CHAPTER 2

ANALYSIS OF THE DEVELOPMENT OF KNOWLEDGE, SCIENCE AND TECHNOLOGY SYSTEMS IN LATIN AMERICA AND THE CARIBBEAN. THEIR EFFECTIVENESS AND IMPACTS.

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Key Messages

Regarding the Institutions

AKST has been unable to develop its full potential. Latin America has a rich tradition of individual and institutional efforts in science, technology and knowledge, and has made significant contributions in these fields. The different Regions of LAC have an abundant but heterogeneous AKST structure that includes public, private, national, regional and international institutions and organizations, with major differences between countries. However, institutional programming and coordination do not respond to this structure's complexity and potential, and therefore it has not been possible optimize its use and the technological spillover. Recently, some innovative management approaches have been implemented in these organizations, with the participation of civil society.

Regarding the clients

The AKST agenda has not been sufficiently equitable in responding to the problems of small farmers and indigenous communities or resolving poverty and hunger. Its best results have been associated with productivity. The AKST system has made valuable contributions to agriculture that have been used mainly by large and medium producers and, to a far lesser extent, by smaller, less organized farmers with few resources, and by Afro-American and indigenous communities. The latter groups have had little participation in defining the AKST agenda, and insufficient attention has been paid to identifying the problems (challenges) associated with poverty that negatively affect the nutrition, health and well-being of the urban and rural poor. This suggests the need to design, finance and implement a pro-poor AKST agenda at the global, regional and country levels.

Regarding the agenda

Insufficient attention has been paid to social and environmental aspects related to the development of new technologies and production systems. On the environmental front, not enough consideration has been given to the direct impacts of production systems on water and soil resources, or to the effects of deforestation and the expansion of agriculture into new areas. The priorities of the AKST agenda have been food security, the production of agroindustrial commodities and low-cost foods for consumption and export. Consequently, the lines of research that have been prioritized are those directed at boosting productivity in the primary sector, but few efforts have been made to produce technological developments geared to the competitiveness of the agrifood chains, and to the production of non-agricultural goods and services in rural areas. Social, cultural and environmental aspects have also received less attention, and the Region has not taken full advantage of its significant biodiversity, fresh water and marine resources. However, there have been efforts to revert this situation and to address new environmental and social issues. Hopefully, AKST will be capable of resolving and reconciling conflicting goals such as competitiveness, sustainability and social inclusion.

Very few AKST institutions are able to address, by themselves, such diverse and complex demands; cooperative work and networking are essential among institutions and countries, with appropriate strategic planning, driven by the demands of society. In response to social demands, the AKST agenda has become more diverse, more complex and more holistic in its efforts to address problems of poverty, food security, environmental degradation, deforestation, biodiversity loss, natural disasters and global climate change. It has incorporated social, economic, environmental aspects and the notion of working with all links of the production chains, from primary production to marketing. However, users and society as a whole have had little participation in defining the AKST agenda, although more recently this has been influenced by consumer demand, prompting a shift towards participatory innovation development systems.

Regarding the constraints

It is important to understand that AKST *per se* has limited capacity to conclusively resolve the problems of adoption and application of technologies and systems that have been developed to promote sustainability and poverty reduction, since many of these problems are more closely linked to public policies. Public policy design receives insufficient contributions from AKST. Many factors external to agricultural technology development limit the potential of AKST to reduce poverty and develop more sustainable production systems. These factors include lack of market access, organizational capacity, education, extension, access to information, and some public policies. Public policies are a more relevant factor than technology development for poverty reduction and in this sense, AKST has not had sufficient impact to ensure the formulation of appropriate policies.

There is a certain level of unawareness in society regarding the impacts of the new technologies and this causes adverse reactions, often based on inaccurate information. Despite visible failings in the realm of communications, society has a positive perception of the S&T sector, though there are growing concerns about the impact of R&D on environmental issues and health.

Regarding the results

The different trade-offs between different aspects (agronomic, economic, social, cultural and ecological) and between stakeholders (different types of producers, businesses, society in general) have not been properly identified. Few strategies have been implemented to mitigate the negative impacts of different technologies and production systems. Despite its overall benefits (with subregional differences), AKST has had both positive and negative results, but these are difficult to quantify due to a lack of research on the different types of impacts (e.g., social, economic, ecological, cultural). Science and technology have provided important benefits in terms of production (genetic improvement, productivity, health, etc.), but sometimes with environmental and social costs that have not been adequately assessed.

Regarding the financing

insufficient funding of science and technology and inefficient use of resources reduces AKST contributions to the development of non-appropriable technologies for the common good. In recent years, there has been a decline in public sector contributions to R&D, in terms of dedicated funds, which has influenced the results obtained. Meanwhile, the private R&D sector has focused on developing appropriable technologies, (including genetics, biotechnology, nanotechnology, information and communication technologies, etc.) and on catching up with technologies generated in developed countries, and then adapting these to local conditions. Non-governmental organizations and other private stakeholders have made efforts to “fill the gaps” - albeit partially - left by public institutions, mainly on environmental and social issues.

Investment in agricultural R&D varies between countries and subregions, but in all cases it is lower than in the industrialized countries and some developing nations. In recent decades, investment has been insufficient and has declined progressively, creating much uncertainty and resulting in the inefficient use of resources in public institutions. In some countries, political, economic and institutional problems limit private sector investment in appropriable technologies.

2.1 AKST and its processes

2.1.1 Introduction

2.1.2 The AKST Agenda

From 1945 onwards, the AKST agenda in Latin America and the Caribbean (LAC) was highly influenced by government policies to support food security. Per hectare yield (Dixon, 2001) was the main parameter used to assess output was production costs were frequently skewed due to the government policy of subsidizing inputs such as seeds, fertilizers, machinery, equipment, etc. Consequently, AKST was geared to the genetic improvement of basic food crop seeds such as wheat, maize, rice, beans, etc. and to developing support technologies or “technology packages” related to economically optimal levels of fertilizers, integrated pest control, weed control, etc.

This research effort had a strong biological orientation and was driven by agricultural export activities, based on the premises of import substitution and the modernization of agricultural export structure (Méndez, 2006:74; Ballarin, 2002:107; Kalmanovitz & López, 2006:112), which prioritized economies of scale. For this reason, the first clients/users of AKST products and services - and therefore its main beneficiaries - were the large and medium producers engaged in commercial agriculture.

In this context, the first improved wheat seeds were produced and widely adapted as a result of an innovative genetic improvement process known as “shuttle breeding”. These improved crops were generously shared with other countries, paving the way for what subsequently became known as the “green revolution”.

Small-scale farmers with limited incomes, mainly subsistence farmers, have benefited little from these developments. However, Mexico’s Agricultural Research Institute has produced superior seeds to the existing types, not of such high production potential but adapted to farmers’ limited purchasing power.

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

At national level, AKST institutions face growing challenges to address a wide range of diverse research agendas 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, designed to meet their needs.

The design, application and financing of some of these research agendas by the State is directed at generating public goods for society as a whole, but mainly for the poorest sectors.

Other efforts, such as the AKST agenda to develop new agricultural products with high export value, require mainly private-sector financing, given its implications. However, the possibility of government support is not ruled out, given countries' interest in improving their balance of trade.

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

The above considerations, together with society's growing environmental and ecological awareness, means that some social sectors expect AKST institutions to be capable of addressing and reconciling apparently conflicting objectives such as productivity and environmental sustainability (Moncada and Muñoz, 1999).

Countries also face the challenge of responding to regional AKST agendas (Central America, Caribbean, Southern Cone, Andean Zone) directed at generating knowledge and technological innovations and providing relevant regional 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
- Bioenergy production

Because individual government institutions have little capacity to meet such a broad array of demands, others have emerged specializing in specific areas such as post-harvest handling, food quality and safety, and in certain promising advanced fields such as biotechnology, genetic engineering, etc.

We are just beginning to witness the emergence of institutions in a front-line scientific field, such as nanotechnology[1]. According to Maynard, (2006), nanotechnology development faces the

1 Nanotechnology: Capacity to see and manipulate microscopically small structures– including atoms and molecules- and use these to create a new generation of materials and substances useful to man

specter of a possible threat– real or imaginary –unless we develop reliable, dependable and authoritative information on the risks and how to avoid them.

As a preventive action, governments, industry and the world's research organizations have begun to study ways of taking advantage of the potential benefits of nanotechnology and of minimizing its potential risks. However, despite firm commitments to support research on risks, many opportunities have been missed to establish cooperative research programs.

A key question would be, who would finance research projects for using the potential of nanotechnology in areas of interest to the poor such as health, nutrition, and energy?

For the AKST agenda in LAC, poverty and/or reducing its negative impacts on the poor has been a secondary concern. The primary goal has been to boost productivity, increase the food supply and reduce food prices. However, Hazell and Haddad (2001) have discussed the possibility of implementing a research agenda aimed at supporting the poor and, 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 examples of this are the pro-poor research initiatives described in Box 2.1. By way of an example, this section mentions the initiative by the Mexico-based International Maize and Wheat Improvement Center (CIMMYT), to promote the use of QPM (Quality Protein Maize) in several Central American and South American countries. It also describes 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 produced statistical evidence showing the nutrition benefits offered by these types of maize to indigenous children in Oaxaca.

Insert Box 1 here

2.1.3 Shift towards participatory innovation development systems.

There is a new current of thought that advocates the need to shift from the existing AKST systems to Participatory Innovation Development (PID) systems, that focus on specific production chains or commodities; another broader and more inclusive vision is the application of such systems focused on watersheds.

This change implies new attitudes and processes of understanding and communication. It also requires an *ex-ante* definition of the expectations and visions by the system's members/components and end-users of the products and services to be developed. The components of an innovation system must have a comprehensive vision of the changes required for development, since sometimes the technology exists, but its use requires nontechnological innovations or changes, for example, organizing farmers for the marketing or assembly of inputs, or storage infrastructure, etc.

These efforts also require the input of other researchers in social, economic and anthropological sciences, in order to understand the interests and the participation of the human factor in these processes. Initiatives of this type have not been common in the past.

There is also a clear need to improve the efficacy and efficiency of universities and institutions engaged in research, development and technology transfer. This requires the establishment of formal and informal mechanisms of interaction, even through service contracts between these institutions and private-sector users, and will put existing governmental regulations to the test.

In this regard, special programs and mechanisms have been established to foster linkages between agricultural research and farmers. For example, the INTA of Argentina has implemented *Cambio Rural (Rural Change)* a comprehensive technology transfer program, while EMBRAPA of Brazil and the INIA of Chile have set up special programs in their regional centers. In Mexico, INIFAP[2] has created several programs, for example the Livestock Producers' Technology Validation and Transfer Groups; the Productor Experimental (Experimental Farmer) and the MOCAT groups[3]. In addition, the *Patronatos* and the *Produce* Foundations were created by civil society to support agricultural and livestock research.

