Food, Agriculture, and the Environment Discussion Paper 9

Agriculture, Technological Change, and the Environment in Latin America: A 2020 Perspective

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

2020 VISION

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Foreword

In March 1995, the International Food Policy Research Institute (IFPRI) joined with the Centro Internacional de Agricultura Tropical (CIAT) and the Instituto Interamericano de Cooperación para la Agricultura (IICA) in sponsoring a workshop on Latin American issues as part of IFPRI's 2020 Vision initiative. The initiative aims to develop a shared view and a consensus for action on how to meet future world food needs while reducing poverty and protecting the environment in developing countries. In this paper, commissioned for the workshop, Eduardo Trigo considers the place of technology in reversing existing conditions of extreme rural poverty and degradation of the environment in Latin America by the year 2020.

Trigo notes that, in the past, even when technological support was available to farmers, public policies often provided economic incentives that led producers to employ practices harmful to the environment. Significant changes in the economic and political climate, including trade liberalization, increasing urbanization, and a greater reliance on the market to provide incentives for production and conservation, are now combining to create additional uncertainty about how the region will acquire the knowledge and technologies needed to achieve the 2020 vision.

Agricultural intensification is needed to improve the trade balance of the region, alleviate rural poverty, and reduce degradation of natural resources. Such intensification must be based on improved use of available technology as well as new scientific and technological developments. Trigo makes clear that, in the face of declining support for public sector research, new technologies and, perhaps even more critically, new institutional models are needed to revitalize the region's capacity to generate and disseminate agricultural technologies to the benefit of producers and society in general. It is hoped that the ideas presented in this paper will contribute to a discussion of the design of these new policies and institutions to help the region to profit fully from the rapidly changing economic and political realities.

Per Pinstrup-Andersen
Director General, IFPRI

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Introduction

Latin American agriculture will confront a tremendous challenge over the next 25 years. In the context of economic globalization, the region's natural resources appear to be a strategic asset the world can use to feed the additional 2.5 billion people who will populate the planet by the year 2020. Of these, about 200 million will be in the region. For many Latin American countries, the agriculture sector is a strategic asset for successful economic reactivation and growth as well as poverty alleviation. For some countries, however, food security is still a growing problem despite the potential of the natural resource base. For other countries, agricultural exports are a critical component of their balance of payments. In almost all, agriculture, including agroindustry, is one of the largest economic sectors.

In the past the interplay among the forces of dualism, surplus extraction policies intended to speed up agricultural modernization, and state intervention have resulted in marginalism, rural poverty, and overexploitation and degradation of resources. Deforestation, soil degradation, water and air pollution, and loss of biodiversity have become widespread problems affecting almost every ecosystem in the region. These problems are evidence of the dangers posed by agricultural intensification if it proceeds within the existing institutional and technological framework.

The challenge facing Latin America is how to exploit existing and future opportunities without further endangering the region's environmental assets. How to make agricultural intensification and resource conservation converge to promote equitable and sustainable agricultural and rural development in the region requires timely discussion. The nature of future technological development and the task of assuring access to knowledge and technological advances are critical issues the region will have to address. Trade liberalization, deregulation, privatization, and decentralization are providing a new set of incentives for agricultural development. In like manner scientific and technological developments in fields as diverse as biology, microelectronics, and information technologies are rapidly broadening the opportunities to employ natural resources in agricultural and food production. Market mechanisms will produce increased efficiency of resource use and, consequently, better economic performance. However, they will not in and of themselves assure a more equitable distribution of income or promote environmentally benign economic and technological behavior.

This paper furthers the discussion on technological development and agriculture in Latin America and on the need to establish a workable strategy that simultaneously promotes agricultural intensification, poverty alleviation, and resource conservation. The linkages among agriculture, poverty, and the environment are addressed in the next section as context for the discussion. The following section briefly examines some of the most relevant processes that will influence these linkages in the future. The paper then turns to likely technological paths and institutional innovations that will also influence technological development. The final section examines the elements of a strategy for technological development and institutional change that might be able to promote the joint goals of agricultural intensification, poverty alleviation, and resource conservation.

Agriculture, Poverty, and Sustainability

Close and complex interactions between people and ecological capital (soil, water, air, flora, fauna, and climate) are fundamental to agriculture. Those interactions involve relationships and conflicts among economic growth, poverty, and the environment that are dramatically visible in agriculture, more so than in any other sector. In developing countries, agricultural performance—defined as the sector's capacity to lead or contribute to income and generate employ-

ment, to achieve greater productivity in the farm and nonfarm sectors, and to provide for the country's food security—is an essential determinant of poverty and in turn of environmental conditions and resource conservation conditions.

In Latin America poor agricultural performance is at the heart of increasing poverty and the rapidly deteriorating natural resource base. Between 1979 and 1990 agricultural production grew just enough to keep per capita food production constant (FAO 1994a). The food staples self-sufficiency ratio fell from 112 in 1965–67 to 93 in 1986–88, with the number of countries with food deficits rising from 26 to 27 over that period (IFAD 1993). Since then, food security at the household level has continued to deteriorate in 8 of the 21 countries included in the latest assessment of the Food and Agriculture Organization of the United Nations (FAO 1994a).

Between 1980 and 1992, the number of people living below the poverty line increased dramatically—from 195 million to more than 250 million. During that period, the number of rural poor increased much less than the number of urban poor—from 73 million to about 80 million—because of a rapid decline in the rural population as a percentage of total population (IFAD 1993). The degradation of resources of all types—increased deforestation, soil erosion, desertification, waterlogging and salinization of soils, contamination of surface and ground waters, and loss of biodiversity—is also on the rise. Since 1960 an estimated 2 million square kilometers of forest have been cut down. In the late 1980s deforestation proceeded at a rate of about 50,000 hectares per year, most of it in tropical areas (Mexico, Central America, and Brazil). Desertification has been advancing apace. The problem appears to be more acute in the mountainous ecosystems of the Andean zone and in Central America and Mexico, where it affects an estimated 40–60 percent of all potentially arable land, but it is also present in subtropical and temperate zones (BID-UNDP 1990, 26; IICA 1993b). It is estimated that desertification and deforestation have severely affected about 19.5 percent of Latin America. According to some calculations, in the mid- to late 1980s more than 2 million hectares suffered from moderate to severe erosion.

In short, Latin America faces a vicious, self-perpetuating cycle of failed agricultural growth that feeds increased poverty, which leads to the overexploitation and degradation of resources, which then lowers agricultural productivity and feeds back into higher levels of poverty.

