Agricultural

Biotechnology in the Americas

economic benefits, capacity, and policy options

Inter-American Institute for Cooperation on Agriculture

Agricultural Biotechnology in the Americas:

Economic Benefits, Capacity, and Policy Options[1]

Inter-American Institute for Cooperation on Agriculture

February 5, 2008

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This publication is also available in electronic (PDF) format from IICA's Web site at http://www.iica.int

Editorial coordination: Assefaw Tewolde, Ramón Lastra, Eduardo Rojas y Bryan Muñoz
Layout: Gabriela Wattson
Cover design: Karla Cruz
Printed: IICA Headquarters

Agricultural biotechnology in the Americas: economic benefits, capacity, and policy options / IICA – San José, C.R.: IICA, 2008.
40 p.; 21.5 cm x 28 cm

ISBN13: 978-92-9039-974-2
Published also in Spanish

1. Agriculture 2. Biotechnology 3. Transgenics 4. Agricultural research 5. Latin America 6. Caribbean I. IICA II. Title

AGRIS	DEWEY
F30	660.6

San José, Costa Rica
2008

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Executive summary

Agricultural Biotechnology in the Americas: Economic Benefits, Capacity, Risks, Opportunities, and Policy Options

Agricultural biotechnology has become an important area of scientific knowledge and of agricultural technologies over the past decades. Among developing country regions, LAC has been a leader in the application of biotechnology. This study discusses the past experience, present status, and near-term potential for LAC countries to access biotechnology science.

In 2006 the region included two of the world's top three genetically modified organism (GMO) growing countries (Argentina and Brazil), and accounted for 78% of the transgenic crop area in the developing world (James, 2006). The use of other biotechnology tools, including cellular biology techniques, marker-assisted selection, and molecular diagnosis of pests and diseases have diffused without controversy, but the advance of biotechnology has been highly uneven across countries. GMOs have been planted commercially in just seven of the region's 33 countries and the majority of the region's countries lack the scientific capacity to productively employ the tools of biotechnology.

In this study, a simple conceptual model of a complete scientific system is used to introduce basic, strategic and applied research, and technology delivery as key areas required for biotechnology to progress. Empirical indicators of research output, the maturity of regulatory structures, and the experience with establishing and implementing intellectual property norms are used to discuss the status of critical institutions supporting biotechnology. Each country is placed in one of four classes based on empirical indicators of basic and applied agricultural research capacity.Issues related to private and public financing of biotechnology in the region are discussed.

Large inter-country differences in scientific capacity exist within the region. Brazil accounts for about 50% of total LAC agricultural research expenditures, employs 36% of all agricultural researchers, and generates 45% of basic and applied agricultural publications. Adding Argentina and Mexico to Brazil brings the shares of the three countries to 85% of agricultural research expenditures, 73% of scientists and nearly 80% of publications. The majority of LAC agricultural R&D systems are small. Twenty-five of the 32 LAC countries have less than 200 researchers.

Legislative action granting regulatory powers is the first step towards realization of a functioning biosafety system. The majority of countries have taken this step, ten have carried out biosafety field trials, and seven have approved a GMO event for commercial use. Multinationals have dominated the execution of field trials, conducting 82% of the trials between 2000-2007 in those countries for which a breakdown is available. The public sector has significant experience conducting biosafety field trials only in Mexico and Argentina. Universities have conducted just 13 trials in all of LAC during the period.

LAC countries are aware of the IP issues involved with biotechnology, but all are struggling with the complexity of passing legislation that meets national needs while conforming to international obligations. The ability of countries to enforce IPR rules will be as important as the actual legislation for IPR protection to be effective. The difficulty in protecting intellectual property rights over GMOs has been a serious concern for the private sector in nearly all developing countries. To date the private sector's experience with generating revenue from the sale of GMOs in developing countries has not been encouraging. A rough estimate is that nearly 90% of the area currently sown to GMOs in developing countries is affected by significant levels of seed piracy. The loss of revenue has been most severe in the Southern Cone of South America, where little revenue has been collected from the planting of a cumulative total of nearly 120 million ha of RR soybeans. The most consistent collection of fees has been on the sale of hybrid maize seed, where it appears that piracy has been a relatively minor problem.

The difficulty in protecting intellectual property has been a serious concern for the private sector in nearly all developing countries. To date nearly 90% of the area currently sown to GMOs in developing countries is affected by significant levels of seed piracy. The loss of revenue has been most severe in the Southern Cone of South America, where little revenue has been collected from the planting of a cumulative total of nearly 120 million ha of RR soybeans. Largely due to difference in the processing harvested seed for replanting, technology fees have been collected on a greater proportion of maize and cotton area than on soybean area. In the face of difficulties in collecting revenues at the point of sale of soybean seed, Monsanto has proposed a royalty system where fees are collected at the point sale of the harvested grain in Paraguay, Argentina and Brazil.

Further dissemination of biotechnology will require increased research investments by the public and private sectors, improved public sector scientific capacity to perform the biosafety assessment, increased ability to offer intellectual property protection to the private sector and a degree of political and social willingness to accept the biotechnology. The many small countries of the hemisphere are severely disadvantaged with respect to their ability to attract needed investments in their seed markets, and with marshalling the scientific talent needed to staff a national biosafety committee.

GMO diffusion has been anything but predictable so far. A decade ago, few would have foreseen that there would be just two commercially successful GMO traits in 2007. Research is underway to improve food maize, wheat, rice, tubers and many vegetable crops, but it is likely to be several years before these events make it to the field in LAC. Biotechnology holds immense potential to address many of the most difficult production problems that plague the region's farmers, but while the science of biotechnology is advancing rapidly, the institutional capacity to deliver biotechnology faces significant challenges.

1 Introduction and Purpose of this study

Increased globalization and increased global investments in agricultural technology in other countries make it imperative that Latin American and Caribbean (LAC) countries renew their efforts to improve productivity. Agricultural biotechnology is an important new area of scientific knowledge and applied technologies that has become more prominent in world agricultural over the past decades. Nonetheless, while the pace of scientific discovery in biotechnology research has been impressive by any standard, the application of the new science to improve agricultural productivity has lagged in most countries of the region (Trigo, et al., 2002).

The pace and direction of the evolution of biotechnology applications, particularly of transgenics, has been unpredictable in all parts of the world, and nowhere has it been more unpredictable than in LAC. The vast potential for biotechnology stands in stark contrast to the modest impact that it has had on agriculture in the region to date. In all instances, the transgenic applications deployed in the region have been temperate crop events developed in the US that have been adapted for use in the region. It is clear that the region remains far from taking full advantage of the potential benefits from biotechnology, and a clear strategy for overcoming the obstacles has yet to be elaborated.

The region is a study in contrasts. The use of cellular biology techniques such as plant propagation, tissue culture, genetic markers, marker-assisted and gene-assisted selection, and molecular diagnosis of pests and diseases have diffused widely and without controversy. On the other hand, the use of genetically modified organisms (GMOs) remains controversial. In 2006 the region included two of the world's top three GMO growing countries (Argentina and Brazil), and accounted for 78% of the transgenic crop area in the developing world (James, 2006). The rate of area expansion of GMO technology has been rapid when compared to nearly any previous agricultural innovation, but this exists alongside disappointment with the limited geographic reach and product line scope of transgenic technology (Traxler, 2005). Furthermore, all GMOs in LAC are the result of technology spillovers from the US commercial seed market, and just two traits and three major commercial crops have been commercially adopted. To date no commercial GMO applications developed specifically to address problems of LAC agriculture have been commercialized. Progress in the use of biotechnology for animal agriculture has been even more modest than for crops.

This study discusses the past experience, present status, and near-term potential for LAC countries to access biotechnology science. A simple conceptual model of a complete scientific system is presented and discussed. Empirical indicators of research capacity will be presented for each country in the region. Issues of related to financing the spread of biotechnology in the region will then be discussed. Other country characteristics are also critical for biotechnology to progress, principal among these are legal and regulatory norms. Information on these aspects will also be presented. From this analysis a broad grouping of countries with similar capacities and societal characteristics will emerge.

2 The impact of transgenic technologies in Latin America

This section reviews the evidence on economic benefits and rates of return to GMOs in Latin America. Other recent papers have reviewed the literature on farm level benefits in all developing countries (Brookes and Barfoot, 2005, Qaim and Matuschke, 2005, Raney, 2006). We present evidence on the size of economic benefits in LAC and on how the benefits have been shared among industry, farmers, and consumers. Some data on the effect of GMO adoption on pesticide use will also be presented.

GMOs have been legally grown in a seven LAC countries since 1996 (Table 1). Latin America has 78% of the total DC area, largely due to the spread of herbicide tolerant (HT) soybeans in Argentina, Brazil and Paraguay. All GMO area is planted to HT, Bt, or stacked (both HT and Bt genes) varieties of soybean, yellow maize or cotton. This review has uncovered published benefit estimates of impact for eight developing country cases, four of which occur in Latin America: cotton, maize and soybeans in Argentina, and cotton in Mexico.

