to respond to the problems of every region in the country, leading to highly complex institutions both from the organizational point of view and in terms of the quantity, variety, and heterogeneity of the topics to be researched. (Piñeiro, 2003).

Recent literature emphasizes the need for research institutions to adopt decentralized management styles with a horizontal organizational structure that promotes discussion and consensus-building among peers. In pursuit of this type of organizational structure and management style, two complementary paths have been followed (Piñeiro, 2003). The first has sought to develop a highly decentralized organizational structure in which different units enjoy a

high level of operational autonomy, a model exemplified by American universities. The second approach, inspired by the reforms introduced in Great Britain, Australia and New Zealand, has been to create relatively small bodies with specific mandates, highly focused on regions, products, or scientific topics.

The main challenges facing AKST System institutions in LAC are to: a) identify and measure all outputs, emphasizing productivity in terms of the products and services generated for clients/users; b) address crucial management issues and constraints; c) create consensus and a sense of ownership; d) improve internal and external transparency; and e) strengthen knowledge of the institution's strengths, weaknesses, and constraints. (Peterson, W., G. Gijsbers, and M. Wilks 2003).

The region's AKST institutions can improve their performance by assessing periodically, and critically, the relevance and quality of their research through the peer review system accepted by the international scientific community. It is also useful to review the modern and practical concept of assessment, which has progressed "from the notion of finding weaknesses and culprits, to an approach where the assessment is at the service of users, with an emphasis on learning to improve organizational and institutional performance." (R. McKay 2003).

2.3.6 Knowledge, science and technology from an agro-ecological perspective

Starting in the 1970s, alternative production models have been developed with a view to reducing the use of pesticides in agricultural production. This has led to a variety of practices, among them integrated pest management (IPM), integrated crop management (ICP), and agroecological pest management (Vázquez Moreno 2006; Burley & Speedy, FAO, 1996).

In the early 1980s, an agroecological alternative to the commercial agricultural system began to develop. This alternative is based on a systemic approach to managing agricultural production that identifies the ecological, social, economic, cultural, and geopolitical dimensions related to the management and use of natural resources, revaluing the exchange between local know-how and scientific knowledge (Bernal, 2006; Sevilla and Gonzales, 1995:33; Sevilla and Woodgate, 2002:88). Other sustainable management approaches have emerged, such as agroforestry, integrated soil management, and integrated watershed management.

The agroecological approach has been adopted by producers' organizations, public research institutions, universities, and non-governmental organizations. The most prominent include the Latin American Consortium for Agroecology and Development (CLADES), based in Chile, the Masters Program in Ecological Agriculture of the Tropical Agriculture Research and Higher Education Center (CATIE) in Costa Rica, and the Masters Program in Agroecology of the University of Caldas, Colombia. Leading NGOs in the field include the Ecological Agriculture Network and the Agroecological Movement of Latin America and the Caribbean (MAELA), an open, pluralistic and diverse movement involved in research, development, training and promotional activities that brings together over 65 institutions.

2.4 Financial resources and administration of the AKST System

2.4.1 Development and impact of investment in AKST

In Latin America, total investment in agricultural R&D in 2000 came to 2.6 million dollars; of these, 2.5 million (95.2 percent) were public investments (Pardee *et al.*, 2006). Most studies carried out in the region, as in other regions, show extremely high rates of return on investment in agricultural research and development (Alston *et al.* 2000; Ávila *et al.* 2002, Días Ávila *et al.* 2006). *(See Table 2.5.)*

Insert Table 2.5

Despite this, from the mid-1980s onward, and especially during the nineties, public investment in agricultural research and development declined. As a result of fiscal and public debt problems, most countries in the region implemented profound reforms in their macroeconomic, commercial, sectoral, and overall public investment policies, aimed at limiting State intervention and reducing public spending and deficits. These policies restricted agricultural credit, making it more expensive, and reduced the budgets allocated to investment in rural infrastructure and those aimed at agricultural research and extension and other programs and services to support rural development.[14]

This less favorable context of macroeconomic and sectoral policies was reflected in lower growth rates for agricultural production in LAC countries — both in terms of cultivated area and average productivity — for the period 1982-2001, compared with those recorded for the period 1962-1981 (Días Ávila *et al.* 2006) *(Table 2.6)*. As the authors note, average growth of production for the main agricultural commodities was 3.05 percent annually in the 1960s and 1970s, and fell to 1.98 percent in the last two decades. But there were significant differences in the growth patterns of the different subregions. In the Andean countries, Central America, and the Caribbean, growth rates declined. By contrast, growth rates increased in the Southern Cone countries, influenced mainly by increases in the productivity of the land both for crops and for livestock.

Insert Table 2.6

Moreover, the restrictions imposed on public budgets for AKST in the last few decades have come precisely at a time when LAC's producers have faced growing pressure to improve their productivity in order to compete at the international level in the context of free trade policies – those stemming from unilateral reforms implemented by the countries of the region, as well as those resulting from multilateral trade negotiations in GATT and the WTO, those corresponding to the different sub-regional integration initiatives (CARICOM, CAN, MERCOSUR, NAFTA), and

[14] These policy changes to support agriculture in LAC also coincided with the start of a review of subsidies and food self-sufficiency policies in developed countries, especially the Common Agricultural Policy.

a growing number of bilateral agreements signed by some countries, especially Mexico and Chile.

It is also important to emphasize that the decline in public investment in the AKST System in LAC has coincided with new demands, associated with sustainable rural development, that have traditionally been assigned a low priority in the agendas of the region's institutions.

The most important of these demands are: a) conservation of natural resources and the environment; b) conservation and sustainable use of genetic and biodiversity resources; c) the development of human resources and social capital as strategic assets for competitiveness and progress; d) the empowerment of civil society; e) proper attention to aspects related to gender and ethnicity; f) the incorporation of new leading-edge technologies that require substantive changes in institutional structure and organization, such as biotechnology, genetic engineering, nanotechnology, telecommunications, and computer science; g) emerging new topics or issues that may have significant impacts on production and on future food demand, e.g. biofuels; and h) new demands linked to such issues as product differentiation and value added.

In short, the political, fiscal and institutional crisis of the State in most LAC countries over the last two decades and the resultant reforms in macroeconomic, trade, and sectoral policies – including cuts in public investment in research and development – have created a less favorable context for promoting sustained growth in the value of agrifood production and a decline in the system's capacity to address traditional demands. And this comes at a time when the new context calls for a change in Latin America and the Caribbean's NARIs, in their institutional strategies, structure, and management models, so that they can fit into the global AKST System (Martinez Nogueira 1997; Machado Allison 1997).

