IICA

REGIONAL OVERVIEW OF FOOD SECURITY IN LATIN AMERICA AND THE CARIBBEAN WITH A FOCUS ON AGRICULTURAL RESEARCH, TECHNOLOGY TRANSFER AND APPLICATION

Prepared for the World Food Council / United Nations Development Program Interregional Consultation on

MEETING THE FOOD PRODUCTION CHALLENGES OF THE 1990s AND BEYOND

January, 1991

PROGRAM II: TECHNOLOGY GENERATION AND TRANSFER

WHAT IS IICA?

The Inter-American Institute for Cooperation on Agriculture (IICA) is the specialized agency for agriculture of the inter-American system. The Institute was founded on October 7, 1942 when the Council of Directors of the Pan American Union approved the creation of the Inter-American Institute of Agricultural Sciences.

IICA was founded as an institution for agricultural research and graduate training in tropical agriculture. In response to changing needs in the hemisphere, the Institute gradually evolved into an agency for technical cooperation and institutional strengthening in the field of agriculture. These changes were officially recognized through the ratification of a new Convention on December 8, 1980. The Institute's purposes under the new Convention are to encourage, facilitate and support cooperation among its 32 Member States, so as to better promote agricultural development and rural well-being.

With its broader and more flexible mandate and a new structure to facilitate direct participation by the Member States in activities of the Inter-American Board of Agriculture (IABA) and the Executive Committee, the Institute now has a geographic reach that allows it to respond to needs for technical cooperation in all of its Member States.

The contributions provided by the Member States and the ties IICA maintains with its 12 Permanent Observer Countries and numerous international organizations provide the Institute with channels to direct its human and financial resources in support of agricultural development throughout the Americas.

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ISSN-0253-4746

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PROGRAM II: TECHNOLOGY GENERATION AND TRANSFER

REPORTS, RESULTS AND RECOMMENDATIONS
FROM TECHNICAL EVENTS SERIES
ISSN-0253-4746
A1/SC-91-06

February, 1991
San Jose, Costa Rica

"The views expressed in signed articles are those of the authors and do not necessarily reflect those of the Inter-American Institute for Cooperation on Agriculture."

CONTENT

Towards a New Agricultural Revolution in Latin America and the Caribbean[1]

INTRODUCTION

As the countries of Latin America and the Caribbean (LAC) enter the last decade of the 20th century and approach a new millennium, food security remains a major item on an unfinished regional policy agenda. What are the dimensions and magnitude of food insecurity in LAC, and what are the functions of technological change in overcoming food insecurity? This is the subject of this report.

1. Dimensions of Food Security in LAC

Access by all people at all times to sufficient food is a multidimensional issue in LAC. On the one hand it includes ***average sufficiency***: production, trade, and stocks of foods for assuring sufficient and stable supplies of staple foods for the population at large[2]. On the other hand it includes ***specific insecurity***: food insecurity for low income and vulnerable groups. Food insecurity in LAC, in turn, encompasses two dimensions. At one level is food insecurity associated with structural rural and urban poverty, the long-term dimension of *chronic food insecurity*. At the other level is food insecurity derived mainly from variability of food supplies, the short-term dimension of *transitory food insecurity*.

In the LAC, the underlying cause of continuous inadequate access to food -chronic food insecurity- is the persistent low earning power of large social groups (Valdez and Siamwalla, 1981). In rural areas large groups of poor peasants cannot produce sufficient food for family consumption within their small plots of land (de Janvry *et al.*, 1989). In addition, many peasants use traditional

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[1] This document was prepared by the Program Technology Generation and Transfer of the Inter-American Institute for Cooperation on Agriculture (IICA). The following experts participated in its preparation: Jorge Ardila, Enrique Alarcon, Carlos Benito, Sue Hayes, Walter Jaffe, Eduardo Lindarte, Edgardo Moscardi, Carlos Pomareda, and Eduardo Trigo

2 The concept food security does not have a well defined meaning. It varies across organizations and authors (Adelman and Berk, 1988) and it has been changing over time (Swaminathan, 1990). This report uses a definition and a typology closely related to those used by IFPRI (Valdez, 1981), the World Bank (Reutlinger, 1985).

techniques, have limited access to credit, input and commodity markets, and face high transportation costs and high post-harvesting losses. In cities and towns, large groups of urban poor cannot generate enough income to purchase foods in sufficient quantities or diversity. Their small purchasing power is a consequence of many factors: their poor nutritional and health status; their lack of skills; their poor information; their location in slumps; and the generalized shortage of jobs in the cities and towns. Small plots of land for peasants and lack of jobs for the urban poor are also the result of high population growth, in particular during the 1960s and 1970s.

This long-standing problem of chronic food insecurity in LAC is compounded by instances of temporary food insecurity. The very same groups, plus vulnerable groups like pregnant mothers and children, are also subject to temporary declines in their access to adequate nutrition. These declines are caused by production and price fluctuations induced by weather variability and by other natural disasters. They are also induced by variations in food imports due to balance of payment problems. However the temporary decline in access to sufficient food is a consequence of variations in households' real incomes. For poor peasants bad weather can reduce their income in kind-- it can reduce food production for family consumption and for exchange. For the urban poor, substantial increases in food prices imply significant declines in their real incomes. This is so because of the costs of food staples represent a large proportion of their consumption budgets.

The external debt crisis which affected LAC since 1982, and the subsequent adjustment processes which followed have introduced an additional source of food insecurity. The main losers have been low-income and vulnerable groups in the cities and towns. Stabilization policies and structural adjustment programs most often have required increases in the real exchange rate. These increases tended to induce a positive response in the production of exportable crops. The responsiveness of food export supplies, however, tended to be faster than the responsiveness of the production of exportable foods[3]. This difference in elasticity values between food supply and the food export supply reduces the domestic availability of foods and increases food prices. Low income and vulnerable groups living in cities and towns, as a consequence, have experienced reductions in their ability to purchase foods during adjustment periods.

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3 The price elasticity of the excess supply of foods or other agricultural productis exceeds the value of the price elasticity of the supply of food or other agricultural products. An increase in the real exchange rate represents an increase in the real export price. Export brokers (trade) respond faster to new price opportunities, but it take a longer period to actually increase the production of exportables. The first effect, then, is to reduce food availability in local markets.

Increases in real exchange rates, however, have a positive effect on the real income of peasants who are netsellers of exportable and importable foods. Peasants or small farmers who are producing exportables like coffee in Costa Rica, or tomatoes in Mexico, have experienced increases in their cash income, thanks to increases in real exchange rates.

Peasants and small farmers who are producing importable crops like wheat in Chile, or corn in Nicaragua, also benefit from a higher real exchange rate. Imports of these grains became more costly and local producers become more competitive.

Peasants and small farmers' abilities to capture the benefits of a higher real exchange rate, however, depend on their transaction and transportation costs. They become de facto producers of non-tradable goods and cannot capture the gains from international trade, when there exist trade monopsonies or a lack of roads and bridges.

Reducing food insecurity in LAC, then, implies increasing the long-term earning power of the structural poor. In also presupposes short-term transfers of real income to low-income and vulnerable groups to supplement their temporarily affected purchasing power.

LAC nations have used numerous forms of organizations and policies to maintain food supply at large, and to reduce food insecurity for low income or vulnerable groups more specifically. The main objectives of these instruments, however, have been to insure average food sufficiency: the availability of staple foods for the population at large. They have also tried to reduce or avoid temporary food insecurity in the cities and towns. Institutional changes and policies for reducing chronic insecurity, on the other hand, have been less pervasive and less effective: widespread poverty, in the country and the cities, still is a dominant structure and outcome of LAC economies.

Up to the beginning of the debt crisis, the main approaches for assuring access to food by urban populations at large were ***cheap food policies***, that is, generalized food pricesubsidies. For most countries of LAC, cheap food policies were consistent with industrial policies for industrial import substitution, or simply with policies biased toward urban and bureaucratic development. The actual implementation of generalized food subsidies varied across countries in the region, from negative protection of agriculture (as in Argentina), to storage and subsidized distribution of foodgrains (as in Mexico and the Dominican Republic).