Herbicide tolerant soybeans

RoundupReady (RR) soybeans were commercially released in the Argentina and the United States in 1996. The sale and use of RR technology is protected in the US through patents and sales contract with farmers, but neither form of intellectual property protection is used in Argentina. Argentine farmers are also legally allowed to use farm-saved seeds. Thus in Argentina, RR soybeans are widely available from black market sources at little or no premium over conventional varieties. By 2003 about 98 percent of the Argentine soybean area was cultivated with RR varieties (Chudnovsky, 2005).

Table 1:
GMO cropped area in LAC, by country, 2006

Country	2006 GMO area (000 ha)	Crops planted commercially
Argentina	18,000	Cotton, soy, maize
Brazil	11,500	Soy, cotton
Paraguay	2,000	Soy
Uruguay	400	Soy, maize
Mexico	60	Cotton, soy
Colombia	30	Cotton, maize, carnation
Honduras	2	Maize

Source: (James, 2006)

Yields of RR soybeans are not significantly different from yields of conventional soybeans in either the United States or Argentina. It is the reduced herbicide and tillage expenses that generate the farm level benefits of RR soybeans. Many farmers switched to low-till or even no-till cultivation practices after adoption of RR soybeans and machinery and labor costs are also lower due to the reduced time needed for harvesting (Qaim and Traxler). In Argentina total variable cost of production is about eight percent ($21 per hectare) lower for RR soybeans than for a conventional crop.

The global welfare effects of the spread of RR soybeans have been analyzed in several studies (Falck-Zepeda, et al., 2000, Price, et al., 2003, Sobolevsky, et al., 2005) but only (Qaim and Traxler, 2005) and (Trigo and Cap, 2003) explicitly model the diffusion of the technology in Argentina.

Qaim and Traxler estimate that in 2001, RR soybeans created surplus of more than $1.2 billion, or about 4 percent of the value of the world soybean crop at the global level. The largest share of these overall benefits went to soybean consumers, who gained $652 million (53 percent of total benefits) due to lower prices. Soybean producers received net benefits of $158 million (13 percent), and biotechnology and seed firms received $421 million (34 percent) as technology revenue[2]. Soybean producers in countries where RR technology was not available faced losses of $291 million in 2001 due to the induced decline of about 2 percent ($4.06/ mt) in world market prices[3]. This underlines that national restrictions to GM technology access can bring about considerable taxation of the domestic farm sector. A case in point is Brazil, the second largest soybean producer in the world. Farm level benefits in Brazil could be similar to those in Argentina (Paarlberg, 2003), yet, due to a protracted biosafety process and uncertainty with respect to legal responsibilities, RR soybeans were not officially approved for commercialization until 2005.

Trigo and Cap estimate that accumulated RR soybean benefits in Argentina from 1996 until the year 2001 were approximately $5.2 billion, with nearly $2 billion occurring in 2001. A number of reasons explain the much higher benefit estimate when compared to Qaim and Traxler. Trigo and Cap attribute a $1.95 billion increase in farm profit due to soybean area expansion to RR soybean adoption[4]. They also include $365 in increased profit accruing to firms selling glyphosate. Overall, Trigo and Cap estimate that 87% of overall benefits from HT soybeans in Argentina accrued to farmers, 9% to sellers of glyphosate and 4% to the seed industry.

HT soybeans had a strong effect on tillage practices and on chemical herbicide use. Glyphosate substitutes for a number of other products, with the result that per hectare herbicide expenditures declined in Argentina even though the average number of herbicide applications and total herbicide use per hectare increased. Herbicides differ in their mode of action, duration of residual activity, and toxicity, so an increase in total herbicide amounts does not inevitably entail negative environmental effects. Glyphosate has essentially no residual activity and is rapidly decomposed to organic components by microorganisms in the soil. According to the international classification

2. Gross technology revenues are used as a measure of monopoly rent. No research, marketing, or administration costs are deducted. If we assume, for example, that these costs amount to 33% of technology fee revenues, the monopoly rent would fall to around $280 million (26% of total surplus).
3. Sobolevsky, et al. show comparatively small producer surplus effects for South America in 2000. In their regional approach the gains for farmers in Argentina are offset by losses to Brazilian producers.
4. The model used by Qaim and Traxler calculates ceterus paribus area expansion induced by the new technology based on assumed supply and demand elasticities. Trigo and Cap implicitly assume that all new soybean area is due to RR technology. The true area expansion due to RR technology is probably somewhere in between these two estimates.

of pesticides, glyphosate belongs to toxicity class IV, the lowest class for "practically non-toxic" pesticides (WHO, 1988). Adoption of RR soybeans led to a 93% decline in the use of herbicides belonging to toxicity classes II and III. There are no other herbicides used in soybeans which belong to toxicity class I. The major reason for the rise in the number of herbicide applications is the farmers' conversion to no-till practices that require pre-seeding chemical weed control. While 42 percent of the farmers in the sample used no-till for conventional soybeans, 80 percent of them use this practice on their RR plots[5]. On average, the technology reduced the number of tillage operations by one passage per field, reduced the number of machinery hours by 20 percent, and led to fuel savings of almost 10 liters per hectare (Qaim and Traxler).

Insect resistant cotton

Bt cotton is highly effective in controlling caterpillar pests such as pink bollworm (Pectinophora gossypiella) and cotton bollworm (Helicoverpa zea), and is partially effective in controlling tobacco budworm (Heliothis virescens) and fall armyworm (Spodoptera frugiperda). These Lepidoptera pests comprise a major pest control problem in many cotton-growing areas, but other cotton pests such at boll weevil are not susceptible to Bt and continue to require the use of chemical pesticides (James, 2002). As a result, the effect of the introduction of Bt cotton on pesticide usage varies from region to region depending on the local pest populations. (Qaim and Zilberman, 2003) argue that the relative performance of Bt cotton is likely to be highest when used by developing country small farmers because of the large pest losses suffered by these farmers. Bt cotton varieties have been rapidly accepted by farmers in areas where Lepidoptera pests are the primary pest problem, particularly when resistance to chemical pesticides is high. When boll weevils or other pest populations are high, farmers achieve coincidental control of the BBWC with the use of broad-spectrum chemicals, or pesticide mixtures, reducing the value of Bt control. Bt cotton adoption has been rapid in China and India, but low and restricted to large-scale farmers in Argentina due to the large price premium charged for transgenic seeds (Qaim and De Janvry, 2005). Adoption has varied widely across growing regions in Mexico because infestation levels vary widely (Traxler, et al., 2003).

Field level studies of the performance of Bt cotton have been completed in five developing countries: Mexico (Traxler et al., 2003), Argentina (Qaim and de Janvry, 2003), South Africa ((Bennett, et al., 2003, Gouse, et al., 2004, Gouse, et al., 2006, Ismael, et al., 2002, Kirsten and Grouse, 2003, Thirtle, et al., 2003), China (Pray et al., 2002), and India (Bennett, et al., 2004, Morse, et al., 2005, Qaim, 2003, Qaim, et al., 2006, Qaim and Zilberman, 2003). The studies have found that the benefits from biotechnology innovations have been widely shared among consumers, producers and industry. Yields were higher for Bt than conventional cotton n all five countries, while insecticide use fell by between 33% and 77% (Table 3). The average farmer share of total benefits was 65% and farmers received a larger share of benefits than industry in all countries except for Argentina. The change in consumer surplus was assumed to be zero in these studies because the increase in the supply of cotton relative to total world production is small.

Bt maize

Bt yellow maize was first planted in Argentina in 1998/99 and by 2004/05 had reached a total of approximately two million ha (60% of maize area) planted (Asociación Semilleros

5. RR technology has similarly increased adoption of reduced tillage and no-till in the US (DMR, 2001).

Argentinos). (Trigo, et al., 2002) simulate benefits from the adoption of Bt yellow maize. In their model they assume a five percent yield advantage of Bt maize over conventional varieties. They estimate total benefits of about $132 million in 2003. Of the total benefits, 79% accrue to industry and 21% to farmers. The output increase is assumed to not affect world prices, so the change in consumer surplus is zero. Total accumulated benefits for the 1998-2005 period were estimated at 481.7 million US dollars, distributed among farmers (43.19%), seed suppliers (41.14%) and the National Government (15.67%) (Trigo and Cap, 2006).