What is the source of this vicious cycle? Biases in technology, as evidenced by both products and use of resources, have played a role. However, agreement is relatively widespread that the self-perpetuating spiral of poverty and resource degradation linked to agriculture is essentially macro-induced, with a combination of institutional and macroeconomic conditions creating the micro-economic logic that allows the cycle to proceed (de Janvry and García 1992; IICA 1993). Technology simply evolved within those conditions. It cannot be identified as a main cause of those conditions, although it may have contributed to a deepening of certain effects (Piñeiro and Trigo 1983). The approach of promoting industrialization through import-substitution has subjected agriculture to extremely high direct and indirect levels of taxation (Schiff and Valdés 1992). Concurrently rural development has been hampered by an unfavorable structural and institutional context, characterized by inadequate and inequitable land tenure systems, misguided settlement schemes, poor infrastructure, and low levels of investment in education and agricultural services for small farmers. Together these conditions created an unpropitious economic environment for agriculture in general and for resource conservation in particular. The end result has been a massive outflow of capital from rural areas, a phenomenon that set the stage for the negative cycle described above (de Janvry and García 1992).

Conditions became more favorable to agriculture following the outbreak of the debt crisis and the stabilization policies implemented to address it. Devaluation of local currencies led to an appreciation of the real exchange rate that produced better terms of trade for agriculture and overall economic performance in the sector. These improvements were, however, counterbalanced by a decline in public investment in agriculture, the result of fiscal austerity programs aimed at the high inflation and high interest rates of that period, and the negative impact of the protectionist policies of developed countries. Ultimately these conditions led to a deepening of anticonservation behaviors and a worsening of poverty (de Janvry 1987; IICA 1992).

These basic forces underlie the poor agricultural performance, poverty, and degradation of resources. The specific manifestations of the problems—and opportunities—vary across the region, however, depending on agroecological and socioeconomic geography and specific poverty and environmental conditions. Table 1 presents a broad, although not exhaustive, typology of agri-

Table 1—Typology of agricultural situations

	Area	Activities	Characteristics of Production Systems	Environmental Problems	Poverty
Temperate commercial agriculture	Argentinian pampas, Uruguay, and southern Brazil.	Grains, oilseeds, cattle production.	Family and large farms; crop-livestock rotation.	Noncritical, but growing with agricultural intensification (biocide use is up); land degradation because of breakup of traditional crop-cattle rotations; poor soil fertility and compaction.	Displaced labor and landless rural population; subdivision of small plots—some *minifundia.*
Tropical commercial agriculture	Brazil, Paraguay, Venezuela, Colombia, Ecuador, Peru, Central America, Mexico, Chile, and Caribbean (commercial farmers).	Cotton, bananas, coffee, sugarcane, fresh fruits, vegetables.	Irrigated systems; intensive use of hired labor; high sensitivity to external markets and macro policies.	High use of chemical inputs; soil and water pollution; deforestation for export crops.	Temporary and seasonal work; insecure and sporadic work; lower wages for women workers.
Minifundia areas	Mostly concentrated on hillsides of Andean countries, Central America, Mexico, northeast Brazil; some cases in almost every country.	Traditional food and specialty crops; mainly subsistence farming.	Lower potential areas; high population pressure; frequently indigenous populations and tenure problems.	Most dramatic resource degradation (from overpopulation and poor quality and availability of resources); overgrazing; soil erosion; deforestation.	High percentage of poorest of poor in region: in 1990, 11.7 million farms, up from 7.9 million in 1980; 70 percent of farms on only 3.3 percent of land.
Entrepreneurial small farmers of the tropics	Resource-rich areas and areas close to urban centers.	Traditional and "new" crops.	Resource-rich areas, high-value crops, capital availability, and medium level of technology.	Similar to larger farmers in temperate and tropical commercial agriculture.	Profile varies; have benefited from nongovernmental organizations and low dependence on purchased inputs.
Agricultural frontier and forest margins	Amazonian and Orinoco basin areas, southeastern Mexico, and Central America.	Cattle, slash-and-burn agriculture.	Settlement process; conversion of forest into pastures.	Soil erosion; lack of technology in land cleared.	Less severe than in *minifundia* areas, but serious deficiency of infrastructure and public services.

Source: Developed by the author on the basis of background documentation and discussions held by the Inter-American Working Group for the Sustainable Development of Agriculture and Natural Resources. The Group is an informal gathering of scientists, businessmen, and politicians from the Americas, jointly convened by the Inter-American Institute for Cooperation on Agriculture (IICA) and the Earth Council to advance the development of consensual views on issues and strategies for the sustainable development of agriculture in the region.

cultural situations that is useful in highlighting and discussing the differences within the region.[1]

In the commercial agriculture categories, both temperate and tropical, poverty and resource degradation are the result of deficient and inequitable rural labor markets and distorted economic incentives that lead to inadequate and unstable labor conditions and over- and misuse of energy inputs. Although technological support has in general been good, distorted economic incentives have led to inefficient resource allocation and low profitability of resource conservation. *Minifundia* (small parcels of land resulting from the division of large estates during land reform) and small farms have resulted from the scissors effect of increasing population—the result of both internal population dynamics and displacement from other areas—and restricted access to land. These farm units are typically located in areas with poor potential for agriculture, a pattern that further complicates the situation. These units often belong to the poorest of the poor. Given the limited resources available to these categories of farmers, improved productivity through technological advances, however important, can contribute little to reducing overall poverty. In many cases these farms are not profitable, but they are competitive in terms of labor use (de Janvry and García 1992).

The agricultural frontier is always in transition and, as such, it involves an evolving array of problems. In its origins, misguided settlement schemes played a critical role in shaping land use patterns (Pinstrup-Andersen and Pandya-Lorch 1994). As these schemes were abandoned, poor infrastructure—in every possible sense—and deficient technological support became the critical problems. It is in this context that future technological strategies should be developed.

These problems are the framework within which future technological strategies should be developed. For positive agricultural intensification to occur, a new technological base that does not cause irreversible environmental damage is imperative. In many cases that type of base is already evolving. Unless the new technological strategies of the future are supported by a different policy and institutional environment, however, it is doubtful they will make much difference (Trigo and Kaimowitz 1994). Recent work by the Centro Internacional de Agricultura Tropical (CIAT) for some of the main agroecologies in the region clearly confirms this assertion (Pachico, Ashby, and Sanint 1994; Smith et al. 1994).

Issues Affecting Agricultural Development and Technological Demand

A number of issues will affect the evolution of agriculture and technological demand and opportunities over the coming decades. They include the changing nature of poverty, the repositioning of agriculture in national economies, the impact of urbanization on the demand for food, and the impact of trade liberalization and regional economic integration, as discussed below.