The viability of cheap food policies depended on the countries' ability to produce more food at lower costs, or their economic abilities to generate foreign exchange earnings to import foods, or political leverage to receive food aid. During the 1950s and 1960s many countries, sometimes with the financial assistance of international banks and agencies, implemented agricultural policies for expanding the land frontier and for increasing agricultural productivity. These programs included colonization projects, irrigation projects, mechanization, and green revolution type of projects. In many instances the adoption of new agricultural techniques was induced by means of subsidy schemes. Subsidies were used for agricultural inputs, low or negative real interest rates for mechanization, subsidized irrigation, free technical assistance for commercial farmers, and price support schemes for grain production, among others.

During the 1970s, some countries scaled down the importance of domestic food production within their food security policies. For example Mexico, Central America, and the Dominican Republic reallocated agricultural resources into the production of exportable crops, and food imports increased at a significant rate. This new approach to food security was made possible by the price bonanza which followed the food and energy crisis. The increasing demand for food imports was also reinforced by population growth and per capita income growth, even when international prices of food remained at a high level until 1981.

Despite the land reform programs of the 1960s and the rural development programs of the 1970s, chronic food insecurity in the rural areas was not reduced in a significant way. The limited success of these actions resulted from a combination of factors: the dissolution of traditional agrarian institutions without developing alternative ones, the limited scope of rural development projects, and the high rates of population growth which offset part of the gains.

Since 1982, most countries of the region began or deepened their stabilization policies and structural adjustment programs; this was the necessary response to the external financial crisis. In order to cut fiscal deficits many countries reduced expenditures for subsidized food consumption in the cities, reduced input and credit subsidies in agriculture, and phased out rural development programs. In order to improve efficiency and to increase foreign earnings, some LAC countries increased their real exchange rates and began operating with positive real interest rates. They also started to scale down input subsidies and price support schemes.

Upward movements in real exchange rates affected food consumption via macro and microeconomic effects. Real devaluations of the national currency tended to reduce the average real wage rate and thereby the average consumption of food, in particular in the cities. At the same time, in those countries with increasing real exchange rates, the production of exportable and importable crops tended to rise. The agricultural export supply, however, responded faster than the production of agricultural exportables, reducing the availability of foods and generating upward pressures in the relative price of foods within domestic markets.

In some countries the above effects took place with the simultaneous implementation of macro stabilization policies which reduced generalized food subsidies. The combined effect of adjustments and stabilization measures was a decline in food purchasing power for low income and vulnerable groups in the cities and towns. This effect was particularly strong during the first stage of the adjustment, between 1983 and 1985.

As a way to cope with this new source of food insecurity, many LAC countries are transforming generalized food subsidies into food programs targeted at vulnerable groups. This is the case in Mexico with the "torti-bonos" program, and in Nicaragua with the food assistance program. Argentina has also developed food distribution transfers for vulnerable groups.

2. Agricultural Technology and Food Security

The possibility of increasing food consumption at large and reducing chronic and temporary food insecurity depends now on a new style of economic growth, one which increases food production or the ability to finance food imports and at the same time increases the earning power of low-income groups. The sources of economic growth for LAC include not only accumulation of capital but also an increase in allocative efficiency. Structural adjustment is an attempt to restore international trade as a source of economic growth. Trade alone, however, is not sufficient for improving the material well-being of much of the population in the region. Investments in infrastructure as well as technological change are also needed.

A lesson has been learned in LAC countries: price interventions are not the most efficient way to promote a sustainable growth path, nor the most effective way to improve income distribution. The issue of poverty, beginning with food insecurity, needs to be tackled directly by increasing the earning power of all social groups. The earning power of rural and urban poor, in the long run, will increase if they are empowered with access to capital. This means access to nutrition, to health care and to education; access to agricultural land in rural areas; and access to housing in urban areas.

Economic growth for food security, and technological change as a source for agricultural growth, represent a unifying approach for inducing growth with equity. What will it take to promote this growth path in LAC? It will require completing the process of policy and institutional reforms which promote freedom of production and trade, both international and domestic trade. It will require institutional reforms which increase peasant access to land via ownership or secure tenancy. It will finally take institutional changes in the research and transfer system to allow technological innovations induced by the price ratios of a market economy without price interventions.

Institutional changes in the research and transfer system are most critical. On the nature of the incentive system embedded in these institutions will depend the bias of the technological path to be induced. This bias in turn will affect the future pattern of distribution of productive knowledge among different type of growers; the earning power of peasants and small farmers (effect on chronic food insecurity). It will also affect the relative productivity of different types of food commodities, and thereby the degree of food diversity; the variability of food availabilities in the region (effect on temporary food insecurity). Finally it will affect the sustainability of agricultural resources.

3. Agricultural Technology and Sustainability

A difficult challenge to increased food production in the future in LAC concerns low to achieve if without further degrading its privileged natural resource base. Even though the natural resources situation is advantageous in general when compared with that of the other areas of the developing world, there are already alarming signs that the region's ecological capital is rapidly deteriorating. Deforestation, soil erotion, pollution of ground and underground waters, loss of genetic diversity and waste accumulation are common and growing problems. Furthermore, in may specific cases they have already started to show in declining productivity and standard of living, particularly for the poorer segments of the population.

Given the very special role that the agricultural sector has to play in the reactivation of the region's economies, it is clear that the future is one of intensification of production and further pressures on the natural resources. With a large share of their productive resources in agriculture and with already deteriorating food availability levels the majority of the countries cannot effort production sacrifices; on the country a progressive more toward the less fertile and more fragile agroecologies will be unavoidable of food security and economic reactivation is to be assured. All there elements point to the need for a major technological effort. Many of today's sustainability problems evolved from a technological development path which does not considers the full impact of production and productivity increases on the natural environment. Consequently, of production objectives are to be met in a sustainable way without further deteriorating the natural resources bases not only increased investment in technology generation and transfer is required but a significant reorientation of the research and technology development process is a necessary condition. The full and effective consideration of the sustainability problem goes well beyond the technological dimension. New more "enviromentaly friendly" technological concepts are indeed essential but they are to be effective only if they are applied in the paper institutional and policy framework. Present unsustainable situations are not the result of perceive behaviors of individual economic agents but the result of wherent decisions under existing institutional and incentive structures. Changing these is an essential challenge if a more toward a more sustainable agricultural development path is to be made successfully.

4. Regional Diversity and Countries Cooperation

Diversity is an innate attribute of the Latin America-Caribbean region. LAC is integrated by diverse resources bases, by numerous ethnic groups and cultures, by different economic institutions inherent to each nation, and by the different size of each country. As a consequence, the food security issue has specific characteristics in each country. From resource-poor Haiti to resource-rich Argentina; from the indigenous peasantries of the Peruvian or Guatemalan highlands, to the African-Anglo peasants of Jamaica, to the German farmers of the Chilean south; from the free market economy of Chile, to the overregulation of the Dominican Republic, to the controlled economy of Cuba; from Grenada island to the Brazilian subcontinent.

Such a diversity has revealed itself through different patterns of nutritional intakes, different patterns of food production and trade, and different food security policies, from the high diversity of energy sources consumed in Paraguay to the low diversity of Guatemala. From the intercropping of peasant farms, through the dual livestock systems of the tropics, to the agribusiness of Chile. From the position of food exporter of Argentina to the position of food importer of Mexico. From price-band systems for imported foods, through generalized food subsidies, to overvaluation of national currencies.

This diversity of LAC has major implications for a new strategy for food security and technological change in the region. One is necessary to address the **distinctive food needs** and production possibilities of each country; another involves technological policies for overcoming food insecurity and requires **financial and institutional cooperation** among LAC countries.

Institutional development for food security requires, then, a **unifying approach** based on the region's diversity. Two major properties for the unifying approach emerging in LAC are *free agricultural trade* within the region, and *common investment* projects in agricultural research. From regional integration schemes toward bilateral trade concessions. From the national research institutes and extension agencies to regional research institutions or research networks.