Insert Boxes *2.2; 2.3; and 2.4*

In Mexico, the National Research and Technology Transfer System has begun to operate under the aegis of the Law for Development, and is coordinated by the Secretariat of Agriculture, Rural Development, Fisheries and Food (SAGARPA), and other Ministries that are users/clients of AKST, with the participation of the National Council of Science and Technology (CONACYT). However, this is a very recent initiative and still in the process of execution.

2.1.4 Monitoring and assessment of institutional performance in AKST

Most AKST institutions in LAC do not attach sufficient importance to assessment and this mechanism is seldom used to improve organizational performance. In general, assessment occurs as an isolated action and is not directed at resolving administrative and internal management problems. This lack of appropriate information makes it difficult to identify structural, organizational, administrative and management problems, and to identify advances in the outputs and results of research.

The main challenges facing AKST institutions in LAC are: identify and measure all outputs, emphasizing productivity in terms of the products and services generated for clients/users; address crucial management issues and constraints; create consensus and a sense of

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[2] National Forestry, Agriculture and Livestock Research Institute. Mexico.
[3] MOCATs. Technology training and transfer model. By specific product system or production chain.

"ownership"; improve internal and external transparency; strengthen knowledge of the institution's strengths, weaknesses and constraints. (Peterson, W., G. Gijsbers, M. Wilks. 2003).

The region's AKST institutions can also improve their performance by periodically and critically assessing 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).

The INIAs were created with a broad mandate that included all the regions of their respective countries and their problems. This resulted in 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. The complexity and scale of these institutions has produced vertical organizations with many hierarchical levels and a bureaucratic management style (Piñeiro, 2003). The 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.

Two complementary paths have been followed in pursuit of this type of organizational structure and management style (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 the 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.

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

Ageing of scientists and support staff

LAC's oldest publicly funded research institutions such as EMBRAPA, INTA[4], 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 those human resources who are due for retirement. In some countries such as Mexico, this has resulted from a government policy of "indiscriminately downsizing the state apparatus". This issue merits critical assessment, with a view to designing a rational, efficient and effective policy.

[4] INTA: National Agricultural Technology Institute. INTA

At the same tie, few AKST institutions have programs for training and updating the knowledge of their scientific and technical staff, or incentives to attract talented young people into cutting-edge research in new, highly promising fields such as biotechnology and 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 to explain and encourage individual and collective attitudes and actions, in order to generate and implement innovations leading to a productive, sustainable and equitable development.

The abovementioned challenges justify efforts to promote increased and more effective interaction between research centers and advanced training and education institutions, and promote their involvement in Participatory Innovation Development (PID) projects of interest to their respective countries and societies.

Institutions can take advantage of PID projects to provide employment for the young generations and put them “to the test”, and for the early detection of new talents and vocations for science and technology innovation.

Experience has demonstrated the practical and positive benefits of research institutions offering temporary employment to young students during their “vacation period”, and enabling them to prepare their Masters and Postgraduate theses, supervised by researchers, on problems relevant to the productive sector.

2.1.5 Knowledge, science and technology from an agroecological perspective

Since the end of the 1960s, the so-called agroecological system - based on a systemic approach to managing agricultural production- has emerged as an alternative to commercial agriculture in Latin America and the Caribbean. The system involves identifying the ecological, social, economic, cultural and geopolitical dimensions related to the management and use of natural resources, and revaluing the interchange between local know-how and scientific knowledge (Bernal, 2006; Sevilla and Gonzales, 1995:33; Sevilla and Woodgate, 2002:88)

This approach to production has been adopted by producers’ organizations, public research institutions, universities and non-governmental organizations. Among the most prominent examples are the Latin American Consortium for Agroecology and Development (CLADES) of Chile, the Agroecological University of Cochabamba with its core group, AGRUCO, the Masters Program in Ecological Agriculture of the Tropical Agriculture Research and Higher Education Center (CATIE) in Costa Rica, the Masters Program in Agroecology of the University of Caldas, the Agroecological Engineering undergraduate course at the Colombian Amazon University, and the agroecology course at the Palmira center of the National University of Colombia, in Valle del Cauca. The leading NGOs in this field include the Ecological Agriculture Network and the Agroecological Movement of Latin America and the Caribbean (MAELA), an open and pluralistic coalition of some 65 institutions engaged in research, development, training and promotional activities.

2.2 Inventory, characterization and development of the AKST system (formal and informal, public and private) and its interactions

Latin America has a rich tradition of individual and institutional efforts in science, technology and knowledge that have made significant contributions in different countries of the region. LAC's different sub-regions have an abundant, but heterogeneous AKST structure (with major differences between countries), involving numerous institutions and organizations – public, private, local, national, regional and international.

The AKST system in LAC has gradually incorporated different institutions, programs and other cooperation mechanisms, with the aim of providing the necessary geographic and thematic coverage. It has also sought to take advantage of, coordinate and integrate the efforts of different 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) the NARIs, universities and other national organizations; iii) regional centers; iv) cooperative programs; v) consortia and specialized networks; vi) international centers; vii) FONTAGRO[5]; and viii) FORAGRO[6]. This system is illustrated in Figure 1.

Insert Figure 1

2.2.1 Local and third sector organizations

Latin America is made up of a heterogeneous and complex system of regions that has generated a socio-biodiversity in historical co-evolution with its respective contexts. The system has a complex and intricate network of local organizations, each with its own links to the AKST structure, whether public, private, mixed or non-governmental (NGO) in nature. These interactions generate potential but also constraints that have expressed themselves in different ways, especially in the last three decades.

Mexico has a rich and varied experience in the creation and successful operation of civil society institutions that support publicly funded AKST programs. Much has been written about the "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 the experimental fields of INIFAP.

Insert Box 2.2 and 2.3 here

Regarding constraints on the interactions between NGOs and AKST institutions, these are generally due to factors such as regional contrasts, decisions of a political nature and limited social participation. They also reflect the trend toward the privatization of research, technical assistance and technology transfer to small and medium producers, as a result of administrative

[5] Regional Fund for Agricultural Technology.
[6] Regional Forum for Agricultural Research and Technological Development.

decentralization, structural adjustment and the liberalization of markets that have occurred in the last two decades (Quiroz, 2001 p.104).

Faced with a historically adverse situation, different countries have used public policies in an attempt to develop production systems that break the cycle of exclusion and environmental degradation and also incorporate a gender perspective and the indigenous and Afro-American worldview, through strategies involving AKST. However much still remains to be done to ensure the real participation of local stakeholders in decision-making processes (Dirven, 2003, p. 442).

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

In relation to AKST, local development processes pursued by communities, either independently or in partnership with universities, foundations, corporations, cooperatives, producers' associations and non-governmental organizations, both national and international, have served to revalue traditional knowledge, develop greater negotiating power, improve territorial administration and strengthen 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, the claims of the Mapuche indigenous community, which have had local impact as well as regional and international repercussions on designing a new epistemological framework and a new AKST paradigm at the Latin American level.

Nevertheless, the governmental and non-governmental institutions whose mission is to generate a new AKST framework for Latin America's agricultural sector continue to avoid the issue of rural reform. Most Latin American countries have not yet resolved the 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 the urban areas (Machado, 2004 p.73).

Although there are some isolated experiences, the new AKST advances – including bioelectronics, bioinformatics and biotechnology - have not been widely incorporated into the production systems. In general, neither *campesino* farmers nor commercial agricultural producers have adopted these advances. Moreover, there have been no reconciliation processes to take advantage of their positive aspects. Generally, the priority is in one direction: towards imported systems and dependence, for which reason there is no innovation based on what exists locally. (León et. al 2004, p.54 Amaya and Rueda, 2004.p.10)

National organizations

LAC's AKST system is made up of a vast network of public, private and third sector institutions in the different countries which, in most cases, have had a major impact, given the relative importance of agriculture in the region. Within this system, the national public agricultural research institutes, generally known as NARIs[7] or INIAs, 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 very varied characteristics. Some are very important and receive the major share of their country's investment in agricultural science and technology, as well as regional investments, such as EMBRAPA in Brazil, INIFAP in Mexico, INTA in Argentina, INIA in Venezuela and ICA in Colombia. In other countries, investment in AKST has been limited and there is no significant institutional structure at the national level.

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

Some 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 in 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 the countries.

In the larger countries with political structures/resources at the level of provinces / states, the AKST system usually includes public institutions of a provincial or regional nature, which tend to specialize in certain crops, production areas or issues of local importance. Some of these have made important contributions to the development of specific activities, such as the Obispo Colombres Experimental Station, in Argentina's Tucuman Province, in 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 declines *vis à vis* the private sector. This has resulted from two simultaneous processes: a) first, 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; b) secondly, the economic, social and technological processes that have affected the agricultural sector in recent decades, particularly the expansion and concentration of production. Both processes have placed greater emphasis

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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 great interest to firms that supply inputs, particularly when they are not commercial producers.

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

Many significant advances in technology have been achieved by “catching-up” with technologies generated in developed countries, and then adapting these to local or regional conditions in different countries. This has led to some very competitive developments in certain crops and regions - especially of temperate zones - with relatively little effort or investment in science and technology at 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[8].

It is also important to mention that the work agenda of the national public institutions has focused mainly on ways of improving farmers’ livelihoods and incomes, while social and environmental aspects have traditionally received less attention. It is only in the last two decades that these issues have become more important in the NARIs’ activities.

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[8] It should be noted that in the 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.

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 member institutions. This has hindered their articulation with the production models, a situation further aggravated by the fact that technology products are often generated from the supply-side, without considering the profile of the end-users. As a result, there is growing support for the idea that the management of technological development should be *democratized,* with greater participation by users and clients.

At the same time, demand-side requirements are becoming increasingly important in determining the types of technologies needed. Better informed consumers and more concentrated distribution channels require producers to consider a varied range of new issues, such as product traceability, certifications of origin and processes, respect for the environment, natural products, etc. This, in turn, has placed new demands on the public AKST system, which is currently attempting to respond to the challenge with the support of private firms.

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 institutes have begun to include social issues, subsistence agriculture and urban agriculture in their agendas. However the 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.

Traditionally the NARIs' agenda has concentrated on the aspects of production and competitiveness. However, in the last two decades, as it has become clear that certain agricultural practices cause damage to the ecosystems, the public AKST institutions have increasingly focused their efforts on sustainable development, responding to the concerns voiced by different specialized institutions. However, in most LAC countries, this response has been tardy; this fact, and the relatively limited effort devoted to these issues, means that S&T institutions have not yet addressed the problem of sustainability with the necessary intensity.