The Changing Nature of Poverty

Latin America has become urbanized. From 1950 to 1990 the percentage of the population in urban areas increased from 41.6 percent to 71.5 percent, and it is expected to be well in excess of 80 percent by 2020 (United Nations 1993). As this trend intensifies, the nature of poverty and the emphasis of the strategies designed to confront it are also changing. At the same time the number of rural poor continued to grow during the 1980s, reaching 88 million by 1989; 61 percent of those living in rural areas were poor. Nevertheless, the growth in urban poverty drastically outpaced poverty in rural areas, with the number of urban poor increasing to 104 million in 1989, a 65 percent jump over 1980 (IFAD 1993). This trend is expected to continue, and even if today's high rates of rural poverty remain constant, the nature of population dynamics—the relative rates of growth of the rural and urban segments of the population—implies that the rural poor in the countries of the region will become, over time, an ever smaller proportion of total population. In this context the priority in poverty alleviation will be more the availability of food than the production of food by the poor. This emphasis is especially likely given that a large proportion of the rural poor—about 50 percent—are located

[1]Members of the Inter-American Working Group for the Sustainable Development of Agriculture and Natural Resources (Earth Council) devised the typology of agricultural situations as a tool for organizing their analysis of regional resource conservation and guiding their discussion of policy alternatives to promote sustainable agricultural development.

in regions with low potential for food production (steep hillsides and degraded forests) (Pinstrup-Andersen and Pandya-Lorch 1994).

These population trends are already affecting the poverty alleviation strategies being proposed at the international level. These strategies emphasize diversification of the sources of rural income through off-farm employment and social welfare programs, rather than the integrated rural development strategies followed in the past (BID 1992). The implications of these changes will vary significantly across countries depending on the overall importance of the rural sector in their economies and the incidence of rural poverty. As poverty alleviation depends more on direct transfers, the capacity to sustain these transfers becomes a critical determinant. Larger, more affluent countries such as Brazil, Colombia, Ecuador, Mexico, Peru, and Venezuela appear to be better positioned to deal with the problem than do the smaller countries in Central America and others such as Bolivia, where the overall incidence of rural poverty is very high, agriculture accounts for a high percentage of the total economy, and the availability of natural resources is limited.

Repositioning of Agriculture within National Economies

The abandonment of import-substitution policies after the debt crisis of the early 1980s in favor of an export-led growth model has repositioned agriculture within national economies, creating new demands for agricultural intensification. The realignment of factor prices following the initial stages of adjustment in most countries tended to favor agriculture. During this period the growth rates for agriculture were much better than those of other sectors, a situation that highlights the potential of the region's natural resources as a source of competitiveness in a globalized economy (FAO 1994b).

Over the longer term several factors will increase the demand for agricultural intensification. First, since a large percentage of agricultural output consists of "wage goods," increased production and productivity will have a direct effect on any anti-inflationary policy and will attain growing importance for poverty alleviation. Second, agricultural intensification will affect the trade balance. In 1990 agriculture still accounted for more than 40 percent of all the exports of the region, and 55 percent of all the exports when oil and minerals are excluded (FAO 1994b). Third, agriculture and the food industry have greater backward linkages and income and employment multipliers than are found in the rest of the economy. Increases in production and productivity are therefore strategically important to national economies.[2]

The demand for intensification will have a favorable impact on both rural poverty and resource conservation in the small-farmer sector. Small farmers still account for a significant proportion of the production of food staples in the region, particularly in hillside areas. In some cases they also produce important export crops such as coffee and cocoa and some nontraditional crops such as tropical fruits, specialty vegetables, spices, and medicinal herbs. Stronger demand for the crops of small farmers will not only affect incomes and welfare, but also make investment in technology and resource conservation more attractive.

As the demand for agricultural intensification has grown, financial capital and agroindustry have raised their participation in agricultural production. Trade liberalization and economic deregulation are expanding market opportunities throughout the region for almost all crops—fruits, cereals, cattle production, dairy, and other specialty crops. The increased participation of financial capital and agroindustry has, however, led to a consolidation of large tracts of farm land, as required by economies of scale; lower demand for rural labor because of greater use of capital-intensive technologies and the resultant displacement of rural population; and a greater risk of resource degradation. Some private sources estimate that in Argentina about 1.5 million hectares in the pampas have been consolidated since 1992.[3] High interest rates have meant that projects have tended to be relatively short term, a situation that in turn has made resource conservation unattractive. These trends also mean an impersonal relationship with the land and disregard for the long-term

[2]Estimates for Brazil, Chile, Guatemala, and Mexico indicate that the linkage effects for the food sector are 8.7 percent, 16.7 percent, 10.2 percent, and 15.5 percent larger, respectively, than those for other sectors, excluding oil and services. When compared with the average for linkages for the economy as a whole, those in the food sector are higher by 19.5 percent in Brazil, 15.5 percent in Chile, 10.4 percent in Guatemala, and 12.4 percent in Mexico (Schejtman 1994).

[3]A personal communication from J. Tersoglio to the author. Other sources indicate that about 79 percent of the land that recently changed hands in the pampas went the same way, and foreign investment represented about one-third of that (Del Campo 1994).

sustainability of production patterns. If institutional policymakers and decisionmakers do not recognize these trends, greater poverty and resource degradation are likely. The above trends and demands will grow stronger as economies become more open and the need to balance the external accounts through export growth intensifies.

One important question bearing on the future is the likely long-term impact of the recent capital and currency crisis in Mexico on flows of financial capital into the region. It is probable that the Mexican crisis will create a stronger demand for agricultural intensification, even with reduced financial flows. There should also be stronger pressures to substitute internal savings for foreign capital to finance the economic reactivation; this will in turn contribute to a reemphasis on the role of the agriculture sector in economic growth and balanced external accounts. Some countries will probably devalue their currencies, a step that will also contribute to improved competitiveness of certain agricultural activities, particularly those of the traditional sectors, and make them more resilient to external shocks.

Urbanization and Food Demand

Urbanization is causing significant changes in the structure of food demand, changes that in turn will have important effects on the structure of agricultural production and technological development in the agriculture sector. Increasing incomes, changing lifestyles (greater participation of women in the labor force and changes in family structures, for example), and the growing spatial separation of the production and consumption of food are causing significant shifts in dietary habits. Consumption patterns are more diverse, with greater demand for a product mix of better quality cereals, livestock products, fruits, and vegetables. This type of demand makes processing, storage, and transportation services more important. It also changes the nature of the linkages between the primary sector and the rest of the agricultural food chain. Farmers are getting a lower share of the final prices of their products and increasingly are losing direct contact with consumers and becoming producers of inputs for agroindustry. In the urban distribution system, the increased participation of large retailers and vertical integration of production and marketing systems are deepening the impact of these trends on the structure of the food chain.