This document looks at the dimensions of food sufficiency and insecurity for the LAC region as a whole. It also focuses on a coordinated, unified approach. The specific issues of food security in each country, however, are most relevant and they must be integrated when designing specific projects.

A. FOOD PRODUCTION REQUIREMENTS TO MEET THE FOOD NEEDS OF THE 1990s AND BEYOND

1. Current production, consumption, and trade of staple foods

a. Average food sufficiency in LAC

Total food availability for the whole region, has continued to increase since 1970. However, the food availability index[1] for the LAC region indicates that apparent per capita consumption grew during the 1970s, but it leveled out since 1978 (Figure 1, Table A-1). Per capita food availability decreased during the food crisis years (1972-73), and again during the debt crisis years (1983-86). These downward adjustments in food consumption with respect to a trend indicate that the region as a whole is sensitive to temporary food insecurity problems induced via fluctuations in real per capita income (Figure 2).

The structure of the supply of foods, on the other hand, has changed significantly (Figure 3). Since 1970 the volume of food imports has tended to increase, but with important fluctuations in the trend (Trigo and Runsten, 1989). Food imports peaked in 1980 and 1981, and began declining after the debt crisis. They remain, however, at a high level compared to the first years of the 1970s. Food exports, a relatively stable proportion of domestic production since 1970 to 1981, suddenly increased during the debt crisis (1983-85) and then returned to previous levels.

These simultaneous increases in food exports and decline in food imports were induced by increases in the real exchange rates and trade liberalization policies (de Janvry, Runsten and Sadoulet, 1987). Since food production, the main source of food availability, continued to grow at its historically low level, and the net effect of structural adjustments and stabilization was a decline in food availability per capita between 1983 and 1985.

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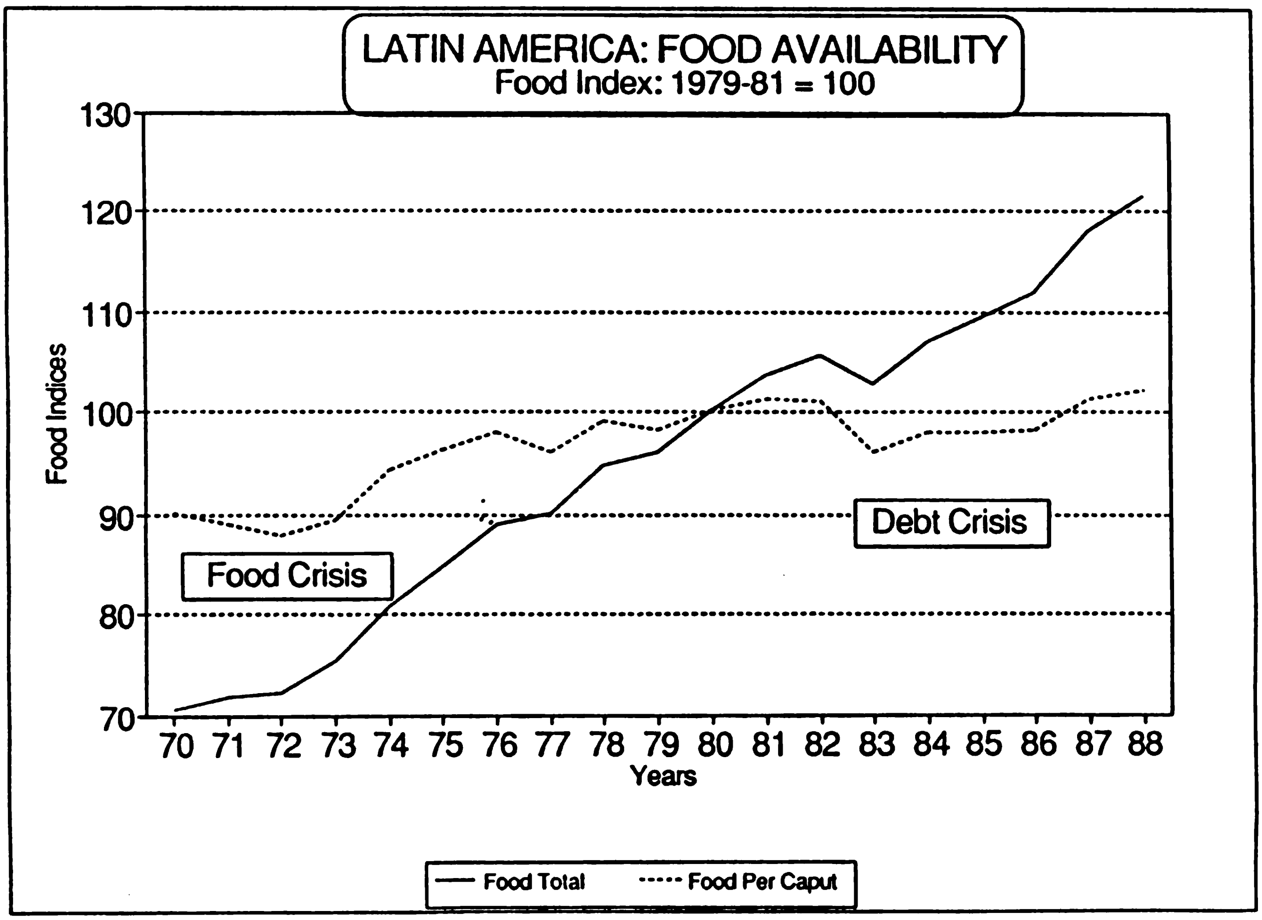
[1] The Food Availability Index is an indicator of apparent food consumption defined as:

$$C = Q.q + M.m - X.x$$

where C is food availability index; Q is FAO's food production index; M is FAO's food import (quantity) index; and X is FAO's food export (quantity index). The weights are q for the relative importance of food production over food availability; m is the relative importance of imports with respect to food availability; and x is the relative importance of exports with respect to food availability. The base year for the weights and the index is 1979-81.

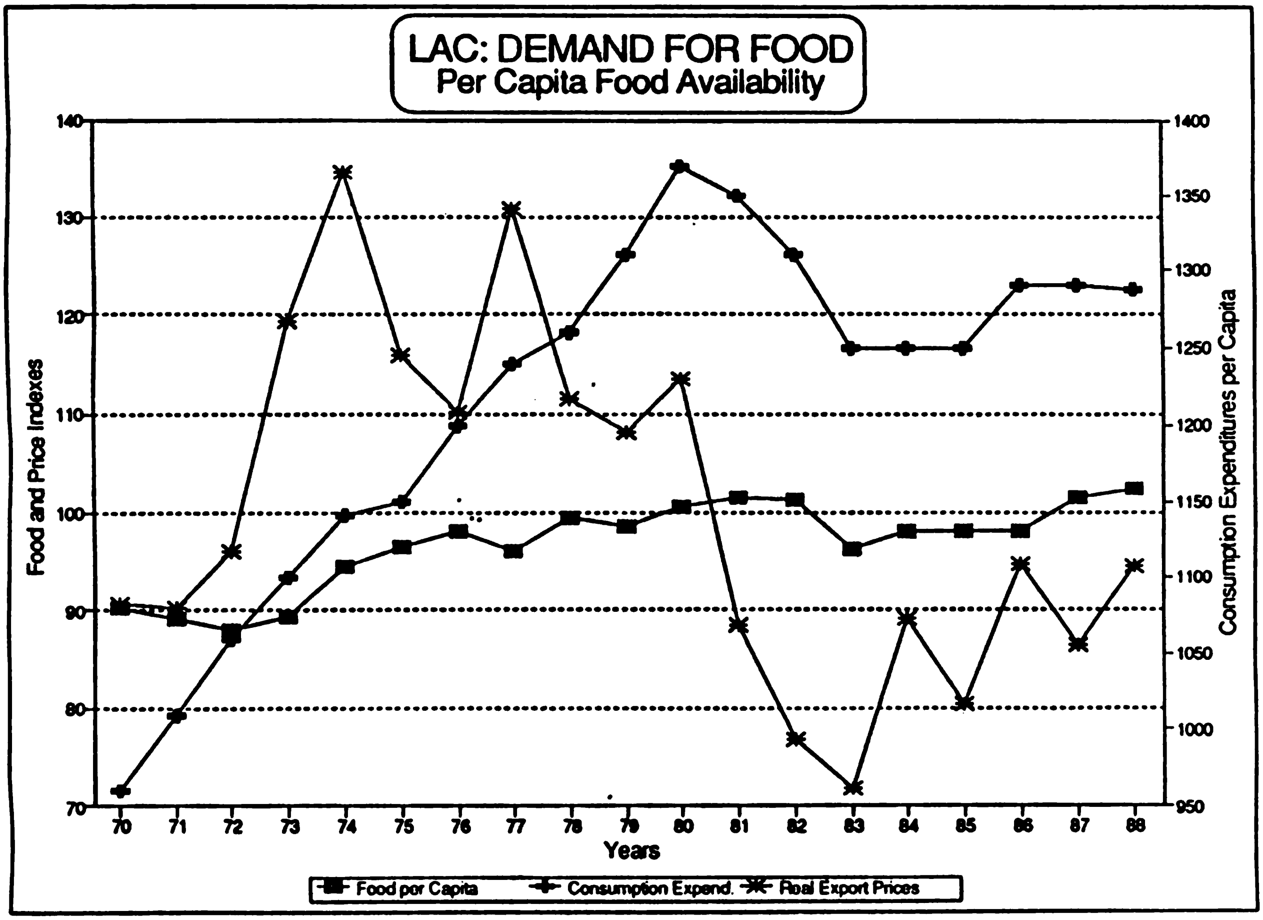
The food availability per capita index is the total food availability index divided by the implicit population index of Latin America and the Caribbean.