2.4.2 AKST funding amounts, trends and consequences

Ardila (1997) underscores that public investment in agricultural research and development in most LAC countries was always low compared to international standards. It is a situation that has worsened in recent decades. Thus, while the ratio of research spending to GDP for the period 1970-75 in industrialized countries was around 2.5 percent, the average in LAC was 0.65 percent; and that ratio fell to 0.5 percent in 1975-85 and to a range of between 0.1 and 0.4 percent in 1985-95.

According to Hertford *et al.* (2005), in the mid 1990s – the last date for which global figures can be compared internationally – a total of US$ 21.7 billion were spent worldwide on agricultural R&D. LAC countries spent US$ 1.95 billion (at 1993 international prices) or close to 8.8 percent of the world total. This was nearly double what those countries spent in 1976. However, there were great disparities. More than half the investment in agricultural research corresponded to Brazil. If Mexico is added, both countries accounted for nearly two-thirds of the region's total. Other three countries spent over US$ 100 million annually. However, a significant number of countries spent US$ 16 million or less, resulting in a serious erosion and decline in the installed

capacity of specialized institutions. Moreover, these have not been replaced by equivalent investments in the private sector.

When one measures overall expenditure in agricultural research as a proportion of the share of GNP that corresponds to agriculture, in the mid 1990s in LAC the average was 1.12 percent, almost twice as much as was spent in 1976 *(Table 6).* However, great disparities persisted, from barely 0.13 in Guatemala to more than 1.7 in Brazil and Uruguay. These coefficients of agricultural research intensity in Brazil and Uruguay are far superior to those of most countries in the region, albeit far inferior to those recorded in industrialized countries, which on average spent 2.62 percent on such activities. Although funding from non-governmental organizations (mainly commodity producer organizations) doubled from 1976 to 1996, this increase started out from a very small base and undoubtedly continues to be insufficient to increase the poor intensity coefficients in the region.

Other private research has not been able to reduce the gap. While in rich countries approximately half of all agricultural research is carried out by private firms, by the late 1990s, in LAC, total expenditures by the private sector in agricultural R&D amounted to no more that 4.4 percent of total expenditures,[15] and with extreme asymmetries, since most of the private investment was carried out in Brazil. In Honduras, private research accounted for 7% of total agricultural R&D. In Panama, the figure reached 46%. Regardless, most private technologies used in the region are based on research carried out in industrialized nations.

Even in those countries where public investment in agricultural R&D increased in the first half of the 1990s, recovery was fragile. Investment was greatest in Brazil and Colombia, but suffered cutbacks in the second half of the decade. In the region's smallest countries, research activities experiences no growth whatsoever, revealing an asymmetry between richer and smaller countries that left the latter lagging behind.

At present, only a handful of countries – Brazil, Mexico, Argentina, Colombia, and Venezuela – can boast of important organizations that have kept up significant levels of investment.

2.4.3 Consequences of reduced financing

In LAC, when analyzing the 1981-2002 period (Figure 2.2 and Table 2.7), a negative evolution in public research can be detected vis-à-vis industrialized nations. In the least developed countries, the lack of public investment in agricultural research is a significant threat if one considers the growing demand for knowledge to ensure the sustained growth of food production — something that can only be secured by innovation and increases in soil and water productivity. It should be noted that in many of these countries the availability of agricultural land per capita will tend to fall over the coming decades, making it likely that food production will not

[15] R&D investments are measured on the basis of where they are carried out, regardless of where the company's headquarters may be located.

meet local demand. Not only will the balance of trade be affected; the population with the lowest income levels will have to pay more for food. Recent increases in international maize prices are indicative of this phenomenon.

Insert Figure 2.2

Insert Table 2.7

Even in the five countries in the region that can boast of relatively strong public research institutions, the decrease in government funding has significantly affected their productivity. By degrading the ratio between operational and personnel costs, they have reduced their efficiency and the possibilities of carrying out the institutional transformation that contextual changes in recent decades call for.

Among other effects, this situation has led to the implementation of a variety of agreements between public institutions and the private sector for the development of certain technologies appropriable by private firms. The lack of government funding has altered the focus of NARI research. It is currently guided by the contributions and demands of companies, particularly those that specialize in providing agricultural inputs, although it also extends to groups of producers, agroindustries, and other components of society.

This entails a reconceptualization of NARIs to incorporate new management schemes that contemplate strategic planning aimed at forging alliances and cooperation mechanisms at the national and international level with the various public and private AKST players – that is, the building of research networks (Salles-Filho *et al.* 1997; Lindarte 1997) without ignoring the demands of the sector as a whole, which in most countries features small producers.

2.4.4 Changes in approaches to mobilizing resources

In the early stages, public funding for NARIs normally came from the national government budget. The main exception to this rule was Argentina's National Agricultural Technology Institute (INTA), whose charter allowed it to receive a direct percentage of revenues from leading agricultural exports. More recently, Uruguay's INIA began to receive a percentage of revenues from agricultural exports, complemented with an equal sum from the national budget. Since the end of 2002, Argentina's INTA has received a percentage of the earnings from imports coming from outside the MERCOSUR trade alliance (Piñeiro, 2003).

The limited experience of these funding arrangements suggests that it is advantageous for NARIs to have an independent financing system in which funds are assigned for specific purposes. This provides security regarding the sums that can be spent and their availability in the course of the fiscal year. Both elements are essential to proper planning. They also encourage a careful use of available resources since, if unused, they remain at the disposal of the institution.

Governments have tended to assign AKST funds as part of their overall budgets. A total annual amount has been generally allocated, divided into partial, normally monthly, payments. However, this periodicity has often not been observed, especially when it comes to operating costs, which are sometimes disbursed in random fashion. This allocation is supposed to cover: salaries, operating expenses, maintenance of infrastructure and equipment, and investment.

The aforementioned trend of declining governmental support for AKST institutions confronts them with shrinking and untimely budgets that reduce their effectiveness and efficiency. They are forced to cover, first of all, their payroll, for which they must use part of the resources earmarked for operations, maintenance, and investment. It is common to find ratios of 90 to 10 to zero regarding salaries, operations and maintenance, and investment. Experts consider that this ratio should be 50:35:15.