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, towards whom agricultural extension and technology transfer is generally directed. In some countries and for specific types of farmers, independent professionals - both agronomists and veterinarians- are an important factor in technological development.

In this regard, 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.

2.2.2 Regional organizations, international centers and other regional cooperation mechanisms

LAC has a long experience - more than half a century - of regional cooperation on agricultural research and education between countries and institutions. The existence of common problems in different regional and sub-regional spheres, and in some common thematic areas, and the constraints encountered in attempting to develop significant independent agricultural research programs, especially in the smaller countries, led to the implementation of different initiatives. In some cases, these efforts were consolidated in new regional institutional structures, while in other cases 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 IICA[9], an institution created in 1942 in Turrialba, Costa Rica, where an experimental station and postgraduate education center was established, and subsequently led to the creation of CATIE[10] 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.

In the mid-1970s the twelve members of the Caribbean Community trade and integration initiative (CARICOM) created CARDI[11] with the aim of strengthening agricultural research and development activities and supporting the agricultural sectors of the member countries. These functions had previously been carried out by the 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 abovementioned sub-regional centers, during the 1970s and 1980s the NARIs and other public and private institutions of the LAC countries gradually established **cooperative agricultural research programs** (known as PROCIS), which have grown notably and continue today. These programs evolved from initial exchanges of knowledge among the 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 different topics and for all the sub-regions of the Americas[12]; the majority of these

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[9] Inter-American Institute of Agricultural Sciences, currently known as the Inter-American Institute for Cooperation on Agriculture.

[10] Tropical Agriculture Research and Higher Education Center (CATIE), currently with 14 members: IICA, Belize, Bolivia, Colombia, Costa Rica, Dominican Republic, El Salvador, Honduras, Mexico, Nicaragua, Panama, Paraguay and Venezuela.

[11] The twleve CARICOM countries (Antigua & Barbuda, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St Kitts-Nevis, St Lucia, St Vincent & the Grenadines and Trinidad & Tobago) created the Caribbean Agricultural Research and Development Institute.

[12] The Cooperative Research and Technology Transfer Program for the Northern Region for Canada, Mexico and USA (PROCINORTE); the Caribbean Agricultural Science and Technology Networking System for the CARDI countries, plua Suriname (PROCICARIBE); the Central American Cooperative Program for the Improvement of Crops and Animals

initiatives received support from IICA and the IDB during their initial stages. These cooperative mechanisms, which do not require new institutional structures, have had positive impacts in promoting technological development in the respective countries; the impact assessments of the investments made in these programs have generally shown them to be highly cost-effective.

There are also **consortia and specialized networks** for different topics, products and sub-regions, which have received support from the FAO's national and regional offices, and from other international institutions. Some of the most important organizations 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 CIMMYT[13]; the Latin American Agricultural Conservation Network; the Consortium for 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 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 the LAC countries in setting priorities and in funding research projects. It was established by a group of countries of the Region[14], with sponsorship from IDB, IICA, the Rockefeller Foundation and the International Development Research Center (IDRC) of Canada. Its purpose its to promote increased competitiveness in the agricultural sector, ensure the sustainable management of natural resources and work to reduce poverty through the development of technologies with the characteristics of international public goods, 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 the projects' coherence with the Fund's objectives and on technical, economic, environmental and institutional criteria established for the priority research

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(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 for 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 Development of Agricultural Technology in the Southern Cone, including Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay (PROCISUR).

[13] International Maize and Wheat Improvement Center

[14] 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 .

areas defined in the Medium Term Plan 2005-2010. The design and execution of the proposals is undertaken by different organizations of 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.

FORAGRO is a mechanism designed to facilitate discussion and support the definition of a Regional agricultural technology research and development agenda, taking into account the growing importance of operating in knowledge networks. FORAGRO's general objective is to contribute to the consolidation of the Regional Agricultural Technology Innovation System for the Americas, facilitating dialogue, coordination and strategic alliances between the different stakeholders that comprise the 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 and, 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, the sub-regional cooperative research programs, the Regional networks, the regional centers of CATIE and CARDI, the CGIAR Centers located in the Americas, as well as FONTAGRO and IICA which acts as the Forum's Technical Secretariat[15]. Although the 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; CIAT, based in Colombia[16]; and CIP, headquartered in Peru[17]. 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 (IFPRI), plant genetic resources (IPGRI), livestock production (ILRI), forestry and agroforestry (CIFOR and ICRAF)[18]. All these institutes carry out activities in LAC and in some cases have offices in several countries of the region.

In synthesis, 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

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[15] 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).
[16] International Center for Tropical Agriculture
[17] International Potato Center.
[18] International Food Policy Research Institute (IFPRI);International Plant Genetics Resources Institute (IPGRI); International Livestock Research Institute (ILRI); Center for International Forestry Research (CIFOR); and International Center for Research in Agroforestry (ICRAF).

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).

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

2.2.3 Institutional structure of AKST in the Amazon

The Humboldt expedition was one of the early historical precedents that promoted the development of knowledge in the Amazon region. Later, UNESCO and FAO addressed the Amazon context from different perspectives and, based on the processes of extraction and export of rubber gum, other major institutional developments emerged in the region (Da Silva, 2002:9).

Between the 1950s and the 1980s, efforts to generate knowledge, science and technology for the Amazon context generally adhered to the principles and systems of modernization based on the expansion of the agricultural frontier and the notion of development poles based on mineral exploitation, (Bergerman, *et al*., 2005), supported by a matrix of communication networks by land, air and river, connected to the respective urban centers (Gutiérrez, *et al*., 2004:71; Domínguez, 2004).

Under these precepts, an institutional complex emerged, which tried to integrate that geographic space into the respective national economies, reinforcing national sovereignty in the face of a possible internationalization of the tropical rainforests (Becker, 2005a: 72; Walschburger, 1992: 359; Chaves de Brito, 2001:23). The latter was prompted by the weak institutional presence in the Amazon region and by the subordination of its economy, despite its great geo-strategic and geopolitical value due to the resources it contains (Becker, 2005a: 72; Cordero de Santana, 1997:234; De Assis Costa, 1997:257).

Nevertheless, over time, the emphasis on generating, adapting and transferring AKST to the Amazon environment had a substantial impact on national scientific and technological development (Comissão Tundisi, 2001:321). The basic problem has been the lack of regional capacity in agricultural science and technology and the absence of an autonomous research body (De Assis Costa, 2005: 14; Aragon, 2005: 788; Franco, 2000; Aragon, *et al*., 2001:3; Dominguez, 2004: 16; Becker, 2005b: 624; Sicsu & Lima, 2001: 25).

The advance of democracy and the subsequent economic liberalization at the end of the eighties and beginning of the nineties redefined and energized the roles and functions of the State. In the context of an environmental crisis, this has generated new approaches to knowledge, science and technology, even including areas such as human rights, intellectual property, biotechnology, biosafety, information technologies, natural disasters, climate change, desertification, biodiversity, water, illicit crops, sects, communications, information and free trade agreements, among others, which have been addressed to a greater or lesser extent by universities, national and international research institutions, ministries, religious groups and international cooperation agencies, (Aragón & Clüsener, 2003:25; Aragón, 1997:591; Díaz, 2005; IIRSA, 2004; IIRSA, 2003, USAID, 2006, GTZ, 2005a; GTZ, 2005b, CAN, 2007, AECI, 2007; MMA, 2007; IIAP, 2005; IIAP, 2001a; IIAP 2001b, LBA, 2005; Luzão, *et al*., 2005).

Today the Amazon region is a territory with its own identity, but it is undergoing a process of change that has repercussions on all aspects of development (Becker, 2005b; Thery, 2005:46). Faced with this scenario, and in an effort to harmonize the Amazon region's institutional framework, the Amazon Cooperation Treaty Organization (OTCA) was established, with its permanent Secretariat in Brasilia, (OTCA, 2007), along with the Coordinator of Indigenous Organizations of the Amazon Basin (COICA) (COICA, 2007), headquartered in Quito. In the realm of higher education the Association of Amazonian Universities (UNAMAZ) was established, based in Santa Cruz de la Sierra (UNAMAZ, 2007). Tables 1, 2 and 3 list the AKST institutions working in the Amazon, with some of their policies, programs and research projects.

Insert Tables 1, 2 and 3.

Development of the AKST system

The AKST system in LAC has undergone major changes throughout its history.[19]. Towards the end of the nineteenth century and beginning of the twentieth century AKST was institutionalized, that is to say, the first stage of organized agricultural research began in the universities or in specialized national institutions sponsored by the State. In their early stages these institutions were organized in departments, by branches of knowledge: edaphology, entomology, plant pathology, animal pathology, weed control, machinery, etc. 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, in a move away from the relatively simple environment of the Experimental Station to the more complex and multifaceted context of farms and production systems. This forced some researchers to interact directly with the milieu, testing their willingness and capacity to communicate and reach consensus with farmers, and to recognize the importance of teamwork with other specialists.

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,

[19] Among the major innovations that have been documented in the Inca civilization are the drainage systems, the development of dark earth soils or anthrosols (Indian Black Earth) and other archaeological findings discovered during the last decade in the Greater Amazon. The diversity of genetic resources found in Peru is an achievement of the indigenous communities, who over a period of at least 10,000 years domesticated, selected and adapted native plants to their ecosystems. With these, and with the domestication of fauna, Peru is one of the largest world centers of genetic resources, with 182 species of plants and 5 of domesticated animals.

2003). This current of thought and action argues that the greatest challenge is to shift from the existing AKST systems to Participatory Innovation Development systems, based on specific production chains or commodities. Another broader and more inclusive vision is “Innovation Systems and Participatory Development based on “Watersheds”, as the natural spaces or territories in which one or more “production chains” operate and interact with each other and with the general context.

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 the genetic improvement of plants, and the characterization and management of natural resources, among other purposes (Araya and Hernández, 2006).

The systematic recording of the knowledge generated and its application in formal genetic improvement programs has been one of the greatest achievements. CGIAR[20] has documented more than 80 participatory programs in genetic improvement, some of which are carried out at its International Centers (CIMMYT[21], CIAT[22] and CIP[23]) in LAC. One objective of the participatory research programs is to take advantage of farmers’ knowledge, which obviously implies identifying their needs, their preferences and their reasons.

Although society in general recognizes the farmers’ role in managing and improving germplasm, there is still little agreement on how to appraise the role of farming communities and contributions in the formal system 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[24].