FIGURE 1



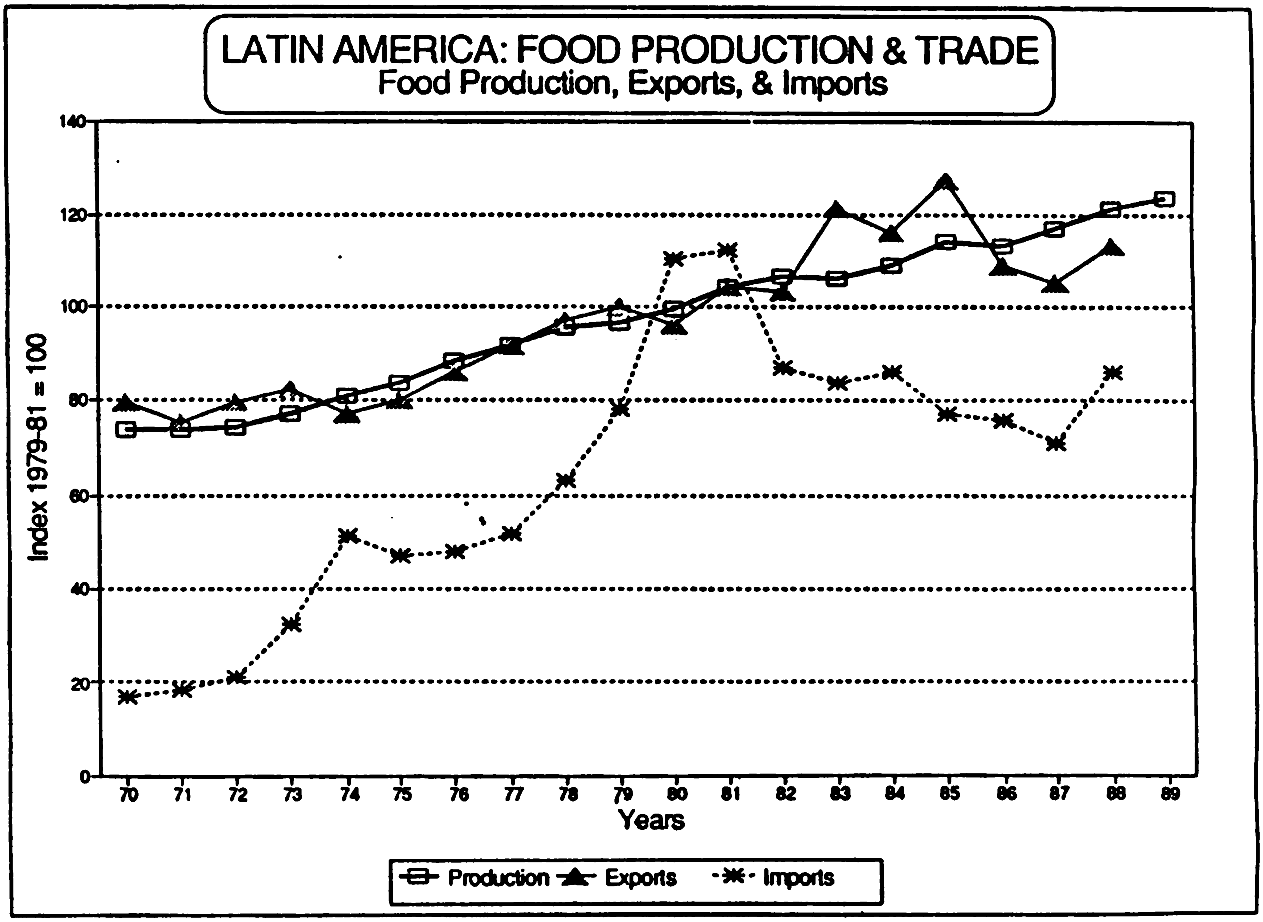
APPENDIX: Table 1

FIGURE 2



APPENDIX: Table 1 and FAO yearboocks

FIGURE 3



APPENDIX: Table 1 and FAO yearboocks

b. Deficiencies in calorie intakes in LAC

Average sufficiency for the region. The average per capita availability of energy, protein, and fats in LAC are slightly above the average intake requirements[2] of WHO/FAO/UNU (Figure 4). LAC availabilities, however, are much smaller than in developed market economies (Figure 5).

Chronic food insecurity for specific countries and low income groups. The distribution of calorie intakes within LAC, however, is very uneven among and within countries. In South America, only the Southern Cone countries and Venezuela have energy intakes above WHO/FAO/UNU average requirements. In North and Central America, only Mexico, Costa Rica and Belize are above that average. In the Caribbean, only Barbados, Cuba, and Trinidad and Tobago are above that average. At the other end of the scale, energy deficiencies with respect to the WHO/FAO average are particularly critical in the Andean countries (Bolivia, Peru, and Ecuador); in Guatemala and Honduras in Central America; and Haiti, Antigua and Barbuda, Dominica, and the Dominican Republic in the Caribbean (Figure 6).

The nutritional intakes of low-income groups, both in rural and urban areas, are still much smaller than the country averages. When this circumstance is taken into consideration, chronic food insecurity reveals itself to be an outstanding and severe problem for large groups of population in region.

c. The diversity of calorie sources in LAC

The food sources of calories in LAC countries are numerous (See tables). Grains account for between 29% (in Argentina) and 58% (in Guatemala) of the energy available in the region. Other important sources of energy are sugars, meats, oils, roots and tubers, and milk. Roots and tubers, combined with fruits and stimulants like cocoa are particularly important in Caribbean countries. Roots and tubers are also important for Paraguay, Bolivia, Peru, and Colombia.

The diversity of calorie sources varies across countries in the region. On the average, the degree of food diversity is higher in the Caribbean countries, followed by South American countries,

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[2] Average intake requirement is here defined as the simple mean of the energy requirements for a male office clerk (2580), for a subsistence farmer (2780), for a housewife in an afluent social strata (1990), and for a rural woman in a developing country (2235).