Consequently, AKST System institutions have been forced to seek external resources to reduce their budget deficits. This has led them to diversify their funding sources through a variety of projects. It has also led them to identify and approach other financial agents they may turn to (multilateral banks, regional research funds, international cooperation), which are not necessarily a solution for AKST institutions confronting a budget deficit and a reduced capacity to cover their essential payroll, operational, and maintenance expenses.

Recently, national AKST System institutes have made major efforts to adapt to the new conditions. In general, they have solved their budgetary problems. In some cases, they have even managed to improve their finances significantly. As a result, changes are evident in their financial structure and composition, and many now generate their own resources through the sale of non-essential assets and technological services and solutions.

Similarly, these organizations are taking their first steps to harness the benefits derived from the intellectual property of some of their own technology packages. This has implied developing new regulatory frameworks on issues such as intellectual property legislation for seeds, genes, and other appropriable innovations that encourage private investment in agricultural R&D, as well as laws to properly regulate the appropriation of benefits in the case of joint initiatives between public institutions and private firms (based on the notion of public goods and private goods).

Finally, it is important to note that the debt crisis of the 1980s and the effects of globalization have forced governments to rethink the administration of science and technology. In developed nations, direct government contributions have been reduced and new mechanisms have been introduced to finance innovation activities, such as competitive funds for research, contracts for the development of specific products, the purchase of new products by the public sector, subsidies for innovation activities in companies, and the formation of public-private consortia (Echeverria 1998; Huffman and Just 1999; Branscom and Florida 1999; OECD 1999).

These new mechanisms have not replaced the traditional financing mechanisms, but instead have complemented them. Although experts agree that funding for public research institutions should combine fixed budget allocations with variable appropriations (Echeverria 1998; Huffman and Just 2000, Huffman and Evenson, 2003), developing countries have given almost exclusive priority to the use of competitive funds.

Gil and Carney (1999) mention that competitive funds can be an efficient mechanism if there is sufficient research capacity in the country. However, the experience of some of the larger research systems of developing countries (including Brazil and India) shows that these conditions are not always met.

Competitive funds have been used in LAC by the World Bank and the Inter-American Development Bank as part of loans to support AKST. In Mexico, competitive funds are the preferred mechanism for allocating public resources for research and innovation. The *Produce* Foundations used these funds from the outset, though their implementation gradually evolved as they gained more experience. However, efforts to identify more effective mechanisms have been slow, in the absence of studies to assess these experiences.

Given the limited AKST institutional capacity in some LAC subregions, it is essential to promote inter-institutional projects to complement and utilize the comparative advantages of each institution (Moncada, 2006). A financing mechanism using competitive funds shared by two or more institutions engaged in cooperative projects is a more effective and efficient strategy. In Mexico, the *Produce* Foundations have used the mechanism of competitive funds through public bids but give preference to inter-institutional projects.

The financing system using shared funds has proven to be a powerful instrument for: a) guiding research based on pre-established priorities, so that it is possible to link the demands or needs of users with research activities; b) enhancing the definition of project objectives and methodology, thereby helping to achieve the expected results; and c) facilitating the development of monitoring and evaluation mechanisms for research activities.

Experience suggests that financing research through competitive funds is extremely useful (Piñeiro, 2003 and Bisang, 2003). However, this form of financing should be complementary to institutional financing, given that each fund sets its own priorities and has its own mechanisms for resource allocation, follow-up, and monitoring. For institutions that finance part of their research projects through competitive funds, this entails increased administrative costs, since several control and monitoring systems must be applied, each following the rules of the specific fund. Similarly, the fact that special resources granted for research are subject to different criteria from those of the institution that receives them tends to alter previously established research priorities and creates asymmetries in the flow of information between researchers and those who are cognizant of the available resources.

One complementary financing mechanism, independent from national budget allocations, is to levy rates or charges on the first-time sale of specific products. This method is used extensively in Australia, and also in Colombia through the so-called Parafiscal Funds, but it is not common in LAC. In both cases, the funds received are channeled to private corporations administered by governing councils made up of representatives of the public sector and producers' associations linked to the specific product, and the resources can only be used to support research and the promotion of exports.

Some AKST System institutions have succeeded in generating income through the sale of technological services not directly linked to their research activities, such as soil analysis, agrochemical tests, and other types of studies (www.inifap.gob.mx). However, these cases are only justified to the extent that there is surplus capacity and the income can help finance research activities; aside from exceptional situations, it would be advisable to use that surplus capacity for research, to avoid sidetracking institutions from their specific goals.

2.4.5 Support institutions

It is important to mention the foundations that have emerged as an initiative of NARIs themselves, created to raise funds to sponsor research and technology-transfer projects. Some of these foundations even execute their own projects, or do so through NARIs and universities.

In Argentina, for example, INTA participated in the creation of a foundation called ArgenInta and set up a technological liaison unit for this purpose. It has also established a company to strengthen links with the private sector.

In Mexico, in order to support specific research projects related to agrifood or agroindustrial chains, INIFAP promoted the establishment of the Mexican Foundation for Agricultural and Forestry Research (FUMIAF A.C.), comprising the leading agribusiness and agroindustrial entrepreneurs.

At the regional level, countries are being encouraged to cooperate on AKST System projects of mutual interest. To support this strategy, FONTAGRO was created as a consortium to promote strategic agricultural research of regional interest with the direct participation of Latin American and Caribbean countries in setting priorities and financing research projects.

2.5 Responses of the AKST Systems to Changes in the Most Influential Contextual Variables

2.5.1 Water

Since the 1950s, knowledge, science and technology efforts related to water in LAC have focused on finding ways to promote its rational and sustainable management, particularly in areas of water scarcity, as well as carrying out inventories, systematizing hydrological and hydro-biological resources, and trying to reverse unsustainable processes like the pollution caused by domestic waste water (IDEAM *et al.*, 2002). However, it is essential to consolidate a

science and technology system that addresses the demands of the 21st century (UNESCO, 2006:438).

Historically, research on water has focused on such issues as its role as a factor in agricultural production and on irrigation systems, the introduction of drought-tolerant materials, and the adaptation of species to saline and sodic soils.

In the case of smallholders and indigenous and Afro-American farmers, some AKST strategies have managed to achieve a positive impact in situations of limited — or in extreme cases, no – water availability (through drip irrigation, micro-aspersion, or gravity irrigation systems), aspects that were emphasized in integrated rural development programs until the end of the 1980s.