In general, greater linkages between food producers and agroindustry will bring important socioeconomic and environmental benefits to rural areas, particularly a decline in the perishability of agricultural produce and postharvest losses and increases in off-farm employment and incomes. Even though the producers' share of the final price may be smaller, the reduction in postharvest losses, greater stability of demand, and increased off-farm employment opportunities can compensate for the decline in income.

Not all types of agriculture are being affected the same way. The impact depends on the product mix and organizational and management capacities. The impact of the promotion of technological progress and growth of farmers' income will be less for traditional agroindustries—those linked to basic grains—and those involved with highly complex food products than it will be with agroindustries linked to oil crops, livestock, and nontraditional products such as fruits and vegetables, flowers, and other specialty crops. The dynamics of final demand and the level of industry concentration appear to influence significantly the extent to which the growth in the linkages of agroindustry with producers affects the farm sector (Schejtman 1994). At the microregional level, the impact on resource conservation will depend on the evolution of product prices relative to off-farm employment and income. In many traditional areas resource conservation in the past has deteriorated as the growth in off-farm income opportunities and falling or stagnant farm product prices have made it less profitable (de Janvry and García 1992). Increasing interest rates—either for the whole economy or as a reflection of imperfect access to credit for some segments of the rural sector—could intensify this effect.

These processes call for research institutions to diversify their research to cover a wider product mix and to pay more attention to incorporating the needs of other aspects of the food chain such as quality and timely delivery. The need for technological research and development in support of subsectors such as packing, storage, and intermediate processing is growing, particularly where there is greater participation by small and medium-size firms, which in general are unable to internalize research and development.

Trade Liberalization and Regional Economic Integration

Trade reform has gradually emerged as a centerpiece in the formulation of Latin America's new development strategy, and it is one of the key factors affecting the development of agriculture in the region. After decades of protectionism and an anti-export bias, the elimination of quotas, prohibitions, and export taxes and the gradual reduction of the average level of

import taxes and export subsidies are creating a drastically different set of relative prices for agriculture. These new conditions will benefit export-oriented activities the most, as they are better able to exploit the new market opportunities. The more traditional segments linked to the previously protected domestic markets will suffer from increasing exposure to external competition. The impact on different countries will vary depending on whether they are net agricultural exporters or net food importers.[4] Greater trade liberalization will also feed into the already mentioned demand that research and development institutions cover a broader mix of products and processes. The effects on the environment will tend to be negative as the new market opportunities will not be accompanied by environmental regulations and institutional reforms directed at inducing market processes to internalize the full cost of intensification.[5]

The General Agreement on Tariffs and Trade (GATT) and the liberalization of global trade can be expected to have an impact on future land use and production patterns. The emerging regional economic integration and trade agreements will likewise have an important effect on land use and agricultural production. The creation of larger economic units such as those under the North American Free Trade Agreement (NAFTA) and the Southern Common Market (MERCOSUR) will spark a significant reorganization in land use as current specialization and production patterns are exposed to market conditions as well as less restrictive rules for investments and capital flows. NAFTA will affect Mexican small farmers producing maize, beans, and other staples the most because they experience greater competition from American commercial producers. Producers of fruits, vegetables, and livestock will benefit from a further consolidation of their already important share of the American market.

MERCOSUR will probably generate an even greater reorganization of land use and production patterns that will affect the production of not only grain, livestock, and dairy products, but also specialty and industrial crops (cotton, sugarcane, and tobacco). MERCOSUR will have the greatest impact on regional economies in Argentina and Brazil. It will also induce the relocation of some agroindustries. Grain and dairy production will probably expand in Argentina, augmenting the demand for intensification already produced by the gradual dismantling of the subsidies of the countries in the Organization for Economic Co-operation and Development (OECD). In Brazil the soybean, citrus, and sugarcane complexes will benefit, whereas the family farms producing wheat and temperate fruits in the southern regions will experience increased pressure from Argentine producers. The size of the markets involved, particularly in Paraguay and Uruguay, will magnify the effects of urbanization, already important in most countries, once their products have free access to the large urban centers in Argentina and Brazil.

From an environmental point of view, in the medium term the elimination of trade barriers implicit in the integration agreements should bring land use patterns more in line with the agroecological potential of the resource base. Environmental and natural resource issues were a minor point in the MERCOSUR negotiations that emerged only when they appeared as a potential restriction on trade and the relative competitiveness of given sectors. The large divergences across the partner countries in their infrastructure, land tenure, environmental regulations and institutions, access to technology, and other factors have not been formally recognized. Negative effects could arise as implementation gets under way, with the outcome depending on how these issues evolve in the coming decades (Novara 1995).

Technological Opportunities and Constraints

The above trends point to a number of areas where technological development will be a critical factor in agricultural production, poverty alleviation, and

[4]A recent study by the Inter-American Institute for Cooperation on Agriculture shows that for the region as a whole trade liberalization will yield an economic benefit of between $189 million and $1,040 million per year. The nine net exporting countries will receive a net benefit of up to $2,088 million per year, whereas the net importing countries will find their bill for food imports might run as high as $1,048 million per year (IICA 1992).

[5]The negative effects of the expansion of banana and livestock production in Central America and of soybeans in Santa Cruz in Bolivia and the disproportionate increase in the use of agrochemicals for vegetable production in Central America and some of the Andean countries are examples of the dynamics of the process (Kaimowitz 1992; Thrupp 1994). However, a trend toward greater discrimination by the markets with regard to natural resource use and greater integration of environmental regulation with trade regulation could compensate for these negative effects.

resource conservation. International trade reform, regional integration, and urbanization will lead to a repositioning of agriculture within national economies and a restructuring of agricultural production in response to significant increases in demand for both traditional and more diversified products.

The region has the natural resources to exploit both emerging domestic and international market opportunities. Can it develop a scientific and technological base that will permit exploitation of these resources without further damaging the environment and increasing poverty? Answering this question in general terms is difficult because of the agroecological and socioeconomic diversity of the region. There is also a host of exceptional cases. Nevertheless, some general points can be made about the adequacy and potential of existing technologies and knowledge, the likely contributions of new biotechnologies and information technologies, and the constraints to be overcome to permit movement toward a new technological pattern that effectively combines higher productivity, equity, and conservation of resources.