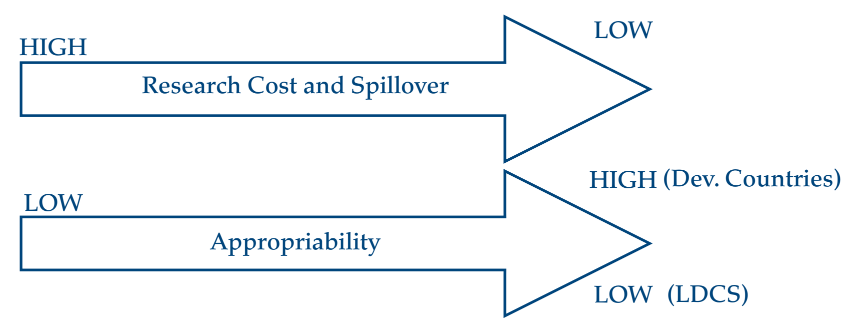
Benefits summary

Transgenic crop varieties have delivered large economic benefits to farmers in some areas of some LAC countries over the past eleven years. Although the environmental benefits have not been detailed here, a number of the studies report strongly positive environmental benefits from HT soybean and Bt cotton. Insecticide use on Bt cotton is significantly lower than on conventional varieties, and glyphosate has been substituted for more toxic and persistent herbicides in RR soybeans (Qaim and Traxler, 2005, Traxler, et al., 2003, Trigo and Cap, 2006). Furthermore, reduced tillage has accompanied RR soybeans and cotton in many cases. Negative environmental consequences, while meriting continued monitoring, have not been documented in any setting where transgenic crops have been deployed to date. Another important conclusion emerging from the studies is that although the transgenic crops have been delivered through the private, rather than the public sector, the benefits have been widely distributed among industry, farmers and final consumers. This suggests that the monopoly position engendered by intellectual property protection does not automatically lead to excessive industry profits, nor does it exclude adopting farmers from benefiting. Finally, the available evidence indicates that transgenic varieties are largely scale neutral with regard to both speed of adoption and per hectare benefits. This evidence is from Argentina (Qaim and De Janvry, 2005), Mexico (Traxler, et al., 2003) China (Pray, et al., 2001), South Africa (Bennett, et al., 2003, Gouse, et al., 2006) and India (Qaim, et al., 2006), and suggests that small farmers have had no more difficulty than larger farmers in adopting the new technologies.

3 The conceptual model for analyzing scientific and institutional capacity in the region

Key institutional capacities can be identified using the model of a system for generating and delivering biotechnology research represented in Figure 1. This simple model depicts the research process as starting with basic research activity, proceeding through strategic and applied research and resulting in the delivery of an improved technology. The diagram suggests a linear path from basic research to technology delivery, with generally reduced levels of research spillovers[6] and reduced research cost and sophistication as the research becomes embodied in farm technologies. Basic, and some strategic research, has worldwide applications, while applied research is often specific to a target market or agro climatic location.

Fig. 1: A simple model of biotechnology research



Worldwide applications to several crops		Specific markets and environments	
Basic Genetic Research	**Strategic Research**	**Applied Research**	**Technology Delivery**
Genomics, genetic engineering, Gene discovery	Genetic enhancement and Preservation	Conventional plant breeding, varietal development	Seed reproduction, marketing and distribution

Institutions with primary responsibility for research in each area:

Multination
US and European Universities
Super- NARS
(China, India, Brazil)

National Agricultural Research
Systems (NARS), LAC
Universities

Local Private
Farmer-to farmer seed exchange
NGOs

Critical Complementary Institutional Capacities

1. Regulatory capacity 2. Seed markets 3. Technology sharing arrangements (IPR)

6. The term spillover is used here to refer to research outputs (knowledge or technologies) that are accessed by those who have not funded the research, or who are not the intended clients of the research institution making the discovery.

Basic research findings are routinely published in international journals and presented at international conferences, facilitating knowledge spillovers. The ability to exclude others from benefiting from basic research discoveries, or the appropriability, is generally low. Historically scientists at universities and non-profit research institutes in developed countries have done the bulk of the world's basic research but scientists worldwide can easily use these findings to further their research. In recent years private sector firms have made large investments in upstream research as they search for strategic advantage in developing biotechnology products. A few developing countries have a modest basic science capacity, but none have a capacity on the scale of the larger developed countries[7].

The next two research stages in Figure 1 are broad categories where basic research discoveries are translated into technologies usable by farmers. Technology delivery is presented in the diagram to emphasize the importance of institutional development in that area. The process is illustrated as a linear, one-way process, but clearly there are many feedback loops that are not shown.

When considering research policy options, a key observation is that countries can benefit from advances in technology without possessing the indigenous capacity to perform all research functions in-country. In fact, research spillovers among countries are pervasive (Alston, 2002, Byerlee and Traxler, 2001, Traxler and Byerlee, 2001). Countries with broader research capacity can more readily access research and technology spillovers, but this does not suggest that investment in upstream research, including biotechnology research, is always appropriate from a financial standpoint. Research budgets are always limited, and in many cases free-riding on research spillovers will deliver a higher return on national research investments.

Argentina's and Paraguay's experience in accessing GMOs that were developed in the US vividly illustrates this point (Qaim and Traxler, 2005, Trigo and Cap, 2006). Public sector scientific discoveries were not a part of the technology development phase of currently employed GMOs. Public sector scientific contributions occurred far upstream, or were missing altogether. National plant breeding capacity and the institutional capacity to regulate GMOs did play key roles in delivering the GMOs that have generated such large benefits. Paraguay has even more limited capacity in all areas, as a result it lagged Argentina in accessing biotechnology but has received large spillin benefits nonetheless. In 2006 it had the seventh largest GMO area in the world, yet it has no biotechnology research capacity.

The next section of this report presents empirical indicators of LAC scientific and institutional capacity in the areas alluded to in Figure 1.

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7. Empirical measures of national basic and applied research output will be discussed in a later section.

3.1 *Scientific requirements and capacity to conduct biotechnology science*

3.1.1. Global agricultural research trends

Public sector agricultural research expenditures in developing countries have increased steadily over the past decades (Table 2). Between 1981 and 2000 the average rate of increase of expenditures for developing countries has been nearly three times that of developed countries (Pardey, et al., 2006). In 1981 developing countries were spending just 81% as much as developed countries on public sector agricultural research. By 2000 they were spending 26% more than developed countries. There are two important caveats to this good news though. First, growth in research expenditures has not been uniform across countries or regions. Expenditures have grown rapidly in some of the large countries while

Table 2:
Agricultural research expenditures and growth rates by region

Expenditures (million 2000 international dollars)		
	1981	**2000**
Latin America and the Caribbean	1.897	2.454
Sub-Saharan Africa	1.196	1.461
China	1.049	3.150
Asia and Pacific	3.047	7.523
Middle East and North Africa	764	1.382
Developing countries	6.904	12.819
Developed countries	8.293	10.191
Total	15.197	23.010
Annual growth rates (percent per year)	**1981-2000**	
Latin America and the Caribbean	2,0%	
China	4,9%	
Asia and Pacific	4,2%	
Middle East and North Africa	3,4%	
Developing countries	3,1%	
Developed countries	1,1%	
Total	2,1%	

Note: Data are provisional estimates and exclude Eastern Europe and countries of the former Soviet Union.
Source: Pardey et al. 2006

expenditures in many smaller countries have not kept pace with inflation. Expenditures grew at an average annual rate of 8% between 1981 and 2000 in India, China, and Brazil, compared to a rate of 2% in the remaining developing countries. LAC was the LDC region with the slowest expenditure growth rate.

The second qualification on the good news about increased research expenditures is the near absence of private sector interest in agricultural research in developing countries. In 2000 the private sector accounted for just 6% of agricultural research expenditures in developing countries, compared to 54% of expenditures in developed countries (Table 3). As a result, total (private and public) agricultural research expenditures were 62% higher in developed than in developing countries (Pardey, et al., 2006). This is a gap of more than $11 billion/yr, with the potential to create an enduring difference in rates technological advance. Spillovers can be large from some types of private sector research, including innovations such as pesticides or machinery. While these inputs are created though expenditures realized in developed countries, the same products are often used in developed and developing countries. Local research is needed for many other types of innovations, particularly in plant breeding.

Table 3:
Estimated global public and private agricultural R&D investments, circa 2000

	Expenditures (million 2000 international dollars)			Share of Spending %	%
Region/country	Public	Private	Total	Público	Private
Asia–Pacific	7.523	663	8.186	92%	8%
Latin America and the Caribbean	2.454	124	2.578	95%	5%
Sub-Saharan Africa	1.461	26	1.486	98%	2%
Middle East and North Africa	1.382	50	1.432	97%	4%
Developing-country	12.819	862	13.682	94%	6%
Developed country	10.191	12.086	22.086	46%	54%

Source: Pardey et al. 2006

The lack of private sector research is an important obstacle to improving the access of developing country farmers to improved crop varieties and biotechnology. Transgenes are a prime example of the potential for investments occurring in a developed country to have an impact in a developing country. The transgenetic events that have accounted for almost all GMO area in developed countries were developed in either the US or Europe. On the other hand, the crop breeding research to develop varieties to combine with the transgenic events has largely been conducted in-country. The private sector has been the main source of improved varieties in the US and other developed countries for many crops. Also, with the exception of China, the private sector has been the source of GMO technology in all areas where it has diffused. The private sector has accounted for 70% of global investment in agricultural biotechnology, and virtually all of that investment has occurred in developed countries (Table 4).