These developments have implied new requirements in terms of attitudes, understanding and communication processes needed to facilitate dialogue and linkages between those who generate technological knowledge and innovation, and those responsible for other links or factors indispensable to the development, productivity and competitiveness of the “production chain” or “watershed”, such as the organization of suppliers (farmers), marketing, financing, infrastructure, public policies and institutions, and information and communication mechanisms aimed at enhancing participatory development, etc[25].

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[20] Ver: http://www.prgaprogram.org/index
[21] CIMMYT: International Maize and Wheat Improvement Center
[22] CIAT: International Center for Tropical Agriculture
[23] CIP: International Potato Center
[24] See: Farmers as Researchers: The Rise of Participatory Plant Breeding by Gerry Toomey

[25] A participatory innovation system to contribute to productivity and sustainable development implies sharing ex ante expectations and visions between the members of the system and the end-users of products and services to be developed. Members of an innovation system need to develop a comprehensive vision of the changes required for development, since sometimes technology exists, but its use requires organizational innovations (for example the organization of producers for the marketing products or assembling inputs).

In some LAC countries we are currently witnessing the emergence of a research and technology transfer system (SINITTA), whose challenge is to promote a networking synergy, based on inter-institutional complementarity, according to the comparative advantages of each institution.

This process is at different stages of development in each LAC country (Piñeiro et al, 2003), since it requires the participation and interaction of research institutions (federal and state institutes, universities, etc.) around a common agenda of national demands. 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 the AKST systems in most LAC Countries has clearly limited their capacity to develop inter-institutional links, which is reflected in a limited number of cooperative projects.

To improve the efficacy and efficiency of the existing research, development and technology transfer institutions it is essential to create formal and informal interaction mechanisms, including service contracts between these institutions and private sector users, in order to generate the required technological innovations and options. To optimize these complex systems from a biological, economic and environmental point of view, it is necessary to involve researchers in socio-economic and anthropological science, to better understand the interests and role of the human factor in these processes.

For several decades, private enterprise has become actively involved in the AKST system and has gradually assumed an increasingly important role in the development of some innovations (genetic products, machinery, agrochemicals, etc). As a result, public research institutions find themselves in the dilemma of competing, withdrawing and focusing their efforts on developing other innovations, or else cooperating on joint strategies. In other words, public AKST institutions face the challenge and opportunity of working with private AKST institutions on projects of mutual interest. This decision has strategic political implications that must be considered; it will also test governments’ vision and willingness to generate new game rules or standards for public-private partnerships, aimed at safeguarding the interests of society.

Another great challenge facing the 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 different paces by some countries of the region. However, although these developments may offer very interesting alternatives in many areas related to human well-being and quality of life, the level of investment required, together with patents and copyright issues, could become insurmountable obstacles to taking advantage of their potential to benefit the region’s poor. Therefore, one of the greatest challenges facing small and medium-sized countries in LAC is to review, update and reinforce the mechanisms and processes of regional cooperation. The new developments are being used by industry and by the service sector, where users have purchasing power and where the interests of the investors are protected by intellectual property rights and patents.

Although there are isolated experiences, the incorporation of new AKST advances into production techniques that include bioelectronics, bioinformatics and biotechnology is not a *continuum*. In general terms, neither subsistence farmers nor the majority of commercial agricultural producers have incorporated these advances. Moreover, there are no reconciliation processes to utilize the positive aspects of each one. Generally, the priority is in one direction: towards imported systems and dependence, for which reason there is no innovation based on what exists locally.

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 on 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, bacteria that promote growth in plants and induced 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).

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[26] identified a number of common problems affecting these institutions, including limited inter-institutional cooperation; lack of and poor allocation of resources; and organizational and management weaknesses. The main problems affecting most AKST systems of LAC cannot be attributed to the quality of their human resources -there are many cases of researchers from LAC countries who work in the International Centers of CGIAR and are considered to be among the most capable and productive scientists, due to the working atmosphere and the resources available to these centers.

National AKST leaders in LAC have long recognized the existence of the abovementioned problems, and have made several attempts to correct them, often through externally funded projects. For example, ISNAR sent specialists to several countries to assess the institutional situation and recommend improvements to the organizational structure and the administrative and management procedures. ISNAR also developed research management tools and made these available through publications and training programs. As a result of this, there has been a considerable improvement in the effectiveness and efficiency of some national institutions. However, many of the problems mentioned still persist, given that these institutions continue to operate in a cultural and political environment that is neither appropriate nor conducive to the changes required.

In order to overcome this problem, several models of semi-autonomous institutions were created, based on the working hypothesis that more autonomous institutions would be free from political influence in the selection and recruitment of their human resources, and would have greater flexibility in establishing their own institutional policies, regulations and administrative procedures. Unfortunately, these new institutions were rarely granted the sought-after flexibility, and when they were, they did not use it. This, however, is not the root of the problem. According to Nickel, no institution that is dependent mainly on public funding can be totally autonomous; if it receives public funds, these must be used to respond to the needs of society and must operate within national policies. In most cases, the prescribed institutional changes have not been made, or have not been allowed to be implemented, or have not been implemented in the to the necessary extent. In other words, they have been superficial or cosmetic and have not brought about the desired improvements in the productivity and quality of agricultural research. If we carefully examine the reasons for this, we find one or more of the following factors: i) the Minister of Agriculture or equivalent was not willing to relinquish control of the AKST institution; ii) the new human resource management policies were not very different to those applied in the departments or directorates of the Ministries; iii) the administrative procedures and financial controls continued to be very complicated.

With regard to human resource policies, it should be noted that a simple improvement in salary scales to attract and retain the most qualified personnel, does not necessarily increase the productivity and quality of research work, unless institutions simultaneously establish selective processes for the recruitment of staff and effective assessment and incentives systems. Sometimes the staff administration and assessment systems have defects, or else are not properly applied. In other cases, the staff does not feel comfortable with a system in which the salary is based on an individualized assessment system. In the traditional governmental human resource management systems, annual salary increases and promotions are based more on length of service (seniority) than on productivity. These systems were adopted to prevent "favoritism", which certainly is important, but they provide a measure of job security and comfort that the majority of personnel are not willing to give up. In some countries this situation is aggravated by labor laws that make it practically impossible to sanction or dismiss unproductive employees or researchers. As a result, productive performance is seldom valued and rewarded, while lack of productivity is rarely sanctioned. This is a serious weakness in the national institutes and, if not corrected, will condemn them to mediocrity.

In administrative matters, 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 these protect them from being accused of mismanagement. Safeguards or controls are necessary to prevent abuses, but it is also

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

essential to adopt more flexible and effective administration and financing systems. This is particularly crucial in AKST institutions, where significant delays in making funds available or in purchasing equipment and inputs can negatively impact the effectiveness of research.

According to Nickel, “the problems indicated are the main reasons why the changes to improve AKST systems have been superficial or “cosmetic”, and have not achieved the desired improvements in the productivity and quality of agricultural research”. Based on the conclusions formulated in 1996, we should ask, to what extent have AKST institutions in LAC overcome these “generic problems” identified by Nickel?

According to Piñeiro, 2003, “experience shows that actions aimed at strengthening the AKST institutions that comprise the institutional technology research and innovation system, should go beyond the traditional institutional strengthening programs that focus on internal organization and management systems”.

“The reforms should give due importance to elements such as: the institutions’ legal character, their institutional mandate, their relations and mechanisms of interaction with civil society, and the strengthening of their governance systems to facilitate the coordination of all governmental and private actors committed to innovation”. “The ultimate goal of restructuring is to achieve greater relevance and efficacy in the operation of the innovation system and thereby secure sustained political support”. This important observation merits a review and assessment of the current situation.

Bearing in mind Nickel’s observations and conclusions - in 1996 he had already noted that “bold changes will be required in the laws, regulations and attitudes to enable AKST institutions to more effectively accomplish their valuable mission, in order to deserve increased and much-needed political and financial support” – the following section outlines some of changes observed in the AKST institutions in terms of their legal status, their governance system, their links with users, etc. Finally we present the current trends described by Piñeiro, 2003, and Bisang, 2003 regarding the common features observed in the AKST institutions within their current development phase.

2.2.5 Changes in the legal nature of AKST institutions

The National Agricultural Research Institutes (NARIs) were created and evolved as public sector organizations with varying degrees of autonomy. However, according to Piñeiro, 2003, the characteristics of their original legal constitutions or subsequent administrative decisions by the central government have forced most NARIs to operate under administrative restrictions and endure the political interference that characterizes the Latin American public sector. Argentina’s National Institute of Agricultural Technology (INTA) is an example of the progressive erosion of autonomy. Created in 1958, INTA’s legal constitution granted it financial and administrative autarchy. However, with the passing of the years, the political authorities curtailed its independence, converting it *de facto* into an institution with the same restrictions as the rest of the central government bodies.

A similar situation occurred with Mexico's National Agricultural Research Institute (INIA), which was widely recognized for its effectiveness, efficiency and productivity. Legally, it was a deconcentrated body of the central administration; however, from the beginning it was endowed with a Trust Fund that allowed it flexible and timely financing and operational autonomy. However, this mechanism was canceled in 1982, as part of a general government instruction to cancel public Trust Funds, and therefore the institute became subject to the regulations of the central administration, unsuited to the functions of research. Nowadays, however, the National Public Research Centers, such as INIFAP, have a Trust Fund, an instrument that contributes greatly to the flexible and timely financing of their research activities.

Nickel argues that no institution that is largely dependent on public funds can be totally autonomous." If it receives public funds, these must be used to respond to the needs of "the greater society" and must act according to national policies. For this reason, Nickel argues that these institutions should be considered as "semi – autonomous", rather than "autonomous".

However, there are some promising initiatives; recent reforms, for example in Britain and Australia, have tried to resolve this problem by granting research institutions a legal framework that gives them the right to be governed under private law.

This legal framework allows for a responsive and flexible management style, essential for achieving greater efficiency (including salary levels and promotion system for scientific personnel, flexible recruitment policies, linkages and association with the private sector, royalty contracts and/or a share in income derived from intellectual property etc.). Examples of this trend in the region include the INIA in Chile and CORPOICA in Colombia (Piñeiro, 2003). A similar system has been implemented in INIFAP in Mexico (See Box 2.6). In response to this problem, Mexican lawmakers took the initiative of creating an *ad hoc* legal definition for public research institutions.

Insert Box 2.6. here

2.2.6 Civil society as an element of political pressure

Faced with new and growing demands for technological knowledge and innovation, the AKST institutions need to be more efficient and effective; they need changes that must be approved, applied and audited. In this regard, experience shows that "external political pressures" must be applied to government authorities to ensure that such changes are approved. This external political pressure may be exerted more naturally and efficiently by society through so-called "social oversight by interest groups", which will also ensure that the AKST institutions apply the approved changes.