The Prospects for New Technologies

How big an impact will biotechnology have on agriculture and food production in Latin America over the next decades? There is agreement that further developments in biotechnology offer potential benefits for the region and the world. They may allow many of the factors that now limit further increases in production and productivity to be circumvented while at the same time improving resource management and environmental conditions (Quintero 1993). However, recent estimates are that at their present level of development the impact of new technologies is unlikely to be felt in the agricultural markets until well into the next two decades. Although new discoveries are occurring rapidly and the number and variety of new organisms are expanding rapidly, initial expectations were overstated. The first genetically engineered crops (such as tomatoes with extended shelf lives) are already on the market, and more are expected over the next few seasons (for example, cotton with genes of the bacterium *Bacillus thuringiensis* [BT] for pest control is expected in 1996/97, BT maize in 1996/97, and herbicide-resistant soybeans in 1996/97), but significant market developments will not be seen until the next decade. The results of work to improve the nutritional value of some basic food crops such as cassava, maize, and potatoes is still 5 to 10 years away from farm-level application. At the production level the impacts will be mostly limited to tissue culture and other rapid propagation techniques for better planting materials (Jaffé and Trigo 1994).

Advances in conventional technologies will remain the primary source of growth in production and productivity. Progress in the near term will involve mostly improvements in research methodology (use of genetic probes and mapping and of in-vitro techniques) and diagnostics (monoclonal antibodies) in both plant and animal production. Such advances are already entering the market, along with new animal vaccines, microbial insecticides, and applications in the food industry (examples being fast contamination tests, genetically modified enzymes, food flavors and enhancers, improved yeasts, and controlled fermentation processes) (Quintero 1993).

Identification of pest- and disease-resistant genes is moving rapidly, as are advances in understanding the genes and mechanisms that determine complex traits such as more efficient photosynthesis and greater tolerance to drought, frost, and poor soils. These products await, however, the resolution of a number of complex technical issues (Schmidt 1995). Within the next five years the more technologically advanced farmers will probably be using pest- and disease-resistant and herbicide-tolerant varieties of soybeans, cotton, alfalfa, sunflowers, and potatoes. Generalized use should not be expected before the end of the decade. Insect and herbicide-resistant fruits and vegetables, as well as varieties with improved organoleptic, industrial, processing, postharvest storage, and nutritional characteristics, will also become available. Progress could be slower with wheat, maize, and rice for technical reasons. For example, researchers working with rice are achieving greater success using traditional breeding techniques in combination with molecular markers than they are with genetic engineering approaches.

A second, and probably more important, factor that will limit the impact of biotechnology on Latin American agriculture has to do with research priorities and levels of investment. Currently the focus of research is on the agricultural priorities and crops of interest in developed countries. Some of the new developments will likely "trickle down" to commercial agriculture in the developing world, but the benefits to small and resource-poor farmers will be marginal and circumstantial (Schmidt 1995). This trend is logical given that the bulk of investments in research come from private sector sources in the developed world (Greeley 1992). The same can be said about environmental impacts, where the re-

search essentially is directed toward the development of chemical tolerance and not pest resistance.

The most serious issue is not the direction of investments in developed countries, however. It is the low level of research and development taking place within Latin America itself. By the early 1990s about 150 researchers in the region were working on biotechnology-related projects, most of them located at universities and basic science or advanced research institutions, including those at the international centers of the Consultative Group on International Agricultural Research (CGIAR) such as CIAT, Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), and Centro Internacional de la Papa (CIP). One simple indicator says a great deal about the inadequacy of investment in biotechnology in Latin America: one multinational company, Monsanto, employs in its laboratories more than twice the number of scientists doing biotechnology work as at all the other institutions in the region combined. According to a study by the Inter-American Institute for Cooperation on Agriculture (IICA), only 33 research groups in the region have a strong capability to carry out traditional biotechnological research (on fermentation, tissue and cell culture, immunology, and embryo technologies), and only 6 have a capacity in modern molecular biotechnology. Weaker capacities were identified at about 20 other institutions. Their links to producers, an essential aspect given the nature of biotechnology, are similarly weak. IICA identified about 60 agrobiotechnology firms, of which about half are involved with plant propagation and seed production, the rest with pharmaceuticals (vaccines and embryo technologies) and food (Jaffé and Trigo 1994).

Experts have identified the lack of long-term capital required to finance research and development and the weakness of the technology infrastructure needed to produce generic technologies as determinants of the slow development and weakness of the industry. Even in the more advanced countries where there are formal biotechnology policies and public programs, the experts found their initiatives to be ineffective, either because they lacked clear priorities and focus or because the levels of funding were inappropriate (Jaffé 1991). Investment by the development assistance community, including foundations, universities, industrialized countries, and donor agencies, however important in specific cases (such as the work on rice and cassava funded by the Rockefeller Foundation or CIP's work on potatoes), will have only limited value and impact (Greeley 1992).

Technological Progress from Conventional Sources

There is increasing evidence that the rate at which yields of some major crops such as wheat and rice are increasing under experimental conditions is slowing significantly (McCalla 1994). It is also true that when compared with the technological leaders, the productivity indicators for most crops in the region are low. The implication is that there is potential for substantial gains in productivity.[6] The significant technological change that has occurred not only in commercial agriculture but also with the crops of small farmers is further evidence of this potential.[7]

The gains in productivity have been achieved mostly by small farmers abandoning traditional farming practices and by greater application of inorganic fertilizers and crop protection chemicals in general. The latter trend, however, has also caused significant and growing natural resource problems. Overall consumption of fertilizers and agrochemicals has grown at high rates: the use of fertilizers doubled between 1970 and 1990 and imports of pesticides rose by more than 30 percent between 1988 and 1992 (FAO 1994a). Although this trend is expected with intensification, there is widespread evidence that these inputs are over- and misused. In

[6]Even though the value of comparisons of crop yields outside homogeneous agroecological contexts is limited, such comparisons provide a good idea of the range of possibilities. For instance, average yields for beans, a major hillside crop, are similar in Andean and Central American countries but are well below national yields in Colombia (15 percent lower) and Guatemala (28 percent lower), countries that are comparable in their agroecological diversity. With rice, Venezuela's yields are 30 percent lower than those in Colombia even though both countries use similar, favorable irrigation methods. Differences of like or even greater magnitude can be found with other crops, such as potatoes, wheat, soybeans, and maize (Pachico, Ashby, and Sanint 1994; FAO 1994b).