Table 4:
Estimated Global R&D Expenditures on Crop Biotechnology, 2001

	$ millions
Private (70%)	3.100
Public (30%)	1.120
Industrial Country Tot. (96%)	**4.220**
China	115
India	25
Brazil	15
Others	25
Developing Country Tot. (4%)	180
World Total	4.400

Source: James, 2002

3.1.2. LAC agricultural research investment trends

The information on agricultural research expenditures for LAC comes from the IFPRI Agricultural Science and Technology Indicators (ASTI) data base. The detailed information dates from the mid to late 1990s. Expenditures have increased more slowly in LAC than in LDCs overall over the past two decades, but countries in the LAC region have generally given greater support to agricultural research than other developing country regions. LAC has the highest research intensity ratio of any developing country region whether measured as research expenditures as a share of agricultural GDP, expenditures per capita, or expenditures per economically active agricultural population (Table 5). Nonetheless, the research intensity measures are less than one-third the average of developed countries. Direct support with government funds (i.e. block grants) was still the prevalent form of financing public research in the early 1990s, averaging 66% of total funding for the countries for which data are available (Table 6). Argentina and Chile are the only two countries with less than 50% of funding coming from a direct government grant.[8]

8. In the case of INTA in Argentina, a special tax on several commodities was the major source of income, while in the case of INIA in Chile research contracts were an important funding sources.

Table 5:
Selected public research intensity ratios, 1976-95

	Expenditures as a share of AgGDP			Expenditures per capita			Expenditures per economically active agricultural population		
	1976	1985*	1995*	1976	1985*	1995*	1976	1985*	1995*
	Percent			(1993 Internationall Dollars)					
Latin America	0,55	0,72	0,98	3,4	4,0	4,6	26,0	36,0	45,9
Sub-Saharan Africa	0,91	0,95	0,85	3,5	3,0	2,4	11,3	10,6	9,4
China	0,41	0,42	0,43	0,7	1,3	1,7	1,8	3,1	4,1
Other Asia	0,31	0,44	0,63	1,1	1,7	2,6	3,8	6,1	10,2
Developing countries	0,44	0,53	0,62	1,5	2,0	2,5	4,6	6,5	8,5
Developed Countries	1,53	2,13	2,64	9,6	11,0	12,0	238,5	371,0	594,1
All Countries	0,83	0,95	1,04	3,3	3,8	4,2	12,9	15,3	17,7

AgGDP: Agricultural Gross Domestic product
*Three-year averages centered on 1985 and 1995.
Source: Pardey and Beintema (2001)

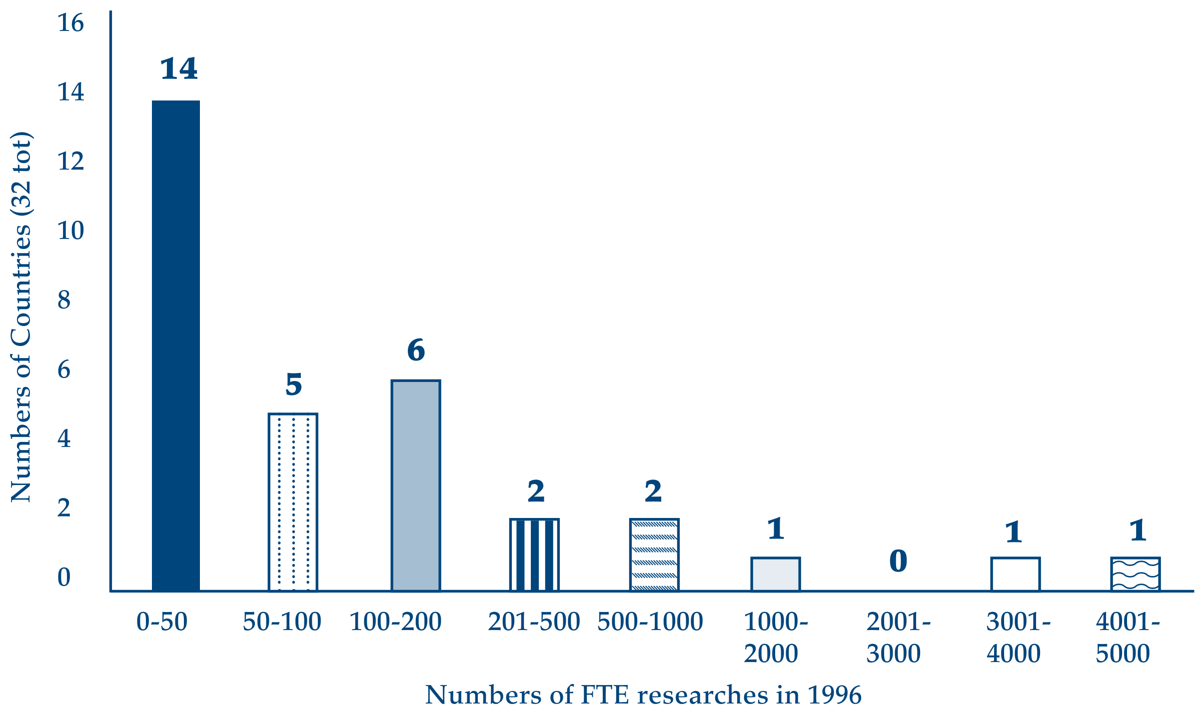
Table 6:
Source of funding for public agricultural research

Country	Year	Government subsidy	Sales produce and services	Earmarked taxes	Donors	Private	Other
		(Percentage share)					
Argentina	1991	21	1	67	0	0	12
Brazil	1991	95	4	0	0	0	1
Chile	1994	41	26	0	8	5	21
Colombia	1991	80	14	0	2	4	0
Ecuador	1991	58	21	0	12	0	9
Guatemala	1991	71	3	0	1	0	25
Mexico	1991	88	5	2	4	0	1
Panama	1986	62	2	0	5	0	31
Venezuela	1987	82	17	0	0	0	1
Sample average		66	10	8	4	1	11

Source: Cremers and Roseboom

Immense inter-country differences exist within the region in size and scientific capacity. Brazil accounts for about 50% of total LAC expenditures. Adding the budgets of Argentina and Mexico to Brazil's brings total agricultural research expenditures of these three countries to more than 85% of the LAC total. The majority of LAC agricultural R&D systems however, are small (Figure 2). Twenty-five of the 32 LAC countries have less than 200 researchers. The total size of these systems is less than that of a large Land Grant university in the US. The 12 countries of the Central America and Caribbean region together spent just $39 million (again about the budget of an average size Land Grant university in the US).

Figure 2
Size distribution of agricultural research systems in LAC region



More than 13,500 full-time equivalent (FTE) researchers were employed by public sector institutions in 1996 (IFPRI). Of that total, Brazil employed nearly 5,000 researchers (36% of LAC total), and together, Argentina and Mexico employ about another 5,000 researchers, bringing to 73% the share of LAC total in these three countries. Differences in the level of training of researchers and in expenditure per researcher are also large (Beintema and Pardey, 2001, Cremers and Roseboom, 1997). While 82% of Brazilian researchers hold graduate degrees , just 20% of the Guatemalan and 27% of the Honduran researchers do. Only Brazil and Mexico have more than half of their researchers with graduate degrees; only Brazil and Chile have 20% or more holding a Ph.D. The educational level of LAC researchers increased steadily between the early 1970s and 1996, the latest date for which information is available (Table 7). There was a six-fold increase in the share of researchers holding a Ph.D., and the share holding an MSc degree more than doubled, while the proportion holding a BSc degree fell from 77% to 33%. These figures for the region are strongly affected by the inclusion of the progress that Brazil and Mexico have made in training researchers. Excluding these two countries, the share of LAC researchers with graduate degrees falls to 55%, with just 18% holding a Ph.D.