An example of this is may be seen in the changes made to the legal status of INIFAP (Mexico) and its recognition as a "National Public Research Center" under the new Science and Technology Law, largely as a result of "positive political pressure" applied to the Government by organized farmers associated with interest groups. (*Produce* Foundations, COFUPRO A.C. and support Patronatos such as PIEAES A.C. Boxes 2.3. and 2.4)

2.2.7 Changes in the governance systems of AKST institutions

There has been a growing tendency among NARIs to include representatives of the leading private sector trade organizations on their governing bodies at the national and regional levels. Among the more interesting examples of this we can mention the INIA of Uruguay, the Colombian Agrarian Research Corporation (CORPOICA) and INIFAP of Mexico. However, sometimes the composition and/or actions of the governing body can be improved, for example in the case of INIFAP in Mexico (Piñeiro et al, 2003).

2.2.8 Changes in the linkages with civil society

Special programs and mechanisms have been established to promote and facilitate linkages between agricultural research bodies and farmers. For example, INTA in Argentina has implemented a technology transfer program, while EMBRAPA of Brazil and the INIA of Chile have special programs in their regional centers. In Mexico, INIFAP has established the Livestock Producers' Technology Validation and Transfer Groups, the Experimental Farmer and the MOCAT groups27. For its part, civil society has created the Patronatos and the Produce Foundations to support agricultural and livestock research. Boxes 2.2; .2.3 and 2.4.

Insert Boxes 2.2; 2.3 and 2.4

2.2.9 Strategy of institutional positioning and accountability

Most public AKST organizations have focused on their own institutional work; however some with a more strategic vision have implemented an "institutional image" campaign as part of a policy and strategy of "accountability", informing society (rural producers and urban consumers) and Legislators, about the products and services generated by AKST, about their benefits and their economic, ecological and social impact on promoting productivity, competitiveness, environmental sustainability and equity. (Castro et al, 2005).

2.2.10 Interactions between organizations and knowledge networks

There are major differences in the ways in which networks have developed in the different countries, and some especially important changes have occurred in the last 25 years:

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[27] MOCATs. Model of training and technology transfer. By specific product-system or production chain.

In several countries, the relative importance of government investment in agricultural research has declined, although this has continued in the universities, and increasingly relies 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, and also due to a greater role by local and international NGOs and by the producers' associations themselves.

There has been a revaluation of the farmers' own knowledge of agro-ecosystems and of production systems that are better suited to local conditions. This has coincided with agroecological studies that comprehensively examine 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. Efforts have begun to study both the constructive and the negative interactions between formal and informal networks for disseminating agricultural knowledge.

Formal research networks have begun to transcend the national sphere, through joint efforts at the international level, although still in an incipient manner.

The development of these 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. This is the case of Brazil, Argentina, Mexico, Colombia and Venezuela.

In Central America, the economic problems and policies of the 1980s, together with structural adjustment and state reform processes, led to the weakening of public agricultural research institutions, as well as their links with international organizations and local universities, where a good part of the formal agricultural and livestock studies continued to be carried out. However, some undergraduate and post-graduate education centers with international projection continued to promote concerted research efforts and served to link researchers within and outside their respective countries: 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 other 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 begun to develop more participatory relations or links between public and private stakeholders engaged in producing and transferring technological knowledge, exploring different forms of research and extension, setting agendas through consultations and negotiations, testing different forms of participation by farmers and their organizations in the different phases of the research process, and also in the assessment and dissemination of the results. On this matter, there have been different assessments and varying positions, and only the first steps have been taken, but it is clear that consensus mechanisms are required in public-private agricultural and livestock research, which may take varied forms and follow different paths.

2.2.11 Society's perception of AKST

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).

Based on the above definition, 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 during the last few decades, when progress and achieving a better quality of life were associated with the use of new technologies (Casanovas, 2006).

However, there are also negative views of technology, usually associated with concerns over an environmental and social crisis. These call into question the impacts generated by many types of production techniques that are used with little thought and awareness (Casanovas, 2006, Albornoz, et al. 2003). For example, there has been much discussion about the consequences of agricultural modernization for peasant farmers, as shown by the results obtained by the External Assessment Commission of INIFAP (Piñeiro et al, 2003).

The lack of response to social problems generated by the use of new production techniques 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 information, or incomplete or biased information, which underscores the importance of ensuring an effective use of the media (Albornoz, 2003).

Some AKST institutions in LAC have adopted policies and strategies to promote greater interaction with interest groups that offer potential moral, political and economic support. This openness of AKST institutions and their eagerness to interact with their environment is highly promising. Unfortunately, it is not a generalized situation.

In order to analyze the links or relations between society, science and technology, we need to establish indicators to help us characterize and analyze three dimensions that underpin these relations: public perceptions, scientific culture and citizen participation. Understanding these dimensions will provide tools to facilitate greater competitiveness in the science and technology institutes and will therefore improve the citizens' quality of life (RICYT/CYTED 2003, SENCYT, 2005).

Clearly there is a need for a greater participation by society in the "social oversight" of AKST institutions, both in terms of their work agenda and their performance. Society can also provide support through "positive external political pressure" on AKST institutions, and on the Government itself.

The challenge for AKST institutions is to develop a strategy and a willingness to interact not only with their public and/or private counterparts, but also improve their capacity to communicate and interact with institutions responsible for factors that can limit innovation and development, such as marketing, credit and producers' organizations in order to ensure that the products and services generated by the AKST institutions contribute to innovation and development.

2.2.12 Lessons and challenges

2.3 Responses of AKST systems to changes in the most influential contextual variables

2.3.1 Environmental variable

Water

Since the 1950s, knowledge, science and technology related to water in LAC has focused on finding ways to promote its rational and sustainable management, its use in areas of water scarcity, inventories and systematization of hydrological and hydro-biological resources and efforts to reverse unsustainable processes such as pollution caused by domestic waste water, among others (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 its role as a factor of agricultural production, and on irrigation systems, introduction of drought-tolerant materials, adaptation of species to saline and sodic soils, among others.

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

The current agenda is revaluing the small irrigation systems that are used in extensive areas around the world, and especially in LAC (Palerm and Martinez, 1997, 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, presence of heavy metals and disappearance of wetlands, etc. (Foundation Ecology and Development 2006).

An important area of research in AKST is the contamination of water with heavy metals produced by the exploitation of hydrocarbons and minerals such as gold, and crop-spraying, among other activities, which creates ecological imbalances and has adverse effects on human health (Aragon, 2002:8).

Climate change has also forced a shift in the direction of research, 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 the ocean currents (IDEAM, *et a*l., 2001:49; MM & IDEAM, 2002b: 19; Obasi, 2000). Networking has been an important factor in mitigating the impacts and designing policies at regional and global level, through bilateral and multilateral cooperation.

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

Global climate change and natural disasters

The Latin American and Caribbean region is affected by a broad spectrum of natural disasters with varying impacts. Their origin is mainly geological (earthquakes, volcanic eruptions and tsunamis), geodynamic (landslides, avalanches), hydro-geodynamic (mudslides, alluvions, moraines, landslides, debris flows, land subsidence), and hydro-meteorological/oceanographic (floods, the Niño/La Niña Phenomenon, droughts, desertification, frosts, hail storms, tropical storms, floods) (CAF, 2006:14). See Figure 2.

Insert Figure 2

Other phenomena, such as El Niño, also affect the Latin American and Caribbean countries in different ways, (Figure 3) (CRID, 2006). This has led to the development of a system of knowledge, science and technology, particularly in those countries that consider it an area of interest because of its social, economic, environmental, prevention and technical-scientific implications. During the last decade, efforts in the Andean Region have focused on the following areas: a) developing knowledge of the dangers, vulnerabilities and risks, and planning methodologies for disaster prevention with a national and sectoral vision; b) supporting the expansion of infrastructure to improve this knowledge; c) institutional strengthening of knowledge institutions, with a view to increasing production capacity and coordination between the generators of knowledge (CAF, 2006:23).

Insert Figure 3

Soils

Approaches to soil science and technology have evolved in different ways in Latin American and Caribbean academic establishments. Initially, regional research in this field focused on aspects of taxonomy, fertility and valuation for cadastral purposes. Particularly noteworthy was the work on soil biology carried out by the Brazilian researcher Ana Primavezi in Brazil at the end of the 1960s.

In the 1970s, the emphasis was on fertility, management and conservation studies (Duque, *et al.,* 1997; SINCHI & INADE, 1998; Brazilian Ministry of Planning and Finance, OAS, PRODEAM, 1998; Institute SINCHI & INADE, 1999; INADE, 2005). During the 1980s, experts introduced research at watershed-level for land use management purposes, with the subsequent methodological and discursive development of Landscape Ecology Theory (LET) and ecological-economic zoning, based on a systemic concept of the environment, particularly of landscapes. The predominant approach was based on an integrated and interdisciplinary analysis of soils within the ecosystems and agro-ecosystems that comprise the landscapes, which were considered as functional structural and temporal units within geographic spaces (Etter, 1992:28). In response to current social needs, the study of soil sciences has defined a series of objectives and challenges that provide a framework for scientific research, extension and application of results, related to demand (according to Latham, 1998, cited by Burban, 2004:74) and shown in Table 4.

Insert Table 4

The area of soil biology has been strengthened, based on molecular techniques and working with DNA and RNA to inventory mezzo-organisms and microorganisms. (Toro, 2004; Peña, 2007).

Other AKST approaches to soil studies in LAC are related to the impact of deforestation, one of main causes of soil degradation, and the impacts of contamination with heavy metals associated with the exploitation of hydrocarbons and minerals such as gold (Franco & Valdés, 2006). These processes result in soil loss, in most cases irreversible, by removing the superficial soil layer.

Urban development trends in LAC have provided a new framework for AKST related to soils, since soil use has been affected by land speculation. These dynamics force the displacement of production and subsequent abandonment of the land. Problems of land concentration, poor solid waste management, contamination, destruction of ecosystems, change of landscape, displacement and loss of traditional knowledge on the use of these soils, are all phenomena derived from changes in the urban-rural structure. (Clichevsky, 2006:).

At present, efforts are under way to incorporate new aspects of soil research, such as ethnotaxonomies (Serna, 2006). “Worldview” is now considered an important component of soil management and conservation, an outstanding example being the case of the “Pacha Mama or Mother Land ” ritual in the Andes. (Otero, 2007; Bernal 2007; Sinchi,)

2.3.2 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, which achieved their best results in the more developed production systems, but provided few benefits to poor farmers, with lower levels of organization or to Afro-American and indigenous communities. (Allison, 1997, Wheat et al, 1983 Morales).