The estimations are based on FAO/WHO/UNU Expert Consultation, *Energy and protein requirements*, Geneva, World Health Organization, Technical Report Series 724, 1985.

and lowest in the North and Central American countries (Figure 7). The degree of food diversity is particularly low in Guatemala, Honduras, and Guyana. The diets of these countries depend heavily on grains: maize in the first two, and paddy rice in the third. In Guatemala, maize as a source of calories, is complemented with consumption of raw cane sugar, dry beans, and cotton seed oil.

Food diversity is particularly high in Paraguay and Argentina. In Paraguay, grain consumption (maize and wheat) is balanced against consumption of roots and tubers (cassava), pulses (dry beans), fruits (bananas and oranges), and meats (beef and pork), among others. In Paraguay consumption of sugars is a much smaller source of calories than in the other LAC countries. In Argentina, wheat consumption is balanced against consumption of potatoes, raw cane sugar, beef, milk, oils, and wine. Fruit consumption is relatively low, except for apples and grapes. The Argentinean diet is based on European-type consumption preferences, supported by natural environment and colonization patterns.

A Caribbean country with higher food diversity is Grenada. Consumption of grains (wheat) is balanced against consumption of sugars (raw cane sugar), nuts (coconuts), milk. oils (coconut oil), and fruits (bananas).

d. Sources of food production growth in LAC

Food production grew at an increasing rate in LAC until the period 1975-80. Since then, it has continued to increase, but at a declining rate. An explanatory factor is the low, and in some countries negative, rate of growth of investment in agriculture (de Janvry *et al*, 1989). This low rate of capital accumulation was induced by the fiscal and external crisis. An additional explanation is the slow-down in the expansion of the land frontier.

Since the 1960s the major source of production expansion has been through yield increases rather than land expansion. A more detailed analysis of the sources of food growth shows a secular decline in the relative importance of domestic resources, namely land and livestock[3]. The contribution of labor, however has remained constant since 1970 (Figure 8).

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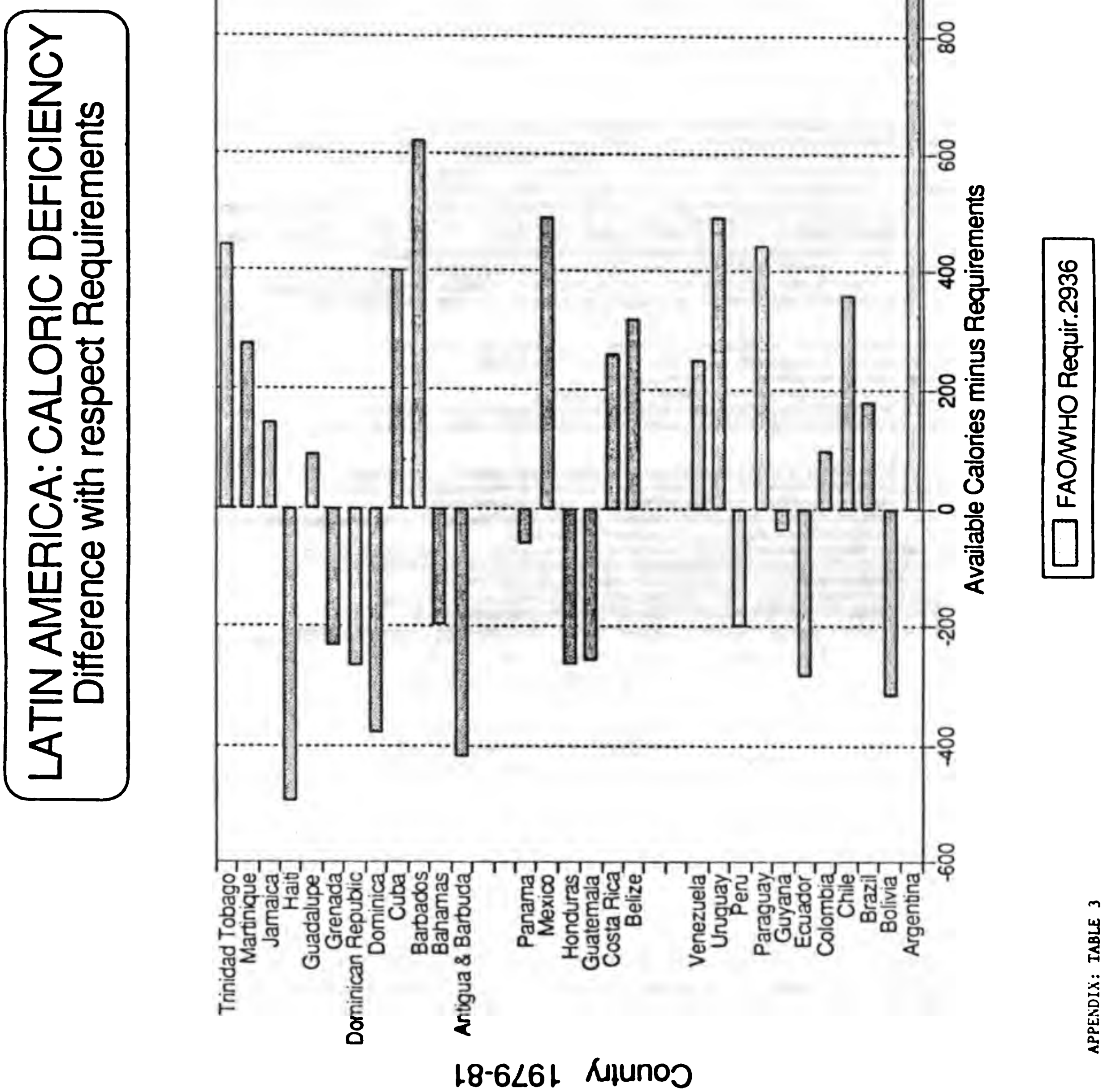
[3] The following analysis of the source of growth is based on the production function approach. The methodology and coefficient values used in this investigation are based on Hayami, Yujiro and Vernon W. Ruttan, *Agricultural Development: An International Perspective*, Baltimore, JHU Press, 1988: 143-153.

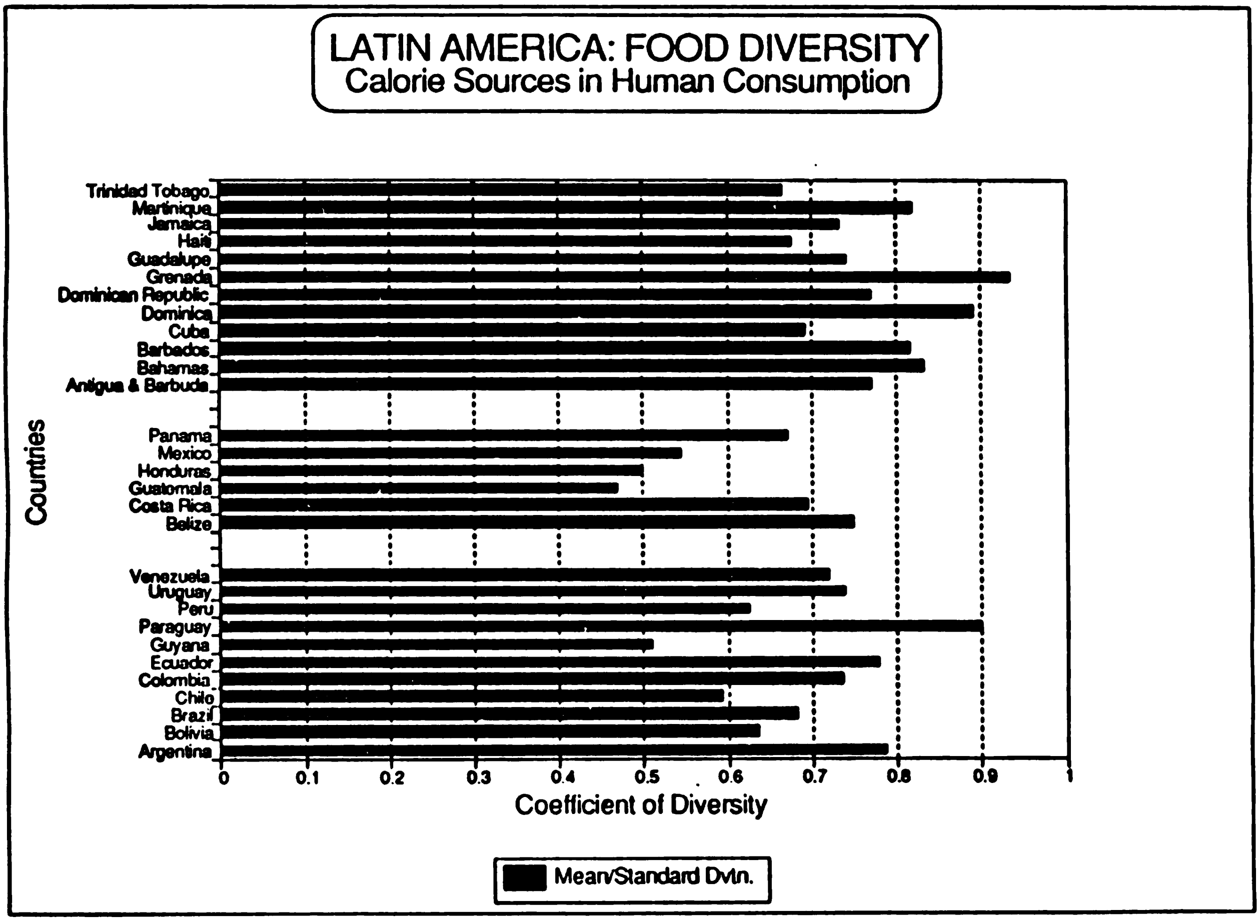
Total factor productivity growth is estimated by the residual method. As such it is an indicator of technical change and other factors.