Table 7:
Degree status of public agricultural researchers, 1996

	PhD	MSc	BSc
	(Percentage)		
By country:			
Brazil	31	51	18
Chile	21	28	52
Colombia	11	38	52
Costa Rica	10	26	64
Guatemala	5	15	80
Honduras	14	13	73
Mexico	19	47	34
Panama	8	29	63
Paraguay	3	34	64
Uruguay	7	29	65
10-country average	23	45	33

Source: Beintema and Pardey (2001)

Despite ongoing efforts to reform and restructure agricultural research in LAC, the most common structure remains the INIA model in the bigger LAC countries and the ministerial department model in the smaller LAC countries. Most of the National Agricultural Research Institutions (INIAs) that form the backbone of the National Agricultural Research Systems (NARS) in LAC are public autonomous institutions created in the 1950s, 1960s, or early 1970s. The involvement of alternate suppliers of agricultural research such as NGOs, universities, and the private sector is of recent origin in most countries. A number of other agricultural research suppliers can now be found in most countries, but the quality of these institutes varies widely and there is often a lack of coherence and cohesion among the efforts of the various research providers. The average share of national public agricultural research capacity of the principal agricultural research agencies (either an INIA or a ministerial research department) is 46%. The university research share is significant, at 28.1%, but tends to be lower in the smaller countries. In developed countries, about 43 percent of the public research was done by universities in the mid-1990s and only 10 percent in Africa in 1991 (Beintema and Pardey, 2001). Latin American countries have moved in the direction of the developed countries, with universities playing a greater role in agricultural innovation. The share of agricultural research conducted by non-profit agencies is small at just 4.6 %, but is much higher in a few of the smaller countries.

3.1.3. Bibliometric indicators of basic and applied science capacity.

Nowhere is the diversity of the region more evident than in the indicators of scientific research. Given the diversity of LAC countries, the role of modern biotechnology will necessarily vary greatly among countries in the region as well.

Advances in biotechnology, like other areas of science require a balance of basic and applied research effort. Basic science research need not be focused on agricultural applications to be important to agriculture, and is conducted in institutions both within, and external to, the public agricultural research system. No measure of investments in basic science research in LAC is available. However informative measures of basic research output can be developed using online bibliometric tools. Bibliometric methods have progressed rapidly over the past decade, particularly with the advent of online databases such as Social Science Citation Index, the Science Citation Index and Scopus. These databases include publication and citation information for manuscripts published in books, journals, conference proceedings and other scientific and popular outlets. Using the online tools, publication counts for individual scientists, for faculties at a given university, or for other aggregations can be generated.

The Scopus database was used to compile counts of the number of journal articles published by scientists in each LAC country. The Scopus database contains articles published in more than 15,000 peer-reviewed journals, including 3,400 journals in the Life Sciences area. Journals from all geographical regions are covered, including non-English titles when English abstracts are provided with the articles. About 36% of the journals covered are published in North America and 3% in South America.

To measure basic science output, a search was made for all journal articles published in the areas of "Biochemistry, Genetics and Molecular Biology" (BGMB) from 1997 to 2006 by scientists affiliated with institutions in each LAC country. The Scopus database was also used to generate counts of the number of articles in the area of "Agricultural and Biological Sciences" (ABS) The results are displayed in Table 8.

Table 8:
Number of articles published by scientists at institutions in LAC countries 1997-2006.

		Biochemistry, Genetics and Molecular Biology	% LAC total	Agricultural and Biological Sciences	% LAC total
1	Brazil	20.939	45%	3.570	45%
2	Argentina	8.908	19%	1.327	17%

3	Mexico	7.126	15%	1.256	16%
4	Chile	3.143	7%	449	6%
5	Venezuela	1.393	3%	398	5%
6	Cuba	1.359	3%	145	2%
7	Colombia	995	2%	210	3%
8	Uruguay	798	2%	135	2%
9	Costa Rica	328	1%	92	1%
10	Peru	319	1%	84	1%
11	Panama	206	0%	102	1%
12	Jamaica	178	0%	40	1%
13	Ecuador	144	0%	32	0%
14	Trinidad y Tobago	129	0%	26	0%
15	Bolivia	105	0%	26	0%
16	Guatemala	50	0%	15	0%
17	Paraguay	39	0%	4	0%
18	El Salvador	36	0%	8	0%
19	Barbados	35	0%	6	0%
20	Nicaragua	28	0%	4	0%
21	Rep. Dom.	22	0%	1	0%
22	Honduras	21	0%	4	0%
23	Granada	21	0%	0	0%
24	Bahamas	7	0%	2	0%
25	Guyana	6	0%	0	0%
26	Haiti	5	0%	0	0%
27	Belice	5	0%	1	0%
28	St. Kitts y Nevis	3	0%	0	0%
29	Dominica	2	0%	0	0%
30	Suriname	0	0%	0	0%
31	St Vicent / Grenadines	0	0%	0	0%
32	St Lucia	0	0%	0	0%
33	Antigua y Barbuda	0	0%	0	0%
	Total	**46.350**	**100%**	**7.937**	**100%**
	Canada	66.815		6.336	
	Estados Unidos	554.180		42.001	
	España	45.452		5.072	
	China	53.397		5.812	
	India	32.325		4.604	

Source: SCOPUS database

A total of 46,350 BGMB and 7,937 ABS articles were published by LAC scientists. Scientists working in Brazilian institutions generated 45% of total LAC publications in both the BGMB and ABS areas. Argentina and Mexico were next, each with roughly similar numbers of publications, followed by Chile, Venezuela, Cuba, Colombia, Uruguay, Costa Rica and Peru. More than half of the region's countries had 50 or less BGMB articles, and 15 or less ABS articles. Totals for the other IICA members, Canada, the US and Spain are included in the table 8 as well.

The review of scientific output suggests that Brazil is capable of becoming an important international source of both basic and agricultural science, though it must be recognized that it still has only about 30% of the basic science output and 45% of the agricultural science output of Canada, and less than 4% of the basic science and less than 9% of the agricultural science output of the US. Canada and the US are the two countries where the most GMOs have been developed. Argentina and Mexico also show significant output in both areas, though not on Brazil's scale. Chile, Venezuela, Cuba, Colombia, and Uruguay show some limited capacity. Scientific capacity in the remaining countries is very small. Two-thirds of the region's countries produce less than 10 basic science and less than 3 agricultural science articles per year. This calls into question whether there is now, or will be in the foreseeable future, enough trained scientists even to staff credible biosafety regulatory institutions in each country. Establishing regional, rather than individual national, biosafety committees would appear to be the more logical option, though political sentiment may be an obstacle to such a change.

Using these indicators of scientific output and staffing, LAC national agricultural research capacity can be placed into four groups. The first group includes the 25 smallest LAC agricultural research systems. These national systems are about the size of a single US Land Grant University, but are at a large disadvantage to US universities in terms of funding and in terms of the training of their scientists, most of whom hold BS or MS degrees. The second group of medium size countries has an increased capacity across the research spectrum, but has large areas of limited expertise. This group includes Peru, Costa Rica, Uruguay, Colombia, and Chile. The third group consists of Mexico, and Argentina who have significantly greater basic research capacity, a higher number of Ph.D. trained scientists, several well staffed universities, and scientists that regularly participate in international scientific congresses than the second group of countries. Finally Brazil stands on its own, as a potential source of spillover benefits for the rest of the countries of the region.

The very small systems lack human capital not just to conduct basic research, but must also be borrowers of virtually all kinds of research, including finished technologies. These countries do not have research capacity in all of the required research disciplines to fully staff research even for important agricultural commodities. A significant challenge for these countries is to increase the level of training of their agricultural researchers, and to retain the scientists with advanced degrees in the research sector. It is clear that the bulk of useful agricultural technologies will be developed abroad and adapted to local conditions. The strategic focus of these countries must be on accessing direct technology spillovers from all sources. But the low numbers of Ph.D. and MS level scientists leave many countries below the threshold level of scientific talent needed even to competently screen and adapt technologies developed elsewhere.

The second tier countries are in a much better position to take advantage of spillovers because their higher numbers of researchers with advanced training are able to screen foreign technologies when given access. These countries will still be dependent on imported technology in many areas, but are able to perform adaptive research. They should also be capable of carrying out strategic research and some basic research in nationally important commodities.

The third tier countries (Argentina and Mexico) have the potential to mount credible research programs in any important area, including basic research, but must carefully prioritize activities due to the great diversity of agriculture, and restrictions on the total level of resources that are available. A significant number of their scientists are tied to the international scientific community, and the number of researchers is adequate to cover all important commodities and disciplines. Nonetheless, efforts to take advantage of spillovers are a key component of technical change in the future. Brazil has the scientific and financial capacity to conduct research on a much larger scale than other LAC countries. The size of Brazil's agricultural sector suggest the potential to attract large amounts of private investment.

4 Regulatory capacity

4.1. *Status of biosafety protocols in each country*

The development of biosafety legislation is an area where the countries of the region have seen important progress. Twenty countries in the region have signed and ratified the Cartagena Protocol on Biosafety (CPB) (Table 9) (Tewolde, 2006). Another nine have signed, but not ratified the CPB, leaving just Guyana and Surinam as countries that have not moved forward on the CPB. However, though nearly all countries have signed the CPB, the majority of countries are still in the process of passing specific biosafety legislation (Table 10).

4.2. *Analysis of field test and commercial approvals*

While the majority of countries have moved forward with biosafety legislation, few have any experience in the crucial step of actually carrying out biosafety field trials. Legislative capacity to grant regulatory powers is just a first step towards realization of a functioning biosafety system. In this section we employ data on GMO field trials conducted and commercial approvals as indicators of evidence of experience with implementation of biosafety protocols.