The need to respond effectively to local demands, mainly from farmers who had 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, (Wheat, Piñeiro and Ardila, 1982; Piñeiro, Wheat and Fiorentino, 1977; Cooperative Research Project on Agricultural Technology in Latin America, 1978, Cited by Wheat et al, 1983). According to Wheat et al, 1983, this denotes a changing perception of the role and effects of technology on the economic organization of society (Valdés, Scobie and Dillon, 1979; Gilbert, Norman and Winch, 1980; Wheat, Piñeiro and Chapman, 1981; Norman, 1980).

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

Lindarte (1997) also emphasizes the importance of recognizing the participation of different stakeholders involved in the process of technology generation. This is evident in the incorporation of private sector representatives and those from producers' organizations, Foundations and NGOs in the national research institutes, and also in the development of technology transfer programs such as *Cambio Rural* implemented by INTA in Argentina and other experiences implemented by EMBRAPA in Brazil and INIA in Chile (Morales, Cetrangolo, see others). In the case of Mexico (See Boxes 2.1.3.1, 2.1.3.2 and 2.1.3.3.). Lindarte (1997), notes that the limitations of this new approach are due to the lack of new and appropriate forms of social and cultural integration.

2.3.3 Policies

The performance of the 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, agriculture has played a relatively important role in production and in the generation of employment. Traditionally, it is also one of the sectors with the highest levels of poverty. For this reason, during the second half of the twentieth century, production, rural development and food self-sufficiency policies received special attention in 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 necessary physical infrastructure to support production and marketing. Governments also implemented policies on land 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 attached a certain importance to the generation and transfer of technology, strengthening the human and financial resources of specialized public institutions and paving the way for the creation of the NARIs. In some of the larger countries, the activities undertaken by these institutions and the favorable policy context played an important role in boosting productivity and agricultural production during 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.

There is ample evidence 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' income is by increasing the productivity of the land (Dias Avila et al., 2006). Similarly, most of the studies carried out in the Region, and in other areas, show that the rates of return on investments in agricultural research and development are extremely high (Alston et al, 2000; Avila et al, 2002,). Dias Avila et al., 2006 prepared a compilation of studies by different authors, which are included in Table 5 of the Annex.

Insert Table 5

Despite the abovementioned points, from the mid-1980s and especially during the 1990s, public investment in agricultural research and development in LAC declined. 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 the 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 Dias Avila et al (2006) note, the average growth of production for the main agricultural commodities was 3.05% annually in the 1960s and 1970s, and was reduced to 1.98% in the last two decades. But there are significant differences in the growth patterns of the different sub-LAC Regions: 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 (See Table 6 of the Annex).

Insert Table 6

When we analyze public investment in agricultural research and development in most of the LAC countries, it is clear that this was always very low compared with international standards, a situation that has worsened in the last decades. Thus, while the ratio between research spending and GDP for the period 1970-75 in the industrialized countries was of the order of

2.5%, the average for LAC was 0.65%; and in LAC that ratio fell to 0.50% during the period 1975-85 and to a range of 0.10 to 0.40% during the period 1985-95 (Ardila, 1997).

However, the aforementioned reductions in public investment in agricultural research have not been homogeneous in the Region. At present only a few countries (Brazil, Mexico, Argentina, Colombia and Venezuela) have large organizations that have maintained significant levels of investment. Hertford (2005) notes that in the mid-nineties more than half the investment in agricultural research corresponded to Brazil; and, if Mexico is added, both countries accounted for nearly two-thirds of LAC's total public investment in agricultural research and development, estimated at around 2,000 million dollars. The other three countries listed each spent more than 100 million dollars annually. However, in most other countries, public investment was very low and in recent years has declined to such an extent that it has resulted in the serious erosion and decline of the installed capacity of the official specialized institutions. Moreover, these have not been replaced by equivalent investments in the private sector[28].

In the least developed countries, the lack of public investment in agricultural research constitutes a major threat, in terms of responding to 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, so there is 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 populations.

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 changes 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 the NARIs, and this 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.

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 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

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

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 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).

It is also necessary to establish new regulatory frameworks on issues such as intellectual property legislation for seeds, genes and other appropriable innovations, in order to encourage private investment in agricultural research and development, and also to properly regulate the appropriation of the benefits in the case of shared initiatives involving public institutions and private firms (based on the notion of public goods and private goods).

The restrictions imposed on public budgets for AKST in the last 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 the free trade policies stemming from the reforms implemented by the countries of the Region, 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 multilateral and regional trade negotiations is copious and will mean new challenges for efforts to improve the competitiveness of agriculture in the region.

It is important to emphasize that the decline in public investment in AKST in LAC has coincided with new demands associated with sustainable rural development, which have traditionally been assigned a low priority on 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 use of genetic and biodiversity resources; c) development of human resources and social capital as strategic assets for competitiveness and progress; d) empowerment of civil society; e) proper attention to aspects related to gender and ethnicity; f) the incorporation of new advanced technologies that require substantive changes in the institutional structure and organization, such as Biotechnology, Genetic Engineering, Nanotechnology, Telecommunications and Informatics, among others; g) emerging new topics or issues that may have significant impacts on production and on future food demand, e.g. biofuels; h) new demands linked to product differentiation and value added, etc.

In synthesis, the AKST system of LAC faces a paradox: at the same time that the reforms in macroeconomic, trade and sectoral policies (including cuts in public investment in research and development) implemented in the last two decades have created a less favorable context for promoting a sustained growth in the value of agrifood production, we see a decline in the system's capacity to generate the innovations required to address traditional demands and the new challenges and requirements related to the conservation of natural resources and the environment, conservation and use of genetic and biodiversity resources, use of new cutting-edge technologies, the development of human resources and social capital, the empowerment of civil society, the incorporation of issues such as gender and different ethnic groups and the inclusion of non-traditional products with value added. We are witnessing a political, fiscal and institutional crisis of the State in most LAC countries, which imposes constraints and at the same time implies challenges to implement changes in the strategies, structure, management models and in the institutional insertion of the NARIs into the global AKST system, as required by the new context (Martinez Nogueira, 1997; Machado Allison, 1997).

2.3.4 Markets

The 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 the world food trade.

These factors, together with growing demand for differentiated products, with more services and value added, plus other characteristics such as more natural-ecological products, identification of origin and processes etc., imply modifications in the traditional demand for innovations from the AKST system. It is not enough to have an approach centered on the product, or the producer and/or the use of technologies to increase productivity and the food supply; every day brings more demands, also new opportunities to build competitiveness through value added, based on a proper understanding of demand and supplying products and services in line with consumer preferences. For this reason, AKST agendas and institutional management models must incorporate the market and other links of the agroindustrial chains, particularly the stakeholders who play a leading role in the distribution of food.

Until now, most AKST 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 for this, and therefore 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 must 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.

2.3.5 Lessons and challenges

2.4 Focus of research

2.4.1 Clients of AKST

Different socio-economic segments determine the focus of research in relation to their own needs and aspirations. In this regard, research has been carried out to assess the importance of different economic-social segments as target groups or beneficiaries of agricultural research, for the public R&D sector.

Castro (et al, 2005) analyzed the situation in six Latin American countries (Brazil, Cuba, Mexico, Panama, Venezuela and Peru). The study showed that there is general agreement in the region on the relatively low importance of subsistence farmers and small family producers, in relation to medium and large producers. This work offers a partial perspective, since only researchers were consulted, and therefore it does not reflect the points of view of other sectors of society. The work by Wheat and Kaimowitz, (1994) carried out for Latin America and the Caribbean confirms that the benefits derived from the agricultural research undertaken by the NARIs were mainly directed towards the larger, market-oriented farmers located in favorable ecological zones (Schuh 1992, De Janvry 1991, cited by Wheat and Kaimowitz, 1994).

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

The study by Castro (et al, 2005) also found that the segment of non-governmental organizations was considered to be of little importance as clients of agricultural research in Venezuela and in Peru; of medium importance in Panama, Mexico and Brazil; and of high importance for Cuba. For their part Wheat and Kaimowitz, (1994) noted the importance of NGO’s in relation to the development of sustainable technologies, which involves highlighting local demands that are difficult to identify through the traditional approach of technology transfer.

This underscores the need to decentralize research activities through the training of local non-governmental organizations, extension agencies and farmers in order to carry out simple adaptive research (Chambers et al. 1989, cited by Wheat and Kaimowitz, 1994).

Wholesalers and retailers are evaluated as important clients in Cuba, of low importance in Venezuela and of medium to low importance in the rest of the countries. Consumers are assessed as important or very important in Brazil and Cuba and of medium importance in Panama and Peru. Input suppliers and agroindustry are considered important clients in Cuba, but far less important in Peru and in Panama.

New priority clients are also mentioned, such as public policymakers and agroindustry. The researchers’ vision includes recent advances in the concept of agricultural research as a task that affects and impacts society as a whole (in this case represented by consumers) and is not only directed at rural producers.

The growing importance of agroindustry as a *client* offers a vision of agricultural research linked to production chains and to the development of processes technology capable of adding value to primary agricultural production and competitiveness of those chains. This concept is more recent in the region and replaces the view of agricultural research linked exclusively to primary production, which prevailed until the 1980s. The trends of demand imply greater specialization and increased demand for technology products for a broader typology of producers (Castro, et al 2005; Wheat and Kaimowitz, 1994, Lindarte 1990).

Finally, the emerging vision (in the nineties) that attaches greater importance to clients such as policymakers, input providers, wholesalers and retailers suggests a more politically-influenced organization of research, and a search for partners to resolve the shortage of financial resources, (Castro, et al 2005; Wheat and Kaimowitz, 1994, Cetrangolo 1993). Table 8 contains the results for the segments analyzed by Castro et al (2005).

Insert Table 8

Historically agricultural research organizations have found it difficult to determine the focus of research for each socioeconomic segment, since this involves many complex dimensions, among them political, scientific, technological, environmental, economic, management aspects (Castro et al, 2005).

As the last column of Table 7 shows, the knowledge available in organizations regarding clients' demands is limited and directed at particular segments of the clientele (Castro et al., 2004).

With the exception of knowledge regarding the demands of medium and large producers, which was evaluated as medium to high, research organizations know little about the demands of other segments, such as subsistence farmers, indigenous communities and small family farmers linked to production chains. In addition, those segments were considered to be of limited importance to agricultural research.

The segments of consumers, agroindustry, wholesalers and retailers were assessed as being of great importance for the performance of agribusiness, but their demands are only moderately well known to research organizations.