In the 1990s, field capacity irrigation through remote sensing began to be implemented, making advances possible in the knowledge of water resources regarding such issues as consumptive use, soil field capacity, water sources, wetlands, and pest and disease control (Vörösmarty *et al.* 2005, cited in UNESCO 2006:445).

Another AKST advance for areas with permanent or seasonal water limitation is the production of biological inputs (biofertilizers, mycorrhizae) that potentiate and capitalize on soil dynamics, expanding the horizons of knowledge regarding soil biology (Ramírez y Santamaría, 2002:90).

The current agenda is revaluing the small irrigation systems used in extensive areas around the world, and especially in LAC (Palerm and Martinez, 1997). This reverses the historical tendency to ignore the role played by local communities in territorial water management, leading to a central strategy to regulate consumption and promote a rational use of the resource that is essential for its sustainability (Aguilera 2002; Utton 1985:992)

In urban and semi-urban contexts, most of the research focuses on aspects related to the efficient management of water resources and the decontamination of water sources. Semi-dry rivers, exhausted or salinized aquifers, sedimented lakes, high levels of organic material, the presence of heavy metals, and the disappearance of wetlands are only part of the current panorama (Fundación Ecología y Desarrollo 2006).

An important area of AKST research is the contamination of water with heavy metals produced by activities like crop-spraying to combat illegal crops and the exploitation of hydrocarbons and minerals such as gold, which creates ecological imbalances and has adverse effects on human health. Another adverse factor that threatens water resources is oil spills, (Aragón 2002: 8).

Climate change has also forced a shift in the direction of research, partly in response to the El Niño phenomenon and its effects on the spatial and temporal distribution of water. This has affected weather patterns, with increasingly frequent reports of extreme events related to maximum and minimum water flows and changes in ocean currents (IDEAM *et al.* 2001: 49; MM & IDEAM, 2002b: 19; Obasi 2000). Networking has been an important factor in mitigating the

impact and designing policies at the regional and global level through bilateral and multilateral cooperation.

One of the most recent trends in water use planning centers around advanced research centers and water treatment laboratories. Outstanding examples include the Network for Water Management in Agriculture, Irrigation and Ferti-irrigation *(Red para la Gestión del Agua en Agricultura, Riego y Fertirriego);* the Ibero-American Water Quality Laboratories Network *(Red Iberoamericana de Laboratorios de Calidad de Agua);* and the project known as "Indicators and Appropriate Technologies for the Sustainable Use of Water in Ibero-America's Drylands" *(Indicadores y Tecnologías Apropiadas de uso sostenible del agua en las tierras secas de Iberoamérica)* (Fernández, n.d.).

Activities include the desalinization of seawater to extract potable water, the use of water as a source of energy (either from hydrogen or kinetic energy from water and tides), the study of ground waters and their decontamination, geothermy, and research on the estuaries of large Latin American rivers like the Amazon, the Río de la Plata, and the Orinoco. Major efforts and progress have also been made in the field of limnology. These new strategies increase our knowledge base and – with the help of case studies, best practices, partnerships between organizations, and the exchange of experiences – constitute essential actions to enhance the capabilities of national statistics institutes and their management of water resources (UNESCO 2006:434).

2.5.2 Biodiversity

LAC is an exceptionally rich territory in terms of agro-biodiversity because it spans important cultural centers for domestication and agriculture: Meso-America, Amazonia, and the Andean region. Approximately 10,000 years ago, the original settlers domesticated scores of native species, originating agriculture in the New World and leading to the rise of highly developed pre-Hispanic civilizations involving extensive empires based on the success of autochthonous agriculture, its genetic and agronomic diversification, and its broad geographical diffusion.

The inter- and infra-specific diversity of these native crops constitutes a rich heritage of genetic resources and an enormous comparative advantage, since this agro-biodiversity contains the elements (unique genes) that are essential for plant genetic improvement and the long-term sustainability of agriculture.

However, in spite of the enormous value of genetic resources in the region, the institutional and political capability of most countries is too weak to conserve such assets properly and use them rationally.

The conservation of genetic resources is achieved through two different but complementary strategies: *ex situ* (in germplasm banks) and *in situ.* In LAC, germplasm banks are typically associated with public agricultural research institutions and agronomic improvement programs. Germplasm collections conserved *ex situ* at these banks are well documented and catalogued,

with information regarding their place of origin, agronomic characteristics, and other information that can facilitate their direct use by farmers, in improvement programs as a source for desirable characteristics, or for their eventual repatriation to the communities of origin should they have been lost for any reason and there is a desire to bring them back.

Advantages of *ex* situ conservation include the assurance provided by banks that the materials will survive, their availability for research and improvement, and comparative studies of different strains to test, for instance, for resistance to a given pest or disease. Disadvantages of this strategy include the cost of the facilities and technical staff needed to regenerate, characterize, and document the conserved materials, and the fact that samples are relatively small with regard to the genetic diversity found in wild populations. In addition, the process of evolution – of natural selection – pretty much stops while the materials are stored in the bank, where they are regenerated no more frequently than five, 20, or more years in between.

In situ conservation refers to preserving various species or varieties in their natural field conditions in the places where they developed their particular characteristics. In the case of domesticated plants, *in situ* conservation is carried out “on-farm”, in the fields of the farmers who have traditionally grown these crops or varieties. For the *in situ* conservation of wild plants (such as the wild relatives of common crops), efforts are made to preserve the ecosystems where the natural populations of such species are to be found, whether in national parks, protected areas, or other ecosystems that have not been intervened. The advantage of *in situ* conservation is that evolutionary processes continue, thanks to large populations of individuals with wide genetic variability. The disadvantages of this strategy include the difficulties of monitoring and protecting wild or cultivated populations in remote areas, the relative lack of documentation and characterization of the genetic materials, and the logistical difficulties of accessing those materials easily to apply them to research or genetic improvement.

Neither *in situ* nor *ex situ* conservation by themself are enough to safeguard the survival and integrity of genetic resources in the long terms. Each strategy has its strengths and weaknesses, which makes it necessary to rely on both mechanisms (*in situ* and *ex situ*) so that they can function together in an integral strategy known as “complementary conservation” (Engels 1995). Thus, if for some reason farmers lose their seed in the field they may reclaim it from the bank, while if due to some accident a bank loses some of its materials it will know where to go to once again collect them in the field and restore them to their germplasm collection. It may also make sense to encourage the exchange of seeds among farmers in the same region, or even different regions and countries.