Two key approval steps are involved in biosafety regulation. The research institution producing a new GMO must first obtain a permit to conduct field trials from the national biosafety agency. Upon completion of field trials over a period of years, the institution may petition the regulatory agency to have an article removed from regulated status. If the petition is granted, the GMO is generally allowed to be commercialized.

The five countries listed in Table 11 have conducted the majority of LAC field trials[9]. Argentina accounts for 60% of the total within this group of countries. Neither the number of countries conducting field trials, nor the total number of field trials conducted in LAC has increased significantly since 2000. Multinationals have been the dominant source of field trials, conducting 82% of the trials between 2000-2007 for those countries for which a breakdown is available. The public sector has significant experience with biosafety field trials only in Mexico and Argentina, and universities have conducted just 13 trials in all of LAC during the period.

9. Chile, Cuba, Colombia, Uruguay, Paraguay, and Honduras have also conducted field trials, but trial information is not available.

Seven LAC countries have approved one or more event for food, feed, environmental or planting (Table 13). All approved events were developed by the multinational private sector, so the approvals indicate that a country possesses the scientific capacity to staff biosafety regulatory mechanisms, and the political climate to see the process, rather than national biotechnology research capacity per se. The political and public support for biotechnology has been volatile in all countries except for Argentina. In Brazil for example, RR soybeans were approved for planting by the national regulatory committee in 1998, but a moratorium on the sale of GMO seed was then imposed until 2005. The approval process in Brazil remains highly political and uncertain. With the possible exception of Argentina, all other countries in the region have found it difficult to move events through the biosafety process. The result has been that there has been little increase over time in the number of events approved in the region (Table 13).

Table 9:
Status of action on Cartagena Protocol on Biosafety (CPB)

Parties to the Cartagena Protocol on Biosafety (CPB)		
Antigua and Barbuda	Dominica	Paraguay
Bahamas	Ecuador	Peru
Bolivia	Guatemala	St Lucia
Brazil	Mexico	Grenada
Colombia	Nicaragua	Trinidad & Tobago
Cuba	Panama	Belize
San Vicente y las Granadinas	St. Kitts y Nevis	
Countries that have signed but not Ratified the CPB		
Argentina	Costa Rica	Jamaica
Venezuela	Haiti	Uruguay
Chile	Honduras	
Countries that have not Signed the CPB		
Guyana	Suriname	

Source: (Tewolde, 2006)

Table 10:
Status of Biosafety legislation by country

Specific Biosafety Legislation	Related Legislation	No Information/ No Access to Legislation
Argentina	Belize*	Antigua and Barbuda
Brazil	Bolivia*	Bahamas
Mexico	Chile	Barbados
	Costa Rica*	Dominica
	Ecuador	Guyana
	El Salvador*	Haiti
	Guatemala	St Lucia
	Grenada	St. Christopher and Nevis
	Honduras	St. Vincent and the Grenadines
	Jamaica*	Suriname
	Nicaragua*	Trinidad & Tobago
	Panama	
	Paraguay	
	Peru**	
	Dominican Republic	
	Uruguay	
	Venezuela	

Source: (Tewolde, 2006)
* In the process of generating and/or modifying laws
** Law pending official publication

Table 11:
Number of biosafety field trials conducted in five LAC countries, 2000-2006.

	2000	2001	2002	2003	2004	2005	2006	Total
Argentina	78	63	70	99	80	73	124	587
Brazil	48	159	36	8	21	9	68	349
Colombia	1	0	0	2	2	10	0	15
Costa Rica	3	2	3	5	5	6	4	28
Mexico			34	12		43	56	145
Total	130	224	109	114	108	98	196	976
Argentina share of total	60%	28%	64%	87%	74%	74%	63%	60%

Table 12:
Source of field trials 2000-2006* by sector

	Multinational Private	National Private	Universities	NARS	Total
Number of Trials in countries with source information available					
Argentina	477	73	10	27	587
Brazil*	88	0	0	7	95
Mexico	95	0	0	17	112
Colombia	14	0	0	4	18
Costa Rica	17	8	3	0	28
Total	691	81	13	55	840
Percent of country total in countries with source information available					
Argentina	81%	12%	2%	5%	100%
Brazil*	93%	0%	0%	7%	100%
Mexico	85%	0%	0%	15%	100%
Colombia	78%	0%	0%	22%	100%
Costa Rica	61%	29%	11%	0%	100%
Total	82%	10%	2%	7%	100%
Other trials (countries where source information is not available)					
Guatemala					3
Honduras					4
Paraguay					?
Uruguay					?

* Data for Brazil are for 2006 only.

Table 13:
Biosafety approvals by type of approval, 1996-2006

Country	Environment Number of events approved (year of first approval)	Planting Number of events approved	Food Number of events approved (year of first approval)	Feed Number of events approved
Argentina	10 (1996)	10	10 (1998)	10
Brazil	2 (1998)	2	2 (1998)	3
Colombia	4 (2000)	3	5 (2002)	5
Honduras	1 (2002)	1	1 (2002)	1
Mexico	4 (1996)	4	36 (1996)	2
Paraguay	1 (2004)	1	1 (2004)	1
Uruguay	5 (1997)	5	3 (1997)	3
Year				
1996	3	3	8	2
1997	2	2	1	1
1998	5	5	6	5
1999	1	1	2	0
2000	3	3	1	0
2001	1	1	5	2
2002	2	1	5	1
2003	2	2	7	2
2004	4	4	12	5
2005	2	2	5	4
2006	2	2	5	0
Total	27	26	57	22

Source: (James, 2006)

4.3. *Intellectual property rights in LAC*

Issues of the protection of property rights in agriculture have received significant attention in the recent literature (Anonymous, 2006, Byerlee and Fischer, 2001, Moschini and Lapan, 1997). The emphasis is the result of the increased importance of the private sector as a research provider as well as interest in the effect of changes in IPR laws and practices that have resulted from new international agreements such as the Convention on Biological Diversity, the International Treaty on Plant Genetic Resources for Food and Agriculture and requirements arising from the TRIPS Agreements. Relatively little attention is paid to the issue of enforcement in the existing literature, yet the inability to protect IP even when legislation exists has been a critical constraint on private sector investment in crop improvement and in GMOs for developing countries. Plant variety protection (PVP) and other laws are only a first step towards effective protection of IP as pointed out in a recent World Bank publication:

"PVP can be expected to have only a modest impact on the direction of domestic commercial seed markets, given that most PVP systems in developing countries cannot control farmer seed saving and possess very limited enforcement capabilities (because of inadequacies in legal systems, insufficient regulatory staff, and insufficient experience in the companies themselves).The protection of transgenic crops has proven particularly difficult in developing countries. an IPR regime, on its own, is not likely to provide the incentives that elicit the emergence of a robust plant breeding and seed sector; attention to other institutions and the provision of an enabling environment are also necessary." (Anonymous, 2006) (pp. xv-xvi)

Table 14 summarizes some aspects of IPR legislation among the larger LAC countries. All of the listed countries except for Peru and Costa Rica have adopted UPOV 1978 rules for protection of plant varieties. Trinidad-Tobago, Panama and Nicaragua have also adopted UPOV 1978. The existence of legislation covering other important aspects of IP protection is spotty, and largely untested in court. It appears that the majority of countries are aware of the IP issues involved with biotechnology, but all are struggling with the complexity of implementing systems that meet national needs while conforming to international obligations. The skill with which countries enforce IPR rules will be as important as the actual legislation for IPR protection to attract private sector investment. No overall assessment of the degree to which case law has supported enforcement of IP protection has yet been published.

4.3.1. Piracy and the enforcement of IPR

The difficulty in protecting intellectual property over GMOs has been a serious concern for the private sector in nearly all developing countries. To date the private sector's experience with generating revenue from the sale of GMOs in developing countries has not been encouraging. Table 14 lists the developing countries and crops where GM crops have been marketed up to 2006. A rough estimate is that nearly 90% of the area currently sown to GMOs in developing countries is affected by significant levels of seed piracy.

The loss of revenue has been most severe in the Southern Cone of South America, where little revenue has been collected from the planting of a cumulative total of nearly 120 million ha of RR soybeans (Table 16). Largely due to difference in the technical aspects of processing harvested seed for replanting, technology fees have been collected on a greater proportion of maize and cotton area than on soybean area. The most consistent collection of fees has been on the sale of hybrid maize seed, where it appears that piracy has been a relatively minor problem. Collections from seed sales have also been high for Bt cotton in Mexico and South Africa, but low in China and India, despite the fact that hybrids are used in India.