The assessments were very uniform in the six countries, with few discrepancies. Only in two variables were there reasonable differences in the evaluations: in the variable 'Public policymakers' there were differences in the views of experts from Cuba and Peru, and in the variable 'non-governmental bodies', with diverging assessments by Cuba and Venezuela.

2.4.2 Research styles

Research activities may be geared to different purposes, which are commonly associated with different research styles: basic, applied, adaptive and strategic (the definitions for each one are outlined in Table 9).

Insert Table 9

Studies that assess current research efforts by the public and private sectors of agricultural research in each type or style of research show that these organizations 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 the Latin American countries (Rice 1971, cited by Wheat and Kaimowitz, 1994).

The role of the private sector was limited to supplying seeds and agrochemicals, and 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; Moura, 1990), cited by 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 the effort in basic and strategic research, which offered a possible development niche for public research, in the face of competition from private organizations with more resources and better working conditions (Castro, et al 2005).

At the same time, the private sector became more interested in technological development with the advent of deregulation, economic liberalization, the regional economic integration processes and the growing recognition of intellectual property rights related to genetic material and other agricultural inputs (Wheat 1981, Wheat and Kaimowitz, 1994).

With regard to strategic research initiatives, according to Wheat and Kaimowitz, (1994) efforts that do not have a short-term commercial application require direct participation by the public sector. According to Castro, et al (2005), at present the assessments on strategic research only represent approximately 10% of public research in the six countries analyzed.

Assessments of the current private agricultural research effort indicate a preferential orientation toward the areas of applied and adaptive research. The current basic research content did not exceed 10 percent and is expected to continue that way in the future. Strategic research follows a similar pattern, with a little more private effort and small changes expected in the future (Castro, et al 2005).

Applied research is currently the province of the private sector, and will continue to be so, according to evaluations by experts. It varied from 30% in the past to 45% at present, according to the assessments (Castro, et al 2005).

The differences in the country assessments are not very pronounced, and rarely exceed 10 percent, in terms of comparing the variables between different countries. The figures for basic research almost coincide. We observe a 15 percent difference between Brazil and Peru in the current applied research effort and of 10 percent in the assessment of future effort. The differences in the assessments related to adaptive and strategic research do not exceed 10 percent at present. Table 10 contains a summary of the results.

Insert Table 10

2.4.3 Priority production processes

Agricultural research may also be directed at developing processes for use in agriculture. Table 11 shows the results of an assessment of the current importance and dominion of knowledge in the processes carried out by public agricultural research institutions in Latin America and Caribbean, based on assessments by regional experts in this field.

Insert Table 11

Only two processes were classified as being of low importance at present: the development of products adapted to specific groups of consumers and agricultural processes related to biosafety. Three processes were considered to be of high importance at present: high productivity, increased resistance to pests and diseases and biological control of pests and diseases. All the rest of the variables shown in Table 11 were considered to be of medium importance for current public agricultural research.

The assessment of the current dominion of processes, shown in Table 11, is highly relevant to indicate possible strategic targets for institutional innovation in research organizations. However, it should be reiterated that the study methodology only reflects the opinion of researchers.

It is possible that those two assessment indicators - showing the high historical importance and medium dominion of research focused on factors that affect production efficiency and, at the same time, a low importance and low dominion for research approaches more focused on scientific topics and social and environmental aspects - may indicate that agricultural research finds itself at a crossroads. The well-trodden paths towards the search for efficiency in production that have sustained research in the last fifty years, have been exhausted, but the new paths are not yet known and research organizations do not have sufficient capacity to pursue these.

The national institutes have taken several steps to identify the technology demands of users and define their research priorities accordingly, mainly by 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)

Recent experiences (Castro et al, 2005) also show 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, provide a framework and nourish discussion by the scientists themselves regarding the relative importance and probabilities of success of different lines of research;

b) institutional mechanisms to facilitate effective links with technology users and to ensure that exert the necessary social oversight over decisions to prioritize and allocate resources;

c) a financial structure to articulate the needs identified with the research initiatives.

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

2.4.4 Advancement of knowledge: Biotechnology

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

The private sector plays an active role in developing biotechnologies given that their economic results are appropriable. This fact will have major impacts on 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.

Castro, et al (2005) consider that the region’s use of scientific advances is uneven, with differences of emphasis among countries regarding the importance and dominion of biotechnology. There are countries with more experience in biotechnology, but this is mainly directed at increasing efficiency in plant and livestock production.

In assessing the current importance of possible biotechnology applications in agriculture and on the current dominion of the necessary knowledge for developing applications for the agricultural sector, it is clear that plant and animal production are the most valued applications of biotechnology. However, biomass, energy and bio-factories for producing industrial raw materials are applications prioritized by Cuba and Brazil.

The results of the experts' assessment show that the countries of the region assign very different degrees of importance to biotechnology, with Cuba, Brazil and Mexico assigning it far higher levels of priority than the rest of the countries.

Insert Figures 3 and 4

2.5 Financial resources and administration of the AKST system

2.5.1 Development and impact of investment in AKST

Most studies carried out in the Region and in other areas, show extremely high rates of return on investments in agricultural research and development (Alston et al, 2000; Avila et al, 2002, Dias Avila et al., 2006).

Despite this, from the mid-1980s 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 at reducing public spending and the deficit. These policies 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.[29]

2.5.2 Changes in approaches to mobilizing resources

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

The limited experience of these funding arrangements suggests that it is advantageous for the NARIs to have an independent financing system, in which funds are assigned for specific purposes. This provides security regarding the amount of funding to be received and on its free availability during the budgetary year. Both these elements are essential for proper planning and encourage a careful use of the available resources that, if unused, remain at the disposal of the institution.

Governments have tended to assign AKST budgets in a global manner. A total annual amount was allocated, divided into partial payments, normally on a monthly basis. However, this periodicity was often not observed, especially for operating costs, which were sometimes disbursed in a random fashion. The allocation was supposed to cover: salaries, operating expenses, maintenance of infrastructure and equipment and investment

Given the aforementioned trend of declining governmental support to AKST, institutions are faced with shrinking and untimely budgets. Consequently, their effectiveness and efficiency are reduced, since they are forced to cover, first of all, the salary payroll, for which they must use part of the resources that are earmarked for operations, maintenance and investment. For this reason, it is common to find ratios of 90:10:0 - salaries: operation/maintenance: investment, while experts consider that this ratio should be 50:35:15.

Consequently, AKST institutions have been forced to seek external resources to reduce their budget deficit. This has led to a strategy to diversify their funding sources, through different projects, and to identify other financial agents (multilateral banks, regional research funds, international cooperation), which is not necessarily a solution for AKST institutions with a budget deficit, with reduced capacity to cover their essential payroll, operation and maintenance expenses.

Recently, the national AKST institutes have made major efforts to adapt to the new conditions and in general have managed to resolve their budgetary situation and, in some cases, improve it 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, technological services and solutions.

Similarly, these organizations are taking the first steps to harness the benefits derived from the intellectual property of their own technology packages. This implies developing new regulatory frameworks on issues such as intellectual property legislation for seeds, genes and other appropriable innovations, which encourage private investment in agricultural R&D, and also 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 1980s and the effects of globalization have forced governments to rethink the administration of science and technology. In the 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,

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[29] These policy changes to support agriculture in LAC also coincided with the start of a review of subsidies and food

subsidies for innovation activities in companies and the formation of public-private consortia (Echeverria 1998; Huffman and Just 1999; Branscom and Florida 1999; OCDE 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 fulfilled.

Competitive funds have been used in LAC by the World Bank and the Inter-American Development Bank within 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 institutional capacity in AKST in some regions of LAC, it is essential to promote inter-institutional AKST projects, in order 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 articulate the demands or needs of users with research activities, b) enhancing the definition of the project's objectives and methodology, thereby helping to achieve the expected results, 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 of resource allocation, monitoring and supervision of their use.

For institutions that finance part of their research projects through competitive funds, this entails increased administrative costs since they require several systems of control and monitoring, each following the rules of the specific fund. Similarly, the fact that special resources granted for

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self-sufficiency policies in developed countries, especially the Common Agricultural Policy.

research are subject to different criteria from those of the institution that receives them, tends to alter previously established research priorities, and also creates asymmetries in the flow of information between researchers and the available resources.

One complementary financing mechanism, independent from national budget assignations, is to levy rates or charges on the first-time sale of some 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 to promote exports.

Some AKST 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 in the measure that there is surplus capacity and the income can help to finance research activities; but, aside from exceptional situations, it would be recommendable to use that surplus capacity for research, to avoid sidetracking institutions from their specific goals.

2.5.3 Support Institutions

It is important to mention the Foundations that have emerged as an initiative of the 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 the NARIs and the universities.

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

At the regional level, countries are being encouraged to cooperate on AKST projects of mutual interest. To support this strategy in LAC, FONTAGRO was created as a consortium to promote strategic agricultural research of regional interest, with the direct participation of the Latin American and Caribbean countries in setting priorities and in financing research projects. See Box 2.7.

Insert Box 2.7

2.5.4 Institutional administrative constraints

The efficacy and current relevance of AKST institutions is increasingly questionable. The lack of consistent political support, the ensuing weakness and randomness of public funding, institutional “obsolescence” in the face of the extraordinary changes in the economic context and the growing complexity of science, requires the AKST institutions of the LAC countries to embrace the challenges of development and modernization (Piñeiro and Wheat, 1983), including their management processes and links with users.

References on the development of the NARIs in LAC may be found in the analysis of the factors that have limited their performance according to the assessment by Nickel[30] in 1996; in a study on “The role of agricultural research” published as part of the idea – thesis on the “Globalization of Science”; the former International Service for National Agricultural Research, (ISNAR) which now forms part of the International Food Policy Research Institute (IFPRI), based in Washington, DC, one the International centers sponsored by the Consultative Group for International Agricultural Research (CGIAR),

According to Nickel, the AKST systems in LAC have varied greatly in size, organizational structure, effectiveness and level of support, each one being different, with very particular characteristics, depending on their institutional, cultural and political environment. He also notes that a number of generic problems were identified, though he recognizes that not all these problems affect all institutions equally, but are fairly “common”, and can therefore serve as a reference or guide to the problems to consider to support the transformation and development of AKST systems in LAC.

The main problems facing the majority of LAC’s AKST systems cannot be attributed to the quality of their human resources, since there are many cases of researchers from LAC countries who work at the International Centers.

The cultural and political environment is influenced by Central Government, with its vision, norms and rules of procedure, which are sometimes not suited to the tasks of research. To overcome this situation, various models of semi-autonomous institutions have been created, under the premise that more autonomous institutions would be free of political influence in selecting and recruiting their human resources, and would have more flexibility in setting their own institutional policies and administrative rules.