[7]Between 1979/81 and 1989/91 the yields of wheat, rice, and sunflowers at the regional level rose more than 3 percent per year; in the case of beans and potatoes, two of the major small-farmer hillside crops, yields during the period 1961–90 grew 20 percent for beans and 40 percent for potatoes in Central America, and 26 percent for beans and 35 percent for potatoes in the Andean countries. Of the major crops, only the yields of maize have been relatively stagnant. For the region as a whole, the annual growth in productivity during the period between 1978–81 and 1989–91 was less than 1 percent, with only Guatemala showing a significantly higher rate of almost 3 percent per year.

many cases aversion to risk and lack of information are the reasons. Studies reported by Pachico, Ashby, and Sanint (1994) indicate that 50 of the 250 chemicals in use in Colombia are banned elsewhere, a situation reported for other Andean and Central American countries (Thrupp 1994; Kaimowitz 1992), as well as for grains and other crops (cotton) in the Southern Cone (INTA 1991). Excessive and careless use of highly toxic chemicals is a significant health hazard for rural laborers that compounds the already important negative impact of the high rates of deforestation on biodiversity.

The question now is whether intensification can continue along the same technological path, and what alternatives should be considered. If in the immediate future the agricultural community cannot turn rapidly to biotechnology as a replacement for inorganic fertilizers and chemical pest and disease control products, gains in productivity will continue to rely mostly on conventional improvements in animal and plant breeding and chemical technologies, with more efficient use of resources and agroecological considerations becoming increasingly important concerns. Rather than going from the "green" to the "gene" revolution, as Quintero (1993) put it, the more likely scenario is technological "hybridization" and "blending," with a shift from existing energy-intensive technologies to "win-win" technologies that increase productivity and improve natural resource management as a byproduct, or to conservation technologies that contribute integrally to gains in agricultural productivity. Work toward more efficient use of technical inputs and better soil and water management in combination with progressive incorporation of ecological and environmental perspectives and increased use of information technologies will mark the initial transition. Biotechnology will play a growing role as its products and technologies enter the marketplace (Ruttan 1992). The distinction between "traditional" and "modern" technological environments will lose relevance as the predominant pattern becomes one in which information and management sciences and biotechnology are blended with traditional knowledge on the basis of specific locational requirements (Gallopin 1992). To support this transition research priorities should evolve toward improving agronomic practices rather than focusing on plant breeding (Ruttan 1992).

The experience to date with integrated nutrient and pest and disease management technologies in both commercial and small farm agriculture is positive. Ecological and environmental paradigms and perspectives are being incorporated into the agricultural intensification strategies at a number of the region's larger national agricultural research institutions.[8] The work of the international and regional centers (CIAT, CIP, CIMMYT, IFPRI, and Centro Agronómico Tropical de Investigación y Enseñanza [CATIE]) on resource management has been a strategic factor mobilizing some of these developments. Nongovernmental organizations have also had an active role, particularly in the smaller countries and with small and resource-poor farmers. The importance of these organizations in this area will probably grow as some expand and develop closer linkages with the research institutions and universities in the region.[9]

Several factors will limit these processes. An initial one is the lack of or inadequate information about some of the major agroecologies, particularly in the tropical areas, and the small numbers of people with adequate training to apply agroecological and environmental perspectives. Effective research using these perspectives requires disciplines and approaches that are more systemic and territorial, such as ecology, geography, agrometeorology, plant physiology, and farming systems, all of which are weak areas in the research institutions. Some traditional disciplines such as entomology, soil sciences, and forestry and agroforestry will need reorientation to incorporate these perspectives and use a more systemic approach (Altieri 1987). Further, since the new approaches are knowledge- and management-intensive, research and technology transfer in the

[8]The Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), for example, has undertaken an extensive reorganization to incorporate resource management and sustainability criteria into its priority-setting and program development and implementation. For several years the Instituto Nacional de Tecnología Agropecuario (INTA) has undertaken a number of strategic research projects to develop resource-conserving technological alternatives for Argentina's major agroecological regions (the humid pampas, the semi-arid pampas, and areas undergoing desertification).

[9]The work of the Consorcio Latinoamericano sobre Agroecología y Desarrollo on methodology and the diffusion of experience and human resource development will probably be critical in this process. The recent agreement with the Latin American Association of Schools of Agriculture and other universities to develop postgraduate programs with an agroecological perspective is an example of a possible contribution.

areas of information and management technologies must be a high priority (Ruttan 1992). These needs come on top of still conflicting and unresolved initiatives to integrate social science work into agricultural research programs, which must be recognized as a limiting factor to technological progress. Finally, the new technologies will be increasingly location-specific, something conventional approaches to technology transfer have not handled well (Agudelo and Kaimowitz 1991).

A second factor is the intensity of management required by these new technologies at the farm level. As noted, the new technologies are more knowledge- and information-intensive. Their application requires capabilities at the farm level and support services not available in most situations. At the same time, in the cases where small farmers are also partially participating in the labor market, incorporating these technologies may be unprofitable because of competition from other income-earning opportunities (de Janvry and García 1992).

The Institutional Environment for Research

The institutional environment for agricultural research and technology transfer in Latin America is in deep crisis. The public research institutions have evolved from a world that sought to modernize agriculture by transferring technology from developed countries and integrating peasant farmers into the market economy. Agricultural research and technology transfer were seen as a public good; institutional organization and market development for agricultural inputs and products were beginning to be developed; and the state was widely recognized as the main actor in the promotion of economic and social development.

In the last two decades this situation has changed dramatically. Scientific and institutional developments have altered the public-private nature of agricultural research and technology development. Political and economic reforms are rapidly modifying what is perceived to be the legitimate role of the state within Latin American societies. The research and technology transfer institutions need to undertake significant changes. This paper cannot analyze these changes in depth, but it is important to anticipate some key aspects of evolving technological scenarios over the next two decades.

The Decline of Public Research and Technology Transfer Institutions. The crisis in the institutions responsible for national agricultural research and technology transfer can be traced to several factors. Technological demands and, consequently, research priorities are changing in a sometimes contradictory manner. As a consequence of agricultural diversification strategies and greater urbanization, there has been a move toward a broader product mix and away from food crops and farm-level technologies. The need for research on nontraditional crops, genetic resources, postharvest technologies, other technologies aimed at boosting value added, and access to biotechnology is increasingly dominating discussions about priority-setting and resource allocations for research. In contrast with this trend, concerns about agricultural sustainability and resource management are emerging (Trigo and Kaimowitz 1993).