An AKST challenge would be to improve national institutional and technical infrastructure for safeguarding and making good use of the agro-biodiversity (genetic resources) that make up the heritage of each country.

The Convention on Biological Diversity (1992) acknowledged the sovereignty of each country over the genetic resources to be found within its borders. But with sovereignty comes the responsibility of conserving those unique and irreplaceable natural resources, not only for the welfare and agricultural development of the country but also for humanity as a whole, which must rely on them to feed future generations.

At the national level, this responsibility implies every government's duty to invest in its national agricultural research institutions so they have the basic resources needed to compile, maintain, characterize, and utilize their genetic resources, both native and imported, to meet the needs of their people and confront the problems of national, regional, and global agriculture. At the regional and international level, it would be advisable for all countries to become affiliated with the multilateral system for accessing and sharing the benefits associated with vegetable resources through FAO's new International Treaty on Plant Genetic Resources for Food and Agriculture (2004).

2.5.3 Soils

AKST System advances regarding soils have gone through several historical and mutually interrelated stages in LAC that have made it possible to advance and systematize knowledge about edapho-biodiversity. Before the 1960s, regional research focused on aspects of taxonomy, fertility, and valuation for cadastral purposes. Then there was a turn toward fertility, management, and conservation studies. During the 1980s, experts introduced research at the watershed level for land use management purposes, with the subsequent development of Landscape Ecology Theory (LET), leading to ecological-economic zoning. In the 1990s, research regarding plant nutrition moved toward the impact of applying fertilizers and pesticides to the soil, their effects on microbial biomass, and their dynamics. At present a great deal of work is being carried out in soil biology based on molecular techniques and working with DNA and RNA to inventory mezzo-organisms and microorganisms. Another field of activity relates to ethnotaxonomies and traditional soil-management techniques, an outstanding example being the case of the Pacha Mama, or Mother Earth, ritual in the Andes.

2.5.4 The social variable

From the 1950s until the end of the 1970s, AKST Systems directed their efforts at boosting agricultural productivity in response to the need to produce more food at a lower cost. This was accomplished through the development of technology packages that, due to their characteristics, achieved their best results in large landholdings but provided few benefits to poor farmers with lower levels of organization, or to Afro-American and indigenous communities. (Allison 1997, Trigo *et al.* 1983; Morales. n.d.)

The need to respond effectively to local demands, mainly from farmers who benefited the least from the technology transfer models that characterized the agricultural modernization phase described in the previous section, led to the first attempts to regionalize AKST (Trigo, Piñeiro

and Ardila 1982; Piñeiro, Trigo and Fiorentino 1977; *Proyecto Cooperativo de Investigación sobre Tecnología Agropecuaria en América Latina* (Cooperative Research Project on Agricultural Technology in Latin America) 1978, Cited by Trigo *et al.* 1983). According to Trigo *et al.* (1983), this reflects a changing perception of the role and effects of technology on the economic organization of society (cf. Valdés, Scobie and Dillon 1979; Gilbert, Norman and Winch 1980; Trigo, Piñeiro and Chapman 1981; and Norman 1980).

Later, in the nineteen-eighties and especially from the nineties onward, the social changes that occurred as a result of urban growth required the agricultural sector to develop new technologies associated with more advanced linkages of the production chain such as post-harvest handling and storage, improving the quality of the final product and the strengthening the industrialization of agricultural producers. To respond to these new demands, AKST System institutes began to rethink their objectives (Morales). However, according to Lindarte (1997), NARIs and extension services have not achieved significant results in this respect, possibly due to constraints in the development model, the interests that govern institutional structures, or a lack of conceptual clarity regarding the direction and implementation of the necessary changes.

Lindarte (1997) also emphasizes the importance of incorporating different stakeholders involved in the process of technology generation. This is evident in the growing involvement of private sector representatives and those from producers' organizations, foundations, and NGOs in national research institutes, and also in the development of technology transfer programs such as *Cambio Rural,* implemented by INTA in Argentina, and other experiences carried out by EMBRAPA in Brazil and INIA in Chile (Morales; Cetrangolo 1992). The limitations of this new approach are mostly due to the lack of new and appropriate forms of social and cultural integration (Lindarte, 1997).

2.5.5 Policies

The performance of AKST Systems, the focus of research and, in particular, the incorporation of innovations, are conditioned by the general public policy context, and are not only limited to specific aspects of AKST.

In most LAC countries, the relatively high contribution of agriculture to GNP and employment generation in the second half of the 20th Century pushed production, rural development, and food self-sufficiency policies toward the top of the agendas of governments, cooperation programs and international development agencies. From the 1950s to the 1980s, these agendas contemplated a broad range of rural development policies and programs with active participation by governments in financing production and the physical infrastructure needed to support both production and marketing. Governments also implemented policies on land-use and irrigation, intervened in commodity and input markets, introduced measures to protect agricultural trade (through the application of tariffs and other quantitative limits on imports), and implemented initiatives to support research and development.

During that period, public policies emphasized the generation and transfer of technology, strengthening the human and financial resources of specialized public institutions and paving the way for the creation of NARIs. In some countries, particularly the larger ones, the activities undertaken by these institutions and the favorable policy context played a significant role in boosting productivity and agricultural production in the 1960s, 1970s and 1980s. However, they did not have a similar impact on reducing rural poverty, nor did they pay much attention to the conservation of natural resources and the environment.

Ample evidence suggests that the sustained and sustainable growth of agricultural production and, in consequence, its positive impacts on the development of rural communities and on the economy as a whole, depends in great measure on the systematic incorporation of innovations, since the current possibilities of increasing the cultivated area are fairly limited. Although there are still opportunities to expand the agricultural frontier in some LAC countries, there is no doubt that the main way to increase the growth of the food supply and farmers' incomes is by increasing the productivity of the land (Días Ávila *et al.* 2006). Similarly, most of the studies carried out in LAC, and in other regions, show that the rates of return on investment in agricultural research and development are extremely high (Alston *et al.* 2000; Ávila *et al.* 2002). Días Ávila *et al.* (2006) prepared a compilation of studies by different authors that is included in Table 2.8.