However, either because of the nature of their legal constitutions or because of subsequent administrative decisions by the Central Government, most NARIs have operated with the administrative restrictions and the 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,

[30] Bonte-Friedheim, C. and K. Sheridan (Eds). 1996. The Globalization of Science. The Place of Agricultural Research. The Hague. International Service for National Agricultural Research (ISNAR). The Netherlands.

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; however, from the beginning it was endowed with a Trust Fund that allowed for flexible and timely financing and operational autonomy. However, this mechanism was canceled in 1982, as part of a general government instruction to cancel public Trust Funds, and therefore the institute became subject to the regulations of the central administration, unsuited to the functions of research. Nowadays, however, National Public Research Centers, such as INIFAP, have a Trust Fund, an instrument that contributes to the flexible and timely financing of their research activities.

Nickel argues that no institution that is largely dependent on public funds can be totally autonomous.”

For this reason he suggests that these institutions be considered “semi-autonomous”, rather than “autonomous”. However, there are some promising initiatives; recent reforms, for example in Britain and Australia, have tried to resolve this problem by granting research institutions a legal framework that gives them the right to be governed under private law.

This legal framework allows 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 association with the private sector, royalty contracts and/or a share in income derived from intellectual property etc.). Examples of this trend in the region include the INIA in Chile and CORPOICA in Colombia (Piñeiro, 2003). In response to this problem, Mexican lawmakers took the initiative of creating an *ad hoc* legal definition for public research institutions.

There has been a growing tendency among the NARIs to include representatives of the leading private sector trade organizations on their governing bodies at the national and regional levels. The INTA of Argentina has a long history in this regard, since half the members of its Governing Council are representatives of producers’ organizations. Among the more interesting examples of this we can mention the INIA of Uruguay, the Colombian Agrarian Research Corporation (CORPOICA) and INIFAP of Mexico. However, sometimes the composition and/or action of the government body can be improved, as in the case of INIFAP in Mexico, mentioned by Piñeiro et al, 2003.

2.5.5 Lessons and challenges

2.6 Effectiveness and impact of AKST

2.6.1 On production systems

2.6.1.1 Traditional indigenous and *campesino* system

A total of 15 agricultural production systems have been identified in Latin America and the Caribbean (shown in Figure 5), namely: 1) Irrigated; 2) Forest-based; 3) Coastal Plantation and Mixed; 4) Intensive Mixed; 5) Cereals-Livestock Mixed; 6) Moist Temperate Mixed Forest-Livestock; 7). Maize-Beans Mesoamerica; 8) Intensive Highland Mixed (northern Andes; 9) Extensive Mixed Llanos and Cerrados; 10) Temperate Mixed Pampas; 11) Dryland Mixed; 12) Extensive Dryland Mixed (Gran Chaco); 13) High Altitude Mixed (Central Andes); 14) Pastoral; 15) Sparse forests (Dixon, et *al*., 2001).

Insert Figure 5

In analyzing agricultural research related to LAC's production systems, we must recognize that it has lacked a systemic approach. Agricultural problems have been addressed in a marginal and reductionist way, ignoring the complex dynamics of rural production areas (Arango, *et al*., 1999: 14- 15), particularly the traditional/indigenous and agroecological production systems (Arango, *et a*l., 1999:14; OAC & IICA, 2006a; Martinez, *et al*., 2006; OAC & IICA; 2007b; Santamaria, *et a*l., 2005:34).

At the same time, declining budget allocations in the eighties and nineties, and the new demands and governmental commitments, prompted a shift from conventional production systems towards agroecological approaches, as a means to gain access to new national and international market niches.

New production systems based on high-yield species are also making headway: molecular engineering, biotechnology and the boom in transgenic crops, has generated a new AKST framework that has been well received in the Southern Cone countries, Colombia, Mexico and Cuba.

With respect to the traditional indigenous and campesino farming systems, AKST has focused on reproducing family production units and food self-sufficiency (Macias, 2002:47; De Armiño, 2002:76; Raigoza, *et al*., 2006:127); this system has historically been regarded as an obstacle to development, given the low political and organizational profile of its social stakeholders.

In the last two decades, the traditional campesino and Afro-American farming systems and the indigenous production systems in LAC have, in some cases, undergone a major transformation into alternative production enclaves (producing organic or "green" products, free of transgenic material, denomination of origin, ethnic products, raw materials for multinationals, among others), in response to the new global markets, using advanced technology and marketing strategies (online communications, networks of farmers and consumers of ecological products, dietetic products, natural pharmaceuticals and cosmetics). Recently, there has also been a move towards service sector, with the adoption of multi-activity systems (hiking trails, horse riding, photography, environmental education, ecological and/or alternative tourism (Naredo, 2006:19; Toledo, 1980) that respond to the new concerns of the international agendas in relation to forests, water, biodiversity, desertification, wetlands, gender perspective, intellectual property rights, precautionary principles, cyber-agriculture, fourth generation rights and exchange of *know-how*, among other issues.

At the same time, the Agroecological Production System emerges as an approach that is at odds with the practices and philosophy of conventional production systems. The AKST 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 services on different scales and intensities from governmental, non-governmental institutions and cooperation agencies.

In all efforts related to the study of production systems, the platforms of the Geographic Information Systems (GIS) have, to a greater or lesser degree, provided important support and an essential tool for the identification, delimitation and management of territories (Ofen, 2006:41; Echeverri, 2000:173.). The preparation of biodiversity inventories, assessments of population dynamics, efficient water management, renewable energy sources, especially biofuels, monitoring of pests and diseases, assessment of CO_2 sinks, survey of aquifers and ground waters, mapping of current and potential soil uses and modeling, are just some of the activities undertaken within the AKST context in LAC.

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 bases in 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 of these organizations have not yet been able to take full advantage of the potential that this progress may provide.

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

However different constraints 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 who 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. These authors note that in a period of five years, RR soy accounted for 95 percent of the total soy crops planted in the country.

Most countries of the Region still face the 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 of GMOs and even the production of biotechnology innovations.

In the aforementioned study by Castro et al 2005, basic and applied research in nanotechnology was assessed as being of lowest current strategic importance, for both sectors, indicating that in recent years, the evaluators consider the advances and impacts of these new frontiers of knowledge to be of medium to low level 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 be noted that when broken down by country, the assessment showed different results between countries, with Brazil’s assessments generally being higher than those of the rest of the countries (Table 11). Biotechnology research achieved higher levels of relative importance than nanotechnology, in all countries. This may possibly be taken as an indicator that nanotechnology is just beginning to become known in LAC and consequently there are few impacts to assess, and limited knowledge of its potential.

In general, Latin America’s innovation systems have not been developed in a planned way and therefore the produced innovations have not been well integrated with the final users. This rests efficiency to the entire process.

With regard to the regulatory bias of Science and Technology, there are asymmetries between the knowledge of users, producers and generators of innovation. In Latin America we repeatedly find that the new technologies are beyond the reach of the very populations for whom they were generated, for different reasons. This problem, in turn, is linked with another issue mentioned, i.e. relations between innovation systems due to the 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 a highly 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. In this context, it should be emphasized that numerous transnational corporations based in MERCOSUR delegate their innovation activities to the parent companies. Although we observe a growing trend in relation to cooperation for research, the technological divide between the Latin American countries and industrialized nations is still very wide.

According to Lundvall (1985), innovation stems from a convergence of technical opportunities and user-demand, this suggests the importance of citizens' participation in research processes, an issue that should be considered by AKST 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 the consumers

There are approximately 520 million consumers in Latin America and the Caribbean. This population grew significantly in the period between 1985 and 2000, by around 120 million people (401 million in 1985, 441 million in 1990, 481 million in 1995 and 520 million in 2000), according to figures from the Department of Economic and Social Affairs of the United Nations Secretariat, disseminated in the study World Population Prospects, 2002, Revision and Word Urbanization Prospects the 2001 and cited by Peres 2005, p67. These consumers, located both in urban and rural areas, represent a plethora of demands for goods and services.

The segmentation of consumers leads to the generation of supply-side production alternatives. Over time, these develop into different knowledge, science and agricultural technology initiatives and, 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).

It is also important to note the low importance and dominion of consumer-oriented processes. However, even in cases where end consumers are not the main priority of research, they indirectly benefit from the other priorities established, for example the reduction in food prices, as shown in the example presented in Figure 6.

In the period illustrated, basic food prices for the population decreased by almost 70 per cent. This occurred due to a decrease in production costs resulting from increases in productivity obtained as a result of agricultural research efforts. Consequently, the end consumers benefited, even though research priorities were more concerned with the performance and productivity of farms.

At the same time, however, there are specific cases where advances achieved by science and agricultural technology could cause damage and losses, for example diseases such as mad cow and bird flu, and Genetically Modified Organisms (GMOs), which have led to genetic erosion, climate change, soil contamination, the creation of super-weeds and insects, new viruses and bacteria capable of causing diseases, the propagation of genes that cause allergies and resistance to antibiotics and a new framework of technological neo-dependence for Latin America's rural sector, (Beck, 1988:204; Sartori & Mazzoleni, 2005:214; Duarte, et al., 2006:3).

At the socio-political level, Latin American and Caribbean there is a danger that farmers could see their incomes reduced due to the low prices of raw materials, which are being substituted by others produced by large national companies and biotechnology corporations. In addition, consumers might be obliged to consume products that do not comply with the agreement of the Cartagena Protocol on Biosafety. But even more worrying is the discourse of some AKST leaders associated with transgenic foods, which fails to address or help to relieve hunger among a large proportion of food consumers who are on the threshold of extreme poverty, especially given the fact that " in the developing world hunger, and severe malnutrition have a socio-political origin; they are the result of poverty and inequality, and are not due to food scarcity ", (Altieri, 1999; Hobbelink, s.f.), cited by (Amador, 2006:9).

Within this analytical framework, is important to emphasize that new spaces for discussion and feedback are emerging between the so-called sector of "responsible consumers" 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.

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 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, although the working conditions remain precarious (Farah, 2004).

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

2.6.4 On the competitiveness of chains, conglomerates and territorial development.

The AKST system has had a very significant impact on the competitiveness of production chains during 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 mentioned previously, the system did not begin to address the production chains as a whole, but rather specific projects, due to the region's considerable technological backwardness until the mid twentieth century.

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

Although agricultural R&D began to be implemented through 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 to improve 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 the production chains and their stakeholders, though the concept is being incorporated mainly in the more competitive chains, leaving aside the weaker ones or those whose stakeholders have fewer opportunities.

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, the non-governmental organizations committed to social and territorial development and certain specific institutions play an important role in promoting better conditions for local populations, within a framework of respect for their culture (Feito, 2005).

2.6.5 Lessons and challenges

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