At the same time, public research institutions are clearly losing the support they once enjoyed. Latin America has been part of the worldwide trend in the past decade toward a smaller public sector. The new ideological and economic perspectives call for less government intervention in agriculture, and public spending has been drastically curtailed. Although, early on, investment in agricultural research was not affected, more recently budgetary support has deteriorated significantly. Between 1977 and 1992 investment in research in the region grew by only about 1.5 percent a year, down from almost 6 percent in the period 1967–77. In every country in the region except Colombia and Argentina the resources available per researcher fell substantially (Lindarte 1994). Further evidence of the magnitude of this trend is that since 1991 the research budgets for INTA in Argentina, the Instituto Colombiano Agropecuario (ICA) in Colombia, EMBRAPA in Brazil, and the Instituto Nacional de Investigaciones Forestales, Agrarias, y Pecuarias (INIFAP) in Mexico, the four largest institutions in the region, have fallen systematically when adjusted for inflation. In every case there are open discussions about the need for major reorganization. A similar trend began even earlier at the extension institutions. Among the reasons were their increasingly bureaucratic nature and inability to respond effectively to the increasing complexity of agriculture. Their reputation became so bad that many countries eliminated their extension services entirely (Rivera and Gustafson 1991).

Nonpublic Alternatives. Parallel to the declining role of public institutions has been a rise in the role of private entities—including suppliers of inputs, large commercial farms, farmers' associations, different types of foundations, and nongovernmental organizations—in research and technology transfer. This trend has been a natural outgrowth of the insti-

tutional development of the agriculture sector, consolidation of the markets for agricultural inputs, and improvement in rural infrastructure that have taken place over the last three decades (Trigo and Piñeiro 1981; Pray and Echeverría 1991).

Current trends to deregulate and open up economies, together with the increasing recognition of intellectual property rights for genetic materials and other agricultural inputs produced through biotechnology, will continue to strengthen private interest in technology development, as both the markets and possibilities for protecting investments expand. Still, direct private investment in agricultural research and development is low, representing only a minuscule proportion of total national investment (Venezian 1992; Falcone 1993). Apart from private firms, foundations that support research and nongovernmental organizations have also become significant players, facilitating the flow of international assistance, particularly for technology transfer efforts directed at small farmers (Trigo and Kaimowitz 1993). However, even where these initiatives are more developed, their magnitude is insufficient to compensate for the retreat of public sector institutions, and their future is uncertain in that most lack stable long-term sources of funding and have limited installed capacity. Nevertheless, this diversification of options and capacities is a positive step.

Another point is that as productive systems and their demand for technology and research diversify, more varied organizational responses will be required. Existing institutions are not, however, adapting easily, in many cases because they are restricted from entering into collaborative and joint efforts with emerging private-sector entities. This constraint, together with budgetary restrictions, is creating a perception of ineffectiveness that is seriously damaging their future capacities.

In the current economic and institutional context it will be difficult to reverse the above trends. It is likely those trends will intensify as many countries undertake a second round of economic adjustment and governmental reform. Even if there is agreement on the need to meet the technological demands discussed above, the countries must regain their ability to define policies and implement programs. It could be some time before clear alternatives emerge. Future strategies should be developed assuming an unstable institutional situation.

Ultimately the nature of the new institutional framework will depend on the characteristics of each country. It is likely, however, that the institutional context for agricultural research and technology transfer will be one of increasing diversity, with a growing number of public and private initiatives coming together to meet the demands and share responsibilities based on the public versus private nature of the demands.

A Framework for Agricultural Research and Technology Development Strategies

The challenges confronting agriculture and food production over the first two decades of the twenty-first century appear enormous. At the same time that food and agricultural production must be increased, both the increase in the number of people living below the poverty line and the growing degradation of resources must be reversed. Latin America possesses the natural resources needed to produce food for a much larger population. It also has the technological base necessary to properly exploit this natural resource base. But these challenges must be met in the context of the dramatic structural, institutional, and policy changes taking place in the region—changes that in many cases seriously limit the capacities of countries to exploit their natural resource bases effectively.

Differentiated Agricultural Potential and Technological Opportunities

Technology is a powerful tool. However, technological progress does not hold the same potential for all agricultural situations. In general its effectiveness is closely related to the quality and quantity or both of natural resources and population density (Schuh 1992). Unfortunately, often this variability in potential has not been recognized, and scarce research and technology transfer resources have been used inappropriately to develop alternatives for marginal, low-productivity areas where the social problems are rooted in overpopulation and not low productivity per unit of resource. As poverty becomes an urban phenomenon, technological development should focus on increasing the production of food and on benefiting the poor as consumers of food, and not necessarily as producers of food. This distinction is relevant given that in many if not most cases the income level of the rural poor can be raised more efficiently through more off-farm employment opportunities (IICA 1993; Chiriboga and Plaza 1993).

A Positive Policy and Institutional Environment

In the past state intervention and public institutions played a substantial role in agricultural development. Emerging political and economic conditions suggest that future processes will increasingly be subject to internal and external market dynamics and opportunities and that agricultural development will be largely market-led, rather than protected by specific policies. This evolution is already occurring as structural adjustment has severely weakened the public institutions that support agriculture, and most agricultural and rural development policies have become subsidiary components of broader macroeconomic policies. If these trends are not reversed and new priorities for public intervention developed, the chances of reducing poverty and implementing agricultural intensification initiatives that conserve resources will be very limited.

Effective initiatives will require continued movement toward opening up and restructuring national economies. Market conditions are essential to guiding adjustments in the patterns of production. At the same time public policies can help guide those adjustments and buffer their negative social and environmental effects. At the technological level win-win alternatives will require not only a renewed—and probably increased—research effort but also a number of concomitant policies and institutions to establish a microeconomic environment conducive to their adoption. Ruttan (1992) refers to "incentive compatible institutions"—entities that bring private, institutional, and social objectives and behaviors together. If all are not present, required technological advances will continue to be chimeric. There is little agreement on what those institutions should be like. Many rightly argue that no recipe applies to all situations and that the success of any arrangement will be tied to its ability to respond to the needs and idiosyncrasies of particular cases.

Many actions need to be taken at the national level. International institutions can also make a significant contribution by providing information, generating needed debates, and assisting with the transition. Research on alternative scenarios for land use, farming and food systems, the environmental impacts of different agricultural and natural resource policy options, and the relative effectiveness of alternative mechanisms to internalize environmental costs in economic decisionmaking should be high priorities in the short run. They will not only feed into the institutional and policy innovations but will also help guide identification of the priorities for research and technology in consonance with policy development.

Research and Technology Generation Capacities

Public research is in crisis not just in Latin America. The ongoing resource problems confronting the CGIAR system show clearly that the roots of the problem go far beyond regional manifestations. This issue is serious because future demands for technology can be met only through a gigantic technological transformation. In the past, technology was needed for just a few major commodities produced in rural areas. A much larger mix of products extending beyond primary production to include increased efficiency in storage, transportation, and processing will drive the demand for technology in the future.