Insert Table 2.8

Despite the points mentioned above, starting in the mid-1980s and especially during the 1990s public investment in agricultural research and development declined in LAC. As a result of their fiscal and public debt problems, most countries in the region implemented profound reforms in their macroeconomic, trade, sectoral and public investment policies with the aim of limiting State intervention and reducing public spending. These policies also restricted agricultural credit, making it more expensive, and reduced the budgets allocated to investments in rural infrastructure, and those corresponding to agricultural research and extension and other programs and services to support rural development.

This less favorable context of macroeconomic and sectoral policies was reflected in lower growth rates of agricultural production in LAC countries — both in terms of the cultivated area and average productivity — for the period 1982-2001, compared with those recorded for the period 1962-1981. As Días Ávila *et al.* (2006) note, the average growth of production for the main agricultural commodities was 3.05% annually in the 1960s and 1970s, and fell to 1.98% in the last two decades. But there are significant differences in the growth patterns of the different LAC subregions. In the Andean countries, Central America and the Caribbean, growth rates declined. By contrast, growth rates increased in the Southern Cone countries, influenced mainly by increases in the productivity of the land both for crops and livestock.

When analyzing public investment in agricultural research and development in most LAC countries, it can be seen that it was always low compared with international standards, but the situation has worsened in recent decades. Thus, while research spending for the period 1970-75 in industrialized countries amounted to 2.5% of GDP, the average for LAC was 0.65%; and it fell to 0.5% during the period 1975-85, and to a range of 0.10 to 0.40% during the period 1985-95 (Ardila, 1997).

The aforementioned reductions in public investment in agricultural research have not been homogeneous throughout the region. At present only a few countries (Brazil, Mexico, Argentina, Colombia and Venezuela) can boast of large organizations that have maintained significant levels of investment. Hertford (2005) underscores that in the mid 1990s more than half the investment in agricultural research corresponded to Brazil. If Mexico is added, both countries accounted for nearly two-thirds of the region's total. Only the other three countries mentioned spent over US$ 100 million annually each. In most countries, instead, public investment was very low, and in recent years fell to such extremes that it has given rise to a serious erosion and decline in the installed capacity of official specialized institutions. Moreover, these have not been replaced by equivalent investments in the private sector.[16]

In the least developed countries, the lack of public investment in agricultural research constitutes a major threat, in terms of responding to a growing demand for knowledge to ensure the sustained growth of food production, which should essentially be based on innovation and on increased productivity of the land. In many of these countries, the availability of farmland per capita will tend to fall in the coming decades, leading to a high probability that they will be unable to produce enough food to be self-sufficient. This will not only have negative repercussions on their balance of trade, but will also result in higher food prices for the poorest segments of the population, who depend to a large extent on personal consumption.

Even in the five LAC countries that have relatively strong public research institutions, the decline in public funding has had a significant impact on their productivity. In most of these institutions the ratio between operating costs and personnel costs has deteriorated, thereby reducing their efficiency and the possibilities of implementing the necessary institutional changes required by the broader contextual transformations that have occurred in last two decades. This has implied, among other things, implementing different types of agreements between public institutions and the private sector to develop technologies that can be appropriated by companies. The lack of public resources has shifted the focus of research in NARIs, which is now conditioned by the contributions and demands of companies, mainly suppliers of agricultural inputs. But it also affects producers, agroindustries and other social organizations.

[16] It should be noted that in LAC private investment in AKST is even less significant than that of the public sector.

These changes in the public policy context call for the establishment of a new institutional framework that goes beyond that of the traditional public AKST System institutions. In other words, it is necessary to redefine the roles and scope of the public and private spheres, with regulatory frameworks that allow for effective links between both sectors. Among other aspects, this implies rethinking the NARIs, with the aim of incorporating new management systems that contemplate strategic planning for the implementation of partnerships and cooperation mechanisms at the national and international level with different public and private stakeholders of the AKST System. In other words, a high priority should be given to the formation of research networks (Salles-Filho *et al.* 1997; Lindarte 1997).

The restrictions imposed on public budgets for AKST in recent decades have come precisely at a time when LAC's producers have faced growing pressure to improve their productivity in order to compete at the international level – all this in the context of free trade policies stemming from the reforms implemented by the countries of the region, as well as those resulting from the multilateral trade negotiations in GATT and the WTO, those corresponding to the different sub-regional integration initiatives (CARICOM, CAN, MERCOSUR, NAFTA) and a growing number of bilateral agreements signed by some of the countries, especially Mexico and Chile. The agenda of future or imminent multilateral and regional trade negotiations, including those that Central America is launching into with Europe and those that being explored with Asian countries, is copious and will produce new challenges in terms of improving the competitiveness of agriculture in the region.

2.5.6 Markets

Urbanization and globalization processes in LAC and worldwide, together with increases in per capita income, have had a major impact on creating demand for different types of goods, and also on the characteristics of the products and services demanded by consumers. The last few decades have brought changes in consumption patterns and new requirements associated with changing consumer preferences in terms of health, food safety, food quality and certification, which are being incorporated into national regulations and the international agreements that regulate world food trade.

The growing demand for differentiated products, with more services and value added, plus other characteristics such as the environmental and cultural nature of products, identification of origin and processes, and so on, imply modifications to the traditional demand for innovations from the AKST System. It is not enough to have an approach centered on the product, the producer, or the use of technologies to increase productivity and the food supply; every day brings more demands, but also new opportunities to build competitiveness through value added, based on a proper understanding of demand and the supply of products and services that are aligned with consumer preferences.

In this respect, reference should be made of the many organizations dedicated to Fair Trade, a movement that began in the mid 1980s. Its purpose is to treat rural producers of goods and services in poor countries fairly. This entails offering fair compensation for these products, to cover production and labor costs. It also leads to a revaluation of the work carried out by indigenous peoples, Afro-Americans, and other ethnic minorities, and discourages slave labor and child labor. It makes it possible to secure long-term contracts that ensure a steady source of income and reduce market uncertainty. It also encourages the improved management and conservation of biodiversity and the environment, and provides support for producers to acquire the knowledge and skills needed to become better at business and marketing, and even increases their self esteem. Products marketed under this scheme vary in their characteristics and points of origin. Countries that stand out include Guatemala, Honduras, Nicaragua, Ecuador, Bolivia, Brazil, Panama, Peru, Colombia, Mexico, Chile, and Costa Rica.