FIGURE 4



APPENDIX: TABLE 3

FIGURE 5



APPENDIX: TABLE 3

The most important contributions to growth since 1970 have come from both embodied and disembodied technologies. The contributions of chemical inputs (associated with improved seeds) and mechanization were of particular relevance between 1970 and 1980. There was, however, a signficant change in the sources of growth during the 1980-85 period, that of the debt crisis and the first round of structural adjustments. During this period the most significant contribution came from disembodied technologies, namely a more efficient allocation of resources due to the realignment of real exchange rates and less direct and indirect interventions in agricultural trade. Thus a more appropriate incentive system was developed as a source of growth. Increasing exchange rates and trade liberalization provided incentives for the production of exportables. The same variables increased the price of imported inputs, thus reducing the use of chemicals to a minimum.

During the last period, 1985-89, the importance of chemical inputs has increased once again. Total factor productivity growth, however remains an important source of food production growth.

The above patterns of food production growth in LAC --declining rate of growth, secular changes in the sources of growth, and high variability in the growth of total factor productivity-- point to the necessity of tapping new sources for increasing the overall rate of food production growth. There is a latent demand for new agricultural technologies, for investment in agriculture, and for further ajustment in the incentive system[4].

2. Prospects for Increasing Food Production

a. Production and trade growth required to meet future food needs

LAC countries will be facing a challenge, both to maintain adequate levels of food availability per capita, and to reduce chronic and temporary food insecurity. The following tables depict the likely levels of food consumption, food production and trade during the next twenty years. They are estimated for two major scenarios[5]. The first scenario is without technological change and the second with technological change.

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[4] There exists a growing literature aimed at defining the characteristics of the new research in transfer products in LAC. Not all of these works address the food security issue in a explicit way, but they are related to it. See de Janvry et al., 1989; Kaimowitz and Vartanian, 1990, de Janvry, Runsten and Sadoulet, 1987; Benito, 1989.

[5] See Methodological Appendix for a more detailed explanation of the model and data sources.

The first, or trend-scenario, is based on the following assumptions and forecasts:

a) Population in LAC continues to grow at a declining rate, beginning with 2% and ending with 1.6% in year 2005.

b) Per capita consumption expenditures (purchasing power) grow at a low but increasing rate, beginning with .15% in 1990 and ending with 1% in year 2005.

c) The international prices of food remain at the same levels as the last five years.

d) Consumers maintain the same patterns of consumption as at present.

e) The distribution of food consumption across countries and among social groups within countries does not change.

f) The supply of arable agricultural land grows at .06% per year.

g) Yields grow at a decreasing rate following the trend pattern for the region, beginning with 1.4% in 1990 and ending with 1.1% in year 2005.

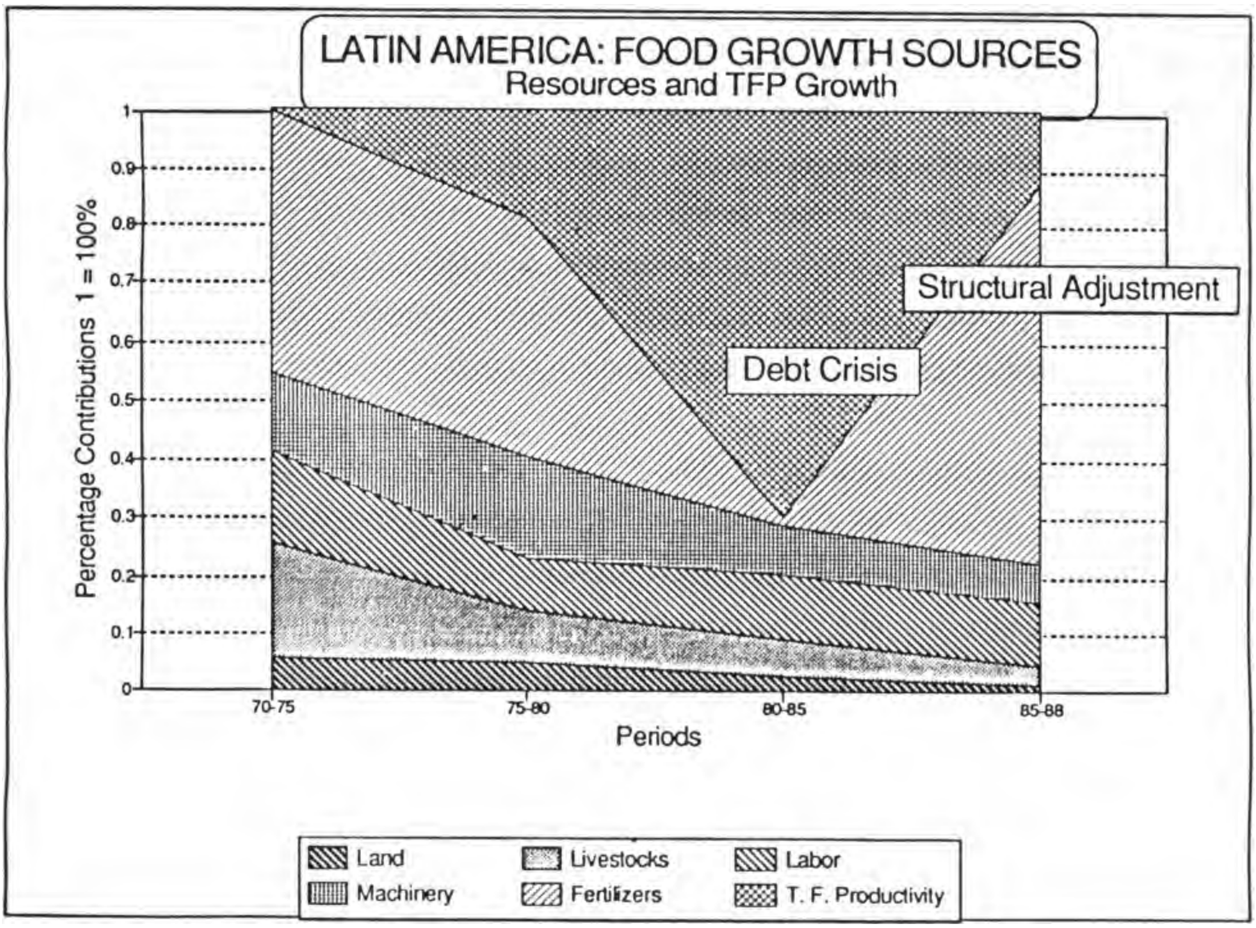
h) Food exports continue to grow in the pattern of the last ten years, as a positive function of prices and total food production, beginning with 1.8% in 1990 and ending with 1.4% in year 2005.

i) Imports of foods grow to close the gap between demand and production net of exports. This implies that imports would have to increase at an average rate of 8.4% per year.