Even minimal analysis would show that a return to previous investment levels would be insufficient and that substantial increases in investments are in order. Although this paper does not analyze investment levels, the evidence indicates the intensity of research is declining in Latin America to the point that some institutions have scarcely enough resources to cover salaries.[10] The task is to regain the legitimacy needed to attract resources. The goal, however, should not be revitalization of these institutions as currently structured. They evolved in a context very different from today's, one in which all segments in society nationally and internationally perceived that a particular set of public goods was essential for development. These conditions have changed, and institutions need to adopt new designs consistent with this reality.

Several specific issues for discussion and action are worth noting. One is identification of what "new" public goods should be produced. Recouping necessary levels of investment will depend on the public sector regaining legitimacy for its claim to a higher share of public resources. The required win-win technologies clearly have the nature of public goods; however, a growing and significant share of

[10]There are no recent studies of the whole region, but there are indications that the scarcity of resources applies throughout (Lindarte 1994). The author confirmed this situation for EMBRAPA in Brazil, ICA in Colombia, and INTA in Argentina.

what research and technology development institutions do today does not fall in this category anymore. The emergence of nonpublic institutional alternatives reflects this new situation, and it needs to be formally recognized in the organizational and funding structures of institutions engaged in technology development. More flexible legal and operational arrangements directed at facilitating cooperation and even sharing strategic capabilities across public research institutions, universities, and other research centers are needed, together with a substantial increase in funding by the private sector. Institutional redesign will have to go beyond just increasing the efficiency of resource use. It must produce new instruments to solve the different problems found in today's different environment.

Exploitation of Biotechnology

Even though biotechnology cannot be expected to have immediate widespread effects, it will be increasingly critical to development. The issues are how to assure access to needed knowledge and how to influence research and development toward the region's priorities. The capacities of agricultural research institutions in molecular biology, biochemistry, and other areas needed for biotechnology development are weak and will probably continue that way even in the larger institutions and countries. Given the dynamics of developments in this field, much of the knowledge and technologies will come from private investment in developed countries. Strategies oriented to creating utilization capacities and an appropriate environment for technology transfer appear to be the most effective alternatives.

Mechanisms for interinstitutional cooperation at both the national level (with universities and other research institutions) and the international level (through regional programs and networks and international centers) would help create the needed critical mass. Explicit efforts should also be made to promote linkages and joint ventures between the region's research institutes and multinational companies. If these links are developed in the proper institutional context, they could be important instruments in keeping abreast of new technological developments and exploiting the potential contribution of new technologies to regional production (sustainability, niche markets, and tropical food crops, for instance).

For technology transfer to take place, setting up biosafety protection mechanisms and a clear framework for protecting intellectual property rights is essential. Most advances in new technologies are proprietary and will only be made available if proper rules are established. Safety considerations have played an important role in public opinion regarding biotechnology in developed economies. Some even argue that the slower-than-expected rate of progress owes much to negative perceptions and public concerns over the safety of new technologies. These concerns extend beyond national environments, surfacing in some strategic international agreements such as the Biodiversity Convention, where at present the signatories are discussing the development of a specific protocol to regulate biosafety in biotechnology-related activities. Given that many of the advances in this field will come from technologies developed outside the region, in some cases linked to direct foreign investments, establishing clear rules for their use could permit faster exploitation of the benefits of these technologies.

Technology Transfer

Promoting the implementation of win-win technologies and reaching small, resource-poor farmers will require significant improvement of technology transfer infrastructures as well as the capacities to bring a wide array of perspectives and capabilities together on a site-specific basis.

Technological changes that conserve resources are knowledge- and management-intensive. Generally they require relatively small amounts of new physical inputs. But they must have the capability to adapt to local conditions and a capacity with certain technologies—biological control, for example—to work with individual farmers and to involve groups and communities. This involvement requires revitalization of participatory research and extension. Greater decentralization of research institutions, with increased emphasis on interactions with farmers' organizations and participation of beneficiaries in the research and its dissemination, will be essential. Nongovernmental organizations are also important, especially for farmers' participation and the coordination of technological activities with efforts in other areas, such as community development, social infrastructure, and broader environmental issues. Success in implementing actions in this direction is not going to come easily. Disappointment with past attempts at institutionalizing research on farming systems and other participatory approaches, and concerns about the cost-effectiveness of integrated rural development projects, are negative factors to be overcome.

A Final Comment

The challenge of making food available for a greatly increased population while alleviating poverty and preserving the natural resource base is enormous. From the technological standpoint, it is doable. As in the past the issue is not technology. Rather, it is ensuring that the institutional and policy environment needed to encourage appropriate production behaviors will emerge.

The economic and institutional reforms under way in most countries in the region are providing a new, less distorted macroeconomic environment for agricultural development. Production should develop more in line with the region's comparative advantage in agricultural and food production, and the agriculture sector should become a dynamic component of economic reactivation.

Parallel with these reforms, urbanization and trade liberalization are demanding deep revisions in poverty alleviation strategies and are setting in motion vast changes in the patterns of production and land use. The impact of these changes on poverty and environmental conditions will ultimately depend on whether they are accompanied by an institutional restructuring oriented to bringing together the often contradictory objectives of production intensification, resource conservation, and increased equity.

Scientific and technological developments hold great promise for increased productivity, particularly as new biotechnologies are applied to priority products and problems in the region. This biotechnological promise will not be realized on a significant scale, however, until well into the next decade. Even then the effects will be highly dependent on the region's making a conscious effort to create the capabilities to exploit these new technologies. In the meantime most technological progress will come from a shift in present technological knowledge toward applications that progressively incorporate both resource conservation and high productivity. In this transitional period new institutional perspectives will be critical.

The needed technologies are often complex, do not necessarily respond to felt needs, are difficult to disseminate, and have results evident only in the mid-term. In this context market-oriented approaches supported by public sector interventions probably cannot create an appropriate environment in which research priorities and microeconomic behaviors converge. Public research institutions have become weak, and the progressive dismantling of public sector capacities to design and implement development policies for the rural sector are signs that institutions are not evolving in an appropriate direction. Concern is warranted about the possibility of the region's effectively exploiting its food production capabilities in an equitable and sustainable way.

Strategies for technological development in agriculture need to address the above issues so as to avoid the frustrations of the past. Beyond a doubt, technological progress is necessary to alleviate poverty and achieve food security. Technology by itself, however, can hardly produce the expected results without a conducive institutional environment. Creating these conditions is essential if the challenge of an environmentally sound and food-secure world is to be achieved by the year 2020.

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