Until now, most AKST System institutions have not assigned a high priority to these aspects, or to the different links of the agrifood chains. Moreover, they do not have the necessary technical and human resources. These new challenges will become more critical in the coming decades. It is clear that, in future, the AKST System will be unable to limit its activities to the traditional supply-side approach to technological innovation. A high priority will have to be given to identifying and responding to demand, and to developing new ways of organizing the production and marketing of agrifood products (organizational innovations), so as to effectively meet new consumer demands.

2.6 Effectiveness and Impact of the AKST System

2.6.1 On production systems

2.6.1.1 The traditional indigenous and *campesino* systems

Traditional indigenous and campesino production systems have historically been considered by the AKST System an obstacle to development. Its social actors have suffered from a low political and organizational profile, and it has been addressed in a marginal and reductionist way, ignoring the complex dynamics of production in the rural milieu (Arango *et al.* 1999:14-15; Macias 2002:47; De Armiño 2002:76; Raigoza *et al.* 2006:127; OAC & IICA 2006a; Martinez *et al.* 2006; OAC & IICA 2007b; Santamaria *et al.* 2005:34).

In the last two decades, the traditional *campesino* and Afro-American farming systems and the indigenous production systems in LAC have started moving into alternative trade spaces, producing organic and ethnic products, free of transgenic material, with denomination of origin, as well as raw materials for multinationals, among others. They sometimes use advanced technology and marketing strategies (online communications, networks of farmers and consumers of ecological products, dietetic products, and natural pharmaceuticals and cosmetics). Recently, there has also been a move towards the service sector with the adoption of multi-activity systems (hiking trails, horse-riding, photography, environmental education, and

ecological or alternative tourism (Naredo 2006:19; Toledo 1980) that respond to the new concerns of international agendas with regard to forests, water, biodiversity, desertification, wetlands, a gender perspective, intellectual property rights, the precautionary principle, cyber-agriculture, fourth generation rights, and the exchange of know-how, among other issues.

2.6.1.2 The agroecological production system

The Agroecological Production System emerged as an approach at odds with the practices and philosophy of conventional production systems. The AKST System framework is increasingly seeking to revalue traditional knowledge or know-how based on local research and "farmer to farmer" extension, with participatory research mechanisms, *in situ* protection of agro-biodiversity, and the study of collective forms of social action (Sevilla & Woodgate 2002:88). These changes in the traditional, indigenous, and agroecological production systems have provided new ways of generating, adapting, and transferring AKST System services at different scales and intensities from the spheres of governments, non-governmental institutions, and cooperation agencies.

In efforts related to the study of production systems, geographic information system (GIS) platforms have provided AKST Systems with important support and are an essential tool for the identification, delimitation, and management of territories (Ofen 2006:41; Echeverri 2000:173). The preparation of biodiversity inventories; the assessment of population dynamics, efficient water management, and renewable energy sources (especially biofuels); the monitoring of pests and diseases; the assessment of CO2 sinks; the survey of aquifers and ground waters; the mapping of current and potential soil uses; and modeling, are just some of the activities undertaken within the AKST context in LAC that involve GIS.

2.6.1.3 The conventional system

The AKST System has had a significant impact on the productivity of agricultural units in recent decades. Starting in the 1980s, one can detect an increase in yields that continues to this day. *(Figure 2.3.)* Most of this growth has been the result of incorporating new technologies, mostly improved seeds, crop protection, and fertilizers. The increase in the production of certain crops, and the resultant increase in the food supply, brought with it a decrease in the price of agricultural products.

Insert Figure 2.3

In spite of this increase in yields, it should be noted that they have been lower than those secured in industrialized nations. Perhaps this difference has been influenced directly or indirectly by the agricultural subsidies prevalent there, which facilitate a greater adoption of new technology. But countries in East and Southeast Asia have also enjoyed a faster rate of growth than in LAC, where the rate of growth has been diminishing in the last five years.

2.6.2 On the advancement of knowledge and innovation systems

Biotechnology, nanotechnology, and information technology are fields of scientific knowledge from which innumerable new technologies are derived. Advances in biology and information science are considered the most influential scientific foundations for agricultural research in the last decade.

Although some authors already note a decline in its rate of progress (Oliver 2000), information science is indicated as one of the most influential branches of science in research organizations. It is possible that many organizations have not yet been able to take full advantage of the potential provided by this progress.

Nanotechnology is another branch of science that could have a major impact on generating other cutting-edge technologies in coming years. In 2004, it is estimated that worldwide investment in this area was in the order of 3.7 billion dollars. (National Nanotechnology Initiative, 2004).

Various constraints, however, have slowed the pace of development in biotechnology and the information sciences in developing countries, especially limited financial resources, lack of information, inadequate research infrastructure, and limited access to technology. In addition, there are groups that are ideologically opposed to biotechnology and its possible impacts on biodiversity and the environment as well as its implications for food security (Castro *et al.*, 2006).

Commercial biotechnology in the region has focused mainly on the transfer of genes to make crops resistant to herbicides and protect them from several types of insects and pathogens that affect commercial commodities, especially soy, maize, and potato. A typical example is the case of RR Soy seeds in Argentina which, according to Regúnaga *et al.* (2003), is the most dynamic example of large-scale adoption of technology innovation in world agriculture. The authors note that in a period of five years, RR soy accounted for 95 percent of the total soy crops planted in the country; it was adopted by farmers because of the lower complexity of the production system and the reduction in prices per unit.

Most countries of the region still face an unresolved conflict between supporters of biotechnology and its products (mainly those associated with public and private agricultural research institutions) and stakeholders linked to NGOs and other social and political movements who oppose the spread of genetically modified organisms. This has curtailed the use and even the production of biotechnology innovations in certain countries.

In the aforementioned study by Castro *et al.* (2005), basic and applied research in nanotechnology was deemed as of the lowest strategic importance; in recent years, the advances and impacts of these new frontiers of knowledge were assessed to be of medium to low significance in the region. For biotechnology, the assessment figures were slightly higher, but did not exceed the category of medium importance. An interpretation of this result reaffirms

the point made previously regarding the slow rate of uptake in the use and production of biotechnological innovations in LAC.

It should also be noted that innovation not only had an impact of the productivity of agricultural units but has also enabled the development of many inputs and productive management technologies that are environmentally friendly, like crop rotation, biological inocula, and natural fertilizers.