The most common form of seed piracy occurs through farmers saving and reselling harvested seed. The size of the legitimate seed market is reduced not just by farmers saving seed for their own use, but by resale of saved seed to other farmers. Often those selling seed are not just farmers selling seed to their neighbors, but are entrepreneurs who market brown bag seed over wide areas, possibly even across national borders. This type of piracy is widespread in the South Cone and is probably present on some scale in all countries. Farmer to farmer sales are difficult to detect and expensive to prosecute through the legal system. Prosecution would require courts and juries to rule against a local farmer in favor of a multinational corporation. Monsanto also found with the Canadian case against Percy Schmeiser that even winning a piracy case in the court of law may entail losses in the court of public opinion.

Monsanto has been able to effectively enforce their property rights in the US. One of the key elements has been the use of contracts to prohibit seed savings. This allows them to prosecute violators for breach of contract, rather than IP violation. From 1997-2005, Monsanto filed similar lawsuits 90 times in 25 states against 147 farmers and 39 agriculture companies (Elias, 2005). Monsanto uses a "tipline" that can be used to anonymously to report farmers are illegally using its seeds and settles many of those cases before a lawsuit is filed. It has gone to trial five times and has never lost a legal fight against an accused pirate. So far protection of IP has proven to be far more difficult and uncertain in developing countries, with the resulting impact of depressing private sector research investment.

In the face of difficulties in collecting revenues at the point of sale of soybean seed, Monsanto has proposed a type of endpoint royalty system in Paraguay, Argentina and Brazil. Monsanto has been able to initiate negotiations on the endpoint royalty system because it holds patents on the Roundup Ready technology in many countries including Australia, European Union, Brazil, Belarus, Canada, Switzerland, Japan, Kazakhstan, Netherlands, Russia, Sweden, Ukraine, Uzbekistan, US, Denmark, Israel, New Zealand, and South Africa. This means that soybeans containing Monsanto IP (the RR gene) cannot be legally exported to any of these major markets. The royalty system has been operating in some form in Brazil and Paraguay since the 2005/06 growing season.

Monsanto has been unable to reach a royalty agreement with farmers and grain merchandisers in Argentina. In 2005 & 2006 Monsanto used legal actions to halt Argentine soy shipments in Spain, Britain, Denmark, and the Netherlands (Haskel, 2006). The Argentine government and producers have counter sued Monsanto, but with no resolution to either the legal issues or to the collection of royalties. In January 2004 Monsanto announced that it would cease seed operations in Argentina. Argentina operates under UPOV 1978 which allows farmers to save seed though not to sell trade saved seed.

Under the Brazilian endpoint royalty system farmers who are unable to provide a sales receipt

Table 14:
IPR Protection in Agricultural Biotechnology Related Areas in LAC

Country	Discovery	Biol. Process	Plants[1]	Plants Varieties[2]	Animals (Breeds)	Genes
Argentina	No	Yes	Yes	Yes	Yes	Yes
Chile	No	Yes	?	Yes	Yes[3]	?
Brazil	No	Yes	No	Yes	No	No
Uruguay	No	No	No	Yes	No	No
Paraguay	No	No	No	Yes	No	?
Bolivia*	No	No	No	Yes	No	?
Peru*	No	No	No	No	No	?
Ecuador*	No	No[4]	No	Yes	No	Yes
Colombia*	No	No	No[5]	Yes	No	?
Venezuela*	No	No	No	Yes	No	Yes
Mexico	No	No	Yes	Yes	No	?
Costa Rica	No	No	No	No	No	?

Source: (Trigo, et al., 2002)
* Legislation is under the scope of Decision 344 of the Cartagena Agreement
1. Genetic modification
2. UPOV 78
3. Animal races are explicitly excluded from patentability (law 19.039, Art. 37b), but not animals as such.
4. Yes to obtain plant varieties, no for animals
5. Not defined. WIPO document reports no exclusion for plants from patentability but it does not appear to be possible to obtain a patent for a plant per se.

Table 15:
Piracy in GMO crops in developing countries, 2006

Country	GMO Area 2006 (m ha)	Crop	Degree of Piracy
Argentina	15,9	Soy	Near Complete
Argentina	1,8	Maize	Low
Argentina	0,37	Cotton	Low
Brazil	11,5	Soy	Complete
Brazil	0,3	Cotton	Complete
India	3,8	Cotton	High (50-66%)[3]
China	1,4	Cotton	High (87%)
Paraguay	2,0	Soy	Total[2]
South Africa	1,4		
South Africa	nd	Maize	Low
South Africa	nd	Cotton	Low

South Africa	nd	Cotton	Low
Uruguay	0,4	Soy	Unknown
Mexico	0,1	Cotton	Low
Philippines	0,2	Maize	Unknown
Colombia	<0,1	Cotton	Unknown
Honduras	<0,1	Maize	Unknown
Total GM area	37		
Area affected by piracy	33		
% area affected by piracy	89%		

Source for total area: Clive James, 2006.
1Ramaswamy and Pray

Table 16:
RR soybean area (m. ha) and estimated technology fee collections ($ m), 1996 to 2006

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	All Years
Argentina	0,1	0,4	1,8	4,9	6,9	8,8	10,4	11,8	13,1	14,4	15,9	88
Brazil	--	--	--	--	--	--	--	3,0	5,0	9,4	11,5	29
Paraguay									1,2	1,8	2,0	5
GM area	0,1	0,4	1,8	4,9	6,9	8,8	10,4	14,8	19,3	25,6	29,4	122
Tech value[1]	$1,5	$5,4	$26	$71	$100	$128	$152	$216	$281	$374	$429	$1.784
Collected[2]	$0,3	$1,2	$6	$16	$9	$11	$13	$15	$16	$18	$20	$125
Lost revenue	$1,1	$4,2	$21	$56	$92	$117	$139	$201	$265	$356	$409	$1.659

1. Valued at US technology fee rate of $16.00/ha
2. Argentina estimates based on Trigo and Capp, Brazil & Paraguay assumed to be 0
Source for area estimates: James

for the purchase of soybean seed from a licensed dealer are required to pay an "indemnity fee" that is paid at the elevator when they sell their harvest. The elevators receive a commission as compensation for handling the fee. The fee is distributed among Monsanto and their seed partners, with an additional percentage allocated to public sector research, or to a foundation that funds research grants.

In Paraguay the fee for the 2006/07 growing season is $3.09/ton, but is slated to increase to $6.00/ton over time. US farmers pay a technology fee of approximately a $5.50/ton for the use of RR soybeans. Royalties in Paraguay are distributed as 53% to Monsanto, 17% to seed Companies, 8% to Grain handlers, 10% to a fund for public research, and 12% to administrative expenses.

5 Summary of Analysis of Scientific and Institutional Capacity

The countries in the region represent a diversity of capacities, with respect to undertake research supporting the development of biotechnology, with respect to their experience in regulating biotechnology research, with respect to the level of diffusion of biotechnology applications, with respect to their attractiveness to private sector investors. There seem little reason to believe that this scientific and technological diversity will diminish in the near future given the immense diversity in the underlying demography, economic circumstances and geography.

Table 17 is an attempt to place the countries in the region into policy-relevant groups. Seven indicators of each country's current ability to harness biotechnology for agriculture are given. Most of the indicators have already been discussed in previous sections. The first two columns assign a 0-3 score to each country's research capacity in basic science, and in applied agricultural sciences, with 3 indicating the most advanced capacity. As discussed above, Brazil is in a class of its own in terms of scientific capacity in both areas of science. The next seven countries in table 16 also have significant basic scientific capacity, and those seven plus Costa Rica, Peru and panama have been assigned a "2" in agricultural science capacity as well. The remaining countries have very limited capacity in either area of science. The smallest LAC countries have a score of zero suggesting that nearly all technology will need to spillin from other countries. The rest of the table summarizes biosafety legislation and experience and indicates whether legislation is in place to protect biological innovations.

The picture that emerges is all countries will need to confront important challenges if biotechonology is to realize its potential to contribute to improved agricultural productivity in LAC. Important progress has been made in the past decade. Progress has occurred in enacting legislation and in conducting field trials, but this progress must be characterized as deliberate, suggesting that it is likely to be many years before the deployment of biotechnology innovations will become routine. Institutional capacity in general evolves slowly. This is especially apparent when the slow pace of biotechnology institutional capacity building that has occurred is contrasted with the impressive pace at which scientific discoveries have occurred.

Implications for Science and Technology (S&T) Policy

Trigo (2007) argues that the environment for science and technology in the Americas is undergoing a fundamental transformation (Table 18). Among the key aspects identified by Trigo are an increasing importance of the provision of private goods by the private sector. This is an important shift in agricultural S&T, where the public sector has long dominated. Accompanying this shift is an increase in the importance of arrangements for protecting intellectual property, and the need for better articulation between research and commercialization. Trigo also points out that innovation is increasingly derived to basic science research. This new S&T environment will require a significant amount of institutional innovation - new policies, new roles and interactions among existing S&T institutions, and the creation of some entirely new institutions.