This is a conservative scenario, on both the consumption and the production sides. For consumption, it is assumed that the main objective of food security policies is to satisfy average consumption needs without substantially reducing chronic food insecurity, nor accumulating sufficient stocks to deal with temporary food insecurity. On the production side, it is assumed that existing agricultural techniques will continue to be adapted and adopted. It is also assumed that yields will not fall because of fertility problems.

Under this trend-scenario, *food imports will have to grow at a higher rate than their current trend and faster than food production*. The possibility of maintaining a high growth rate of food imports will depend on the ability of the region to increase foreign exchange and/or food aid. Since a similar scenario is being predicted for the world as a whole, grain prices may increase during the next five years or so, making it even more difficult to satisfy food security goals. This growing food gap, however, will create incentives to induce technological innovations or to transfer technologies in order to increase local food production. That is, *the prospective rate of return of investment in research and transfer will be high enough to merit expenditure switches in the direction of technological change in agriculture.*

FIGURE 6



APPENDIX: Table 7

b. Technological challenges for food production

The following scenario, with technological change, is based on the same premises regarding the demand for food. With regard to food production and trade, however, it is assumed that:

a) Agricultural lands expand at the same rate as that in the trend-scenario.

b) Yields increase at an average rate of 1.8 % per year.

c) Food exports behave in the same pattern, that is, they are a positive function of real export prices and total food production.

d) Food imports grow to close the gap between food production and net food exports.

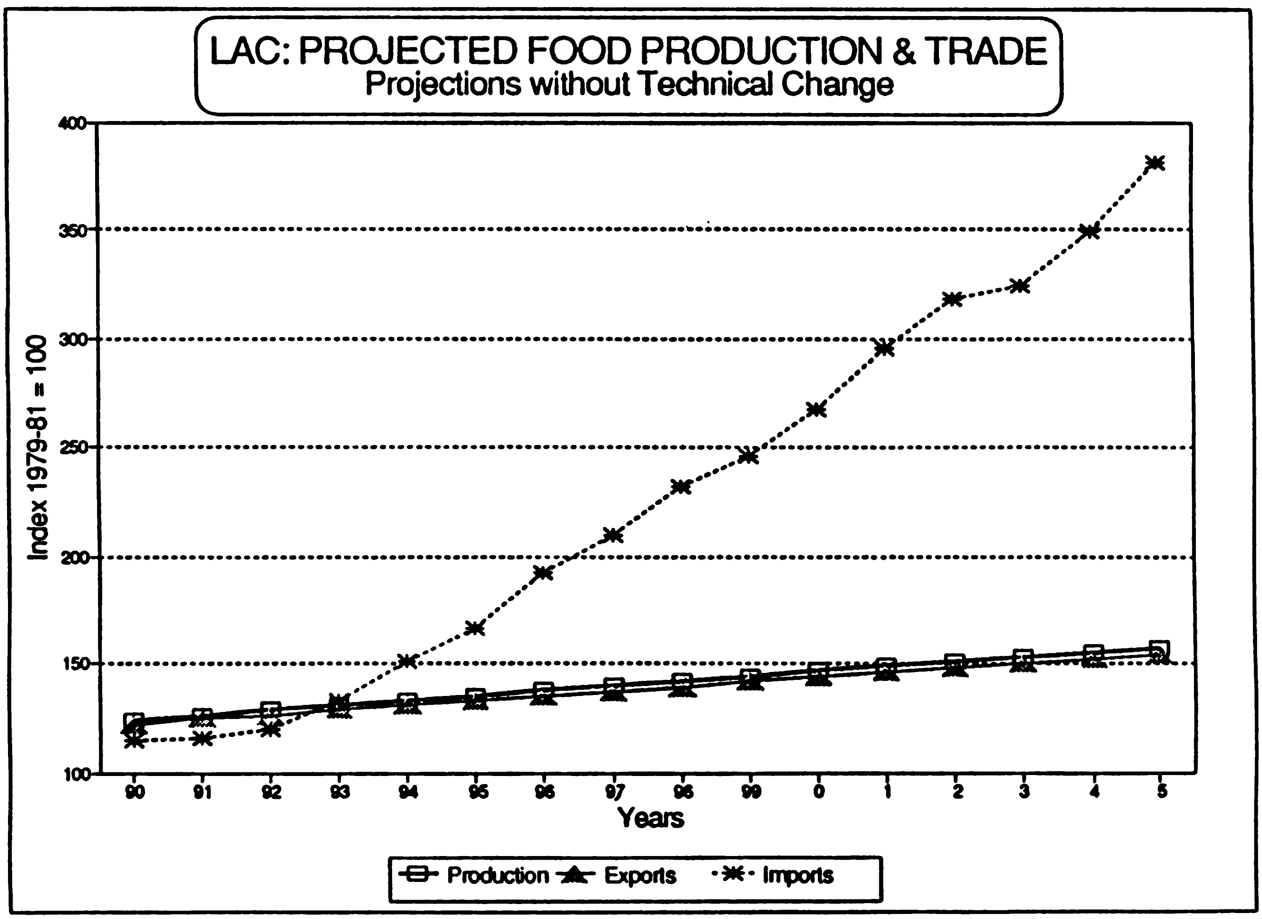
Under a scenario with the projected rate of technological change, the rate of growth of food imports could be reduced to 4.1% per year, nearly half the existing rate. In this case, total food availability is still the same as without technical change. The possible nutritional status of peasants, small farmers, and landless peasants, however, could be improved. Depending on the technological path which is developed and induced, an increase in food production can help to reduce chronic food insecurity in rural areas. If peasants and small farmers have access to the new technologies, they will increases their real income. In addition, growth in food production and processing at large will create new jobs for landless workers or small-town workers.

c. The sustainability challenge

As it was noted the quantity of agricultural land no longer is a major source of growth in the agriculture of LAC. At the same time, yields are not increasing as rapidly as in the past. Further growth in food production must come from increased yields. But even if it still were possible to adopt more existing high-yield varieties, the region is beginning to face soil fertility problems. Soil fertility deficiency, to a large extent, is the result of adopting mechanization and agro chemicals. An improper use of mechanization has created problems of soil compaction, reducing soil fertility. An excessive use of chemicals, in particular pesticides and herbicides, is creating yesitant pests and weeds.

Most marginal lands are located in fragile environments, where a combination of open access and traditional forms of farming generate sustainability problems. Commercial and modern farming in the best soils of some countries, however, also generate fertility declines and chemical contaminations. The intense use of high ratios of chemicals, in addition, have increased chemical residuals in soils, animals, and even in human beings. The alternative use of these lands for the production of foods is now affected by low fertility and chemical residues.

FIGURE 7



SOURCE: See Methodogical Appendix

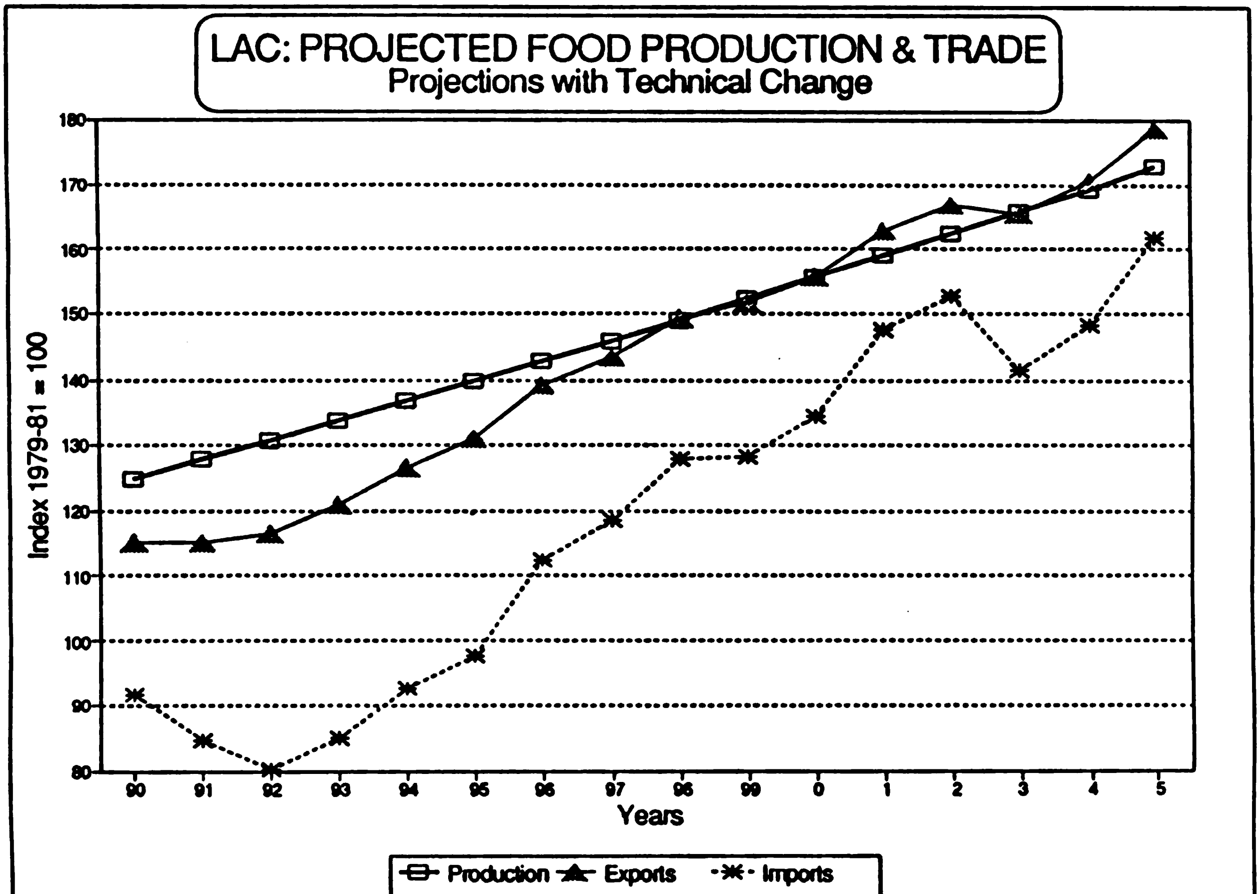
d. Challenges for the research and transfer institutions.

The trends and conditions in the overall food system of LAC point to a decline in the importance of food production as a source of food availability within the region. Were these trends to persist, LAC will be threatened by food insufficiency problems because of two major factors. On the one hand, the maintenance of a high rate of food imports will depend on an even higher rate of real income for the region as a whole. This scenario is unlikely since the growth of agriculture itself is a major contributor to real GDP in the region. On the other hand, an increase in the rate of food imports presupposes an increase in the excess supply of food to the region. This will in turn depend on an increase in the growth of food production in other regions and or a decline in the growth of food consumption in other regions. The increasing demands for food imports or food aid in the Soviet Union and the decline in land productivity growth in Asia contradict this possibility.

A more likely scenario, then, is that, given trends in LAC and other world regions, the demand for technological change will increase. The actual rate of technological change will depend on the degree of response of the supply of technological change: on the rapid generation and transfer of new agricultural technologies which are appropriate to meet the challenge of food sufficiency and agricultural sustainability. What is then the degree of response of the LAC system of generation and transfer of technologies?

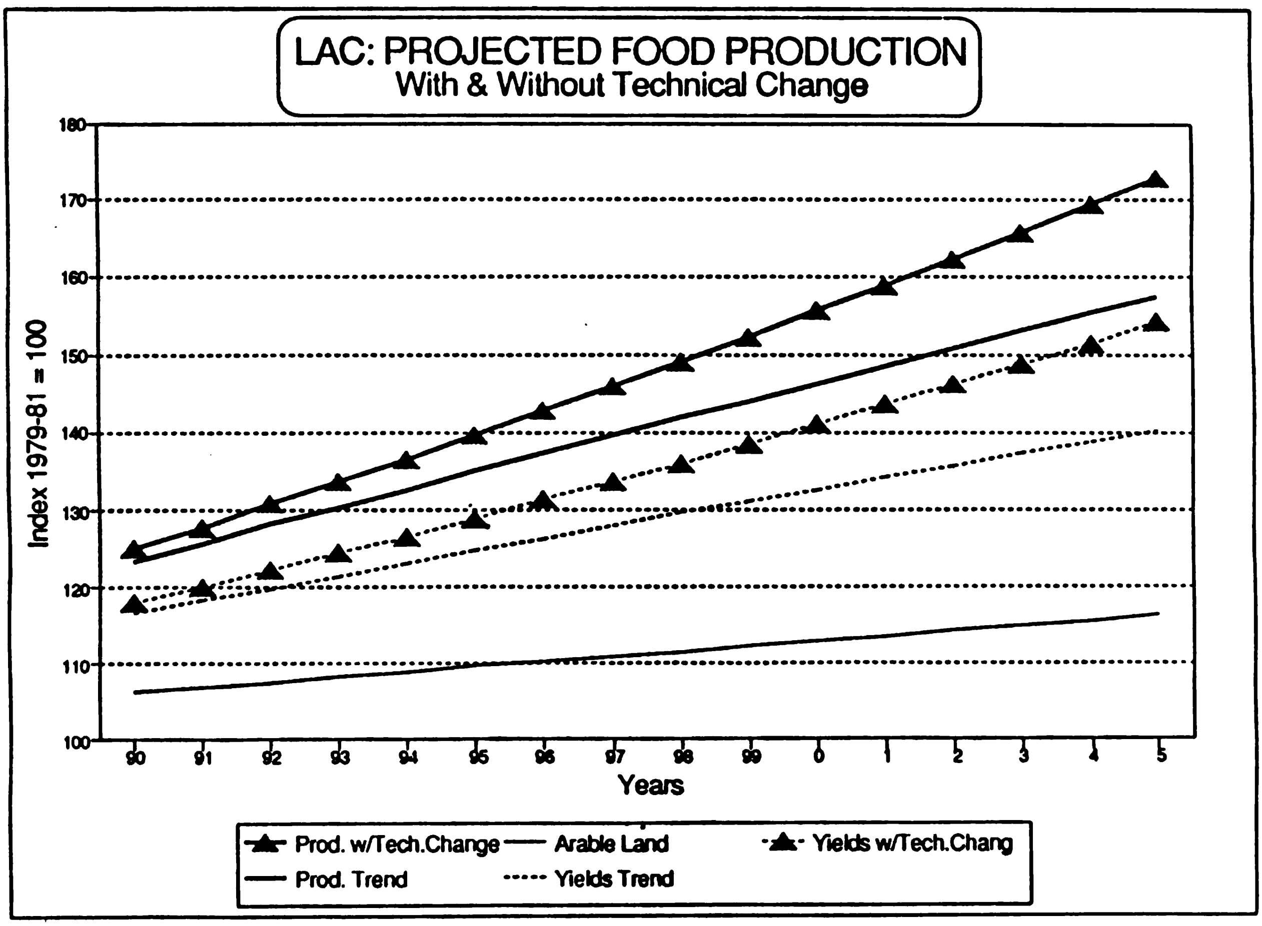
National organizations with the cooperation of international and regional institutions have proven their ability to generate and transfer technologies at critical periods. The new pattern of resource scarcities and the emerging research lines, however, will create a demand for appropriate institutional changes. The challenge for IICA, the World Food Council, and other international agencies and banks, is to make these demands for institutional change into reality by reducing the opportunity costs for national governments. New knowledge and financial assistance regional projects are most necessary (Trigo, 1990).

FIGURE 8