With regard to the regulatory bias of science and technology, there are asymmetries between the knowledge of users, producers, and generators of innovation. In LAC we repeatedly find that new technologies are beyond the reach of the very populations for whom they were generated, for a variety of reasons. This problem, in turn, is connected to another issue mentioned in the studies, i.e., the isolation of the various innovation systems due to lack of participation and linkages between all the actors involved in the innovation process, which generates a regulatory bias (Arocena and Sutz, 1999).

Regarding the notion of an innovation system as a political objective, data gathered through several recent surveys on industrial innovation in different countries indicate that national spending on innovation is fairly low. For this reason, private companies carry out internal R&D activities, even though these may be of an informal character (Arocena and Sutz, 2002).

If we analyze the particular case of innovation systems in MERCOSUR, these respond to the region's current economic situation. In this context, it should be emphasized that numerous transnational corporations based in MERCOSUR delegate innovation activities to their parent companies. Although we observe a growing trend regarding cooperation for research purposes, the technological divide between Latin American countries and industrialized nations is still very wide. Hence much of the innovative technology in the region comes from technological advances that arrive to LAC through inputs, mostly seeds and agrochemicals, produced and distributed by multinationals.

According to Lundvall (1985), innovation stems from a convergence of technical opportunities and user demand, which suggests the importance of citizens' participation in research processes – an issue that should be considered by AKST System institutions in the design of innovation systems. It is also important to consider the systemic nature of innovation, taking into account all related processes and their interdependence.

2.6.3 On consumers

There were, as of 2000, approximately 520 million consumers in Latin America and the Caribbean. According to figures from the Department of Economic and Social Affairs of the United Nations Secretariat, disseminated in the studies *World Population Prospects: The 2002 Revision* and *World Urbanization Prospects: The 2001 Revision* (cf. Peres 2005:67), this population grew significantly since 1985, by around 120 million people (they were 401 million in

1985, 441 million in 1990, and 481 million in 1995). These consumers, located both in urban and rural areas, represent a plethora of demands for goods and services.

Consumer-oriented processes have traditionally had little influence. However, even in cases where end consumers were not the main priority of research, they have indirectly benefited from the other priorities that have been set, that led for example to significant reductions in food prices. Over the period in question, for instance, the population benefited from decreases in the prices of basic foods of almost 70 per cent. This occurred due to a decrease in production costs due to increases in productivity obtained as a result of agricultural research efforts and innovation processes. Consequently, end consumers benefited even though research priorities were more concerned with farm performance and productivity. *(Figure 2.4.)*

Insert Figure 2.4

Consumer segmentation leads to the generation of supply-side production alternatives. Over time, these develop into different knowledge-, science- and agricultural technology initiatives. In the case of the rural sector, this translates into, and is materialized in, agricultural innovation and technology transfer processes (Jacobs 1991:102, Funtowicz & Ravetz 2000:62, Lemkow 2002:180).

At the same time, advances achieved by agricultural science and technology have sometimes been questioned, as in the case of genetically modified organisms (GMOs) or practices that are believed to cause undesirable effects such a climate change or soil contamination and erosion (Beca 1988:204; Sartori & Mazzoleni, 2005:214; Duarte *et al.*, 2006: 3).

As part of this analysis, it is important to emphasize that new spaces for discussion and feedback are emerging between the so-called “responsible consumers” sector and producers, as part of a general policy to ensure compliance with standards and principles related to intellectual property, certification mechanisms, fair trade strategies, denominations of origin, and ecolabelling.

2.6.4 Social aspects

The modernization of Latin America’s agricultural sector sharpened the contradictions between the modern and traditional sectors. On the one hand, it led to poverty for the social groups who were displaced towards large urban centers and border zones or who joined the transborder migratory flows. At the same time, it produced environmental impacts and caused the large-scale destruction of natural resources and the erosion of traditional knowledge.

With regard to the gender dimension, it is clear that the modernization of the agricultural sector provoked changes in labor relations both for men and women. Rural women have a greater presence in the production chains of fresh and processed foods and in other agricultural export products. However, their working conditions remain precarious (Farah 2004) except in the case of exporting firms that have been certified internationally.

In general terms, public policy in Latin American countries has prioritized economic growth as a strategy for overcoming poverty in all its manifestations. This economicist vision has ignored the complexity of the situation of rural populations, failing to consider that poverty is multidimensional and cannot be resolved with one-dimensional strategies (Sen 2000:17).

2.6.5 On the competitiveness of chains and conglomerates, and on territorial development

The AKST System has had a significant impact on the competitiveness of production chains over the period analyzed. The region's growing agricultural output has largely been the result of the technological development promoted by the AKST System (Regúnaga 2003). This has occurred despite the fact that, as previously mentioned, the system did not begin to address production chains as a whole until the middle of the 20th Century, focusing before that on specific projects due to the region's considerable technological backwardness.

For several decades, research efforts pursued productivity without taking into consideration the social aspects of a given territory. The populations historically and culturally linked to these territories were not adequately inserted into the technological changes underway, often not only for cultural reasons but also for economic and financial ones. This lack of a holistic vision of the system has produced negative externalities such as social exclusion and the degradation of natural resources (Molina 1980; Trucco 2004).

Although agricultural R&D began to be implemented through individual projects a few decades ago, it was not until the end of the 1990s that strategies were developed to address the requirements of the production chain as a whole. An example is Argentina's Multi-annual National Science and Technology Plan (SECyT 1997), which used the concept of the production chain to design its technology policy and worked with this unit of analysis in pursuit of the greater competitiveness of the whole.

In recent years, the development and expansion of the concept of agribusiness (Davis and Goldberg 1957) and the implications of the new institutional economy for the competitiveness of production chains (North 1993; Zylbersztajn 2001) have introduced an institutional and organizational framework that has improved the productivity and competitiveness of chains and conglomerates.

This new vision of agribusiness is encouraging discussion on ways of ensuring a more harmonious and balanced development of production chains and their stakeholders. The concept, however, is being incorporated mainly in the more competitive chains, leaving aside the weaker ones or those whose stakeholders have fewer opportunities to make them heard.

Consequently, this new way of integrating technological development with institutional aspects has limited importance for the communities linked to a territory, since there is less interest, knowledge, or efforts on the part of the AKST System to improve their conditions of relative development.

In this regard, non-governmental organizations committed to social and territorial development, as well as certain specific institutions, plays an important role in promoting better conditions for local populations with respect for their culture (Feito, 2005).