Increased role of the private sector

One of the most profound changes in the S&T environment is the evolving role of the private sector. To a greater or lesser extent, all LAC S&T systems are dominated by public

Table 17:
Summary of present status for accessing biotechnological innovations

Country	Basic Science	Science	OMG area	Aprobación OMG	Ensayos OMG	Legislación bioseguridad	DPI proc. biol.
Brazil	3	3	Yes	Yes	Yes	Yes	Yes
Argentina	2	2	Yes	Yes	Yes	Yes	Yes
Mexico	2	2	Yes	Yes	Yes	Yes	
Chile	1	2	Yes[1]	Yes[1]	Yes	Yes	Yes
Venezuela	1	1	No	No	No	Yes	No
Cuba	1	1	No	No	Yes	Yes	No
Colombia	1	1	Yes	Yes	Yes	Yes	No
Uruguay	1	1	Yes	Yes	Yes	Yes	No
Costa Rica	1	1	No	No	Yes	Yes	No
Peru	1	1	No	No	No	Yes	No
Panama	0	0	No	No	No	Yes	No
Jamaica	0	0	No	No	No	Yes	No
Ecuador	0	0	No	No	No	Yes	No
Trin / Tobago	0	0	No	No	No	No	No
Bolivia	0	0	No	No	No	Yes	No
Guatemala	0	0	No	No	No	Yes	No
Paraguay	0	0	Yes	Yes	Yes	Yes	No
El Salvador	0	0	No	No	No	Yes	No
Barbados	0	0	No	No	No	Nd	No
Nicaragua	0	0	No	No	No	Yes	No
Dom. Rep.	0	0	No	No	No	Yes	No
Honduras	0	0	Yes	Yes	Yes	Yes	No
Grenada	0	0	No	No	No	Yes	No
Bahamas	0	0	No	No	No	No	No
Guyana	0	0	No	No	No	No	No
Haiti	0	0	No	No	No	No	No
Belize	0	0	No	No	No	Yes	No
St. Kitts/ Nevis	0	0	No	No	No	No	No
Dominica	0	0	No	No	No	No	No
Suriname	0	0	No	No	No	No	No
St. Vincente/ Grenadines	0	0	No	No	No	No	No
St. Lucia	0	0	No	No	No	No	No
Antigua/ Barbuda	0	0	No	No	No	No	No

Table 18:
The transformed environment for science and technology (S&T) in the Americas

Traditional S&T	Modern S&T
• System focused on public goods provided by public institutions • Technologies generated by applied research • Relatively small investment requirements • Little attention given to Intellectual property protection • Little interaction between public and private sector • Low intensity of regulation • Little articulation between technology generation and commercialization	• Innovation momentum provided by private sector - Public sector plays a supporting role • Enabling technologies derived from basic science discoveries • Linkages between industry and public sector are crucial • Large requirements for new investments; "Big science" • Strong Intellectual Property Protection

Source: Adapted from Trigo, 2007

sector institutions. The private sector accounts for barely 5% of LAC agricultural research investment, and much less than this in most countries. On the other hand, the private sector now supplies more than half of all agricultural research investment in industrialized countries. The implications of increased private sector investment are profound, requiring governments to rethink a range of policies. Countries of the region face the prospect of falling further behind industrial countries unless they can find a way to encourage private sector investment. This includes policy actions such as ensuring that credit is available and easing the regulatory burden on startup firms, and a range of other country-specific actions.

The evolving role of public sector institutions

An enlarged private sector presence also presents the opportunity for public sector institutions to redeploy research resources upstream to basic and strategic research areas. Private sector investment will focus on developing applied technologies - an area that is presently the focus of LAC public sector institutions. Only a few countries in the region have significant upstream capacity at present, but should the private sector begin investing in agricultural research, the public sector may be able to reposition itself. This suggests a very positive new research dynamic to countries that are agile enough and bold enough to embrace new opportunities to engage the private sector. Those countries that can find a way to coordinate public sector strategic research with private sector applied research will have a large technological advantage.

Intellectual property rights (IPR)

A critical policy area is that of intellectual property rights. The evolving environment for IPR has implications for both the private and public sector. The private sector will only invest in areas where they expect reasonable levels of IPR protection. Those countries that are able to enforce IPRs will have an advantage in attracting private sector investment. It is important to be aware that the will and capacity to enforce IPR is as important as the existence of IP legislation. As pointed out above, the experience to date with protection of IPR for transgenic products has not been encouraging for the private sector. IPR enforcement is a difficult issue, but one that is critically important if countries in the region hope to gain access to future transgenic technologies.

The inadequacy of IPR institutional infrastructure in the public sector is an issue that is seldom discussed. Of particular importance are improved arrangements for the sharing of intellectual property by public sector institutions; public-private sharing as well as public-public sharing. The differences between private sector companies and public sector institutions in their approach to accessing and sharing technology is striking. The private sector is intensively engaged both in contracting for use of technological components of other private sector firms, and in the out licensing of their own technology. There is virtually no recent private sector agricultural product that has been brought to market without numerous negotiations for access to technological components. Public sector institutions lag far behind in their ability to gain access to technology. It is still rare for public sector institutions to share intellectual property – the fact that Brazil, Argentina or Mexico have advanced technology has done little to benefit the smaller countries of the region, and it is rare even for the larger countries to share technology among themselves. Institutional arrangements for public sector institutions to share IP among themselves have been slow to develop, and their lack of experience in negotiating agreements has hampered the flow of IP between the private and public sectors. Just as important as the technical aspects of IP contracts, is a change of attitude on the part of public sector policy makers. It is no longer reasonable for any country or institution to expect to be "technologically autonomous". Research progress in the future will be closely tied to an institution's ability to access technology developed elsewhere. This will require a new breed of research managers who are aware of freedom to operate issues and who are eager to share to technological components. It is also imperative that research managers have realistic estimates of the value of their own technologies and of the technologies of their negotiating partners.

Regulatory infrastructure

Further dissemination of biotechnology will also require a greatly enhanced regulatory capacity for biosafety and other types of food safety assessment. The many small countries of the hemisphere are severely disadvantaged with respect to their ability to marshal the scientific talent needed to staff a national biosafety committee and nearly all countries have a great deal of work to do in order to gain the confidence of consumers in the regulatory systems once they are in place. A willingness to enter into transnational agreements for regulation will be a key distinction of enlightened policymaking in the future. Transnational arrangements have two important advantages. First, pooling regulatory functions will ease the burden of committing scientific talent within each participating country. Secondly, a common set of regulations and a unified regulatory system reduces the cost of entry for the private sector, making them more willing to introduce new technology into smaller countries.

Summary and Perspective

The overall progress in deploying GMOs has not proceeded with the speed that many had expected when GMOs were first introduced in 1996, yet GMOs have generated several billions of dollars in benefits for the region. And even though the transgenic crops have been delivered through the private, rather than the public sector, the benefits have been widely distributed among industry, farmers and final consumers. This suggests that the monopoly position engendered by intellectual property protection does not automatically lead to excessive industry profits. Evidence from Argentina and Mexico suggests that small farmers have had no more difficulty than larger farmers in adopting the new technologies. The environmental effects of transgenic crops have also been strongly positive to date. In virtually all instances insecticide use on Bt cotton is significantly lower than on conventional varieties and glyphosate has been substituted for more toxic and persistent herbicides in RR soybeans, canola, cotton and maize. Furthermore, an increase in the use of reduced tillage has accompanied RR soybeans and cotton. Negative environmental consequences have not been documented in any setting where transgenic crops have been deployed to date.

At present all GMOs in use are the result of technology spillovers from the US commercial seed market, and just two traits and three major commercial crops have been commercially adopted. To date no commercial GMO applications developed specifically to address problems of LAC agriculture have been commercialized. The delivery of GMOs has also been concentrated in the hands of a few providers and are based on genetic events that are the property of multinational corporations, yet this has not prevented the benefits from being widely shared among adopting farmers, industry and consumers. The primary obstacle to delivering benefits to more farmers has been the lack of investment in research tailored to their needs. Important policy questions will have to be addressed over the coming years if the benefits of biotechnology are to reach small farmers and growers of minor crops.

GMO diffusion has been anything but predictable so far. A decade ago, few would have foreseen that there would be just two commercially successful GMO traits in 2007. Research is underway to improve food maize, wheat, rice, tubers and many vegetable crops. Biotechnology holds immense potential to address many of the most difficult production problems that plague the region's farmers. While the science of biotechnology is advancing rapidly, the institutional capacity to deliver biotechnology faces significant challenges. Of particular concern to policymakers is the evidence of sharp differences among LAC countries in their positioning for utilizing the potential of biotechnology and modern agricultural science. The technological gulf appears to be widening as a result of a variety of economic, social and geographic factors. Narrowing this gulf will require bold and timely action to develop new policies to support modern science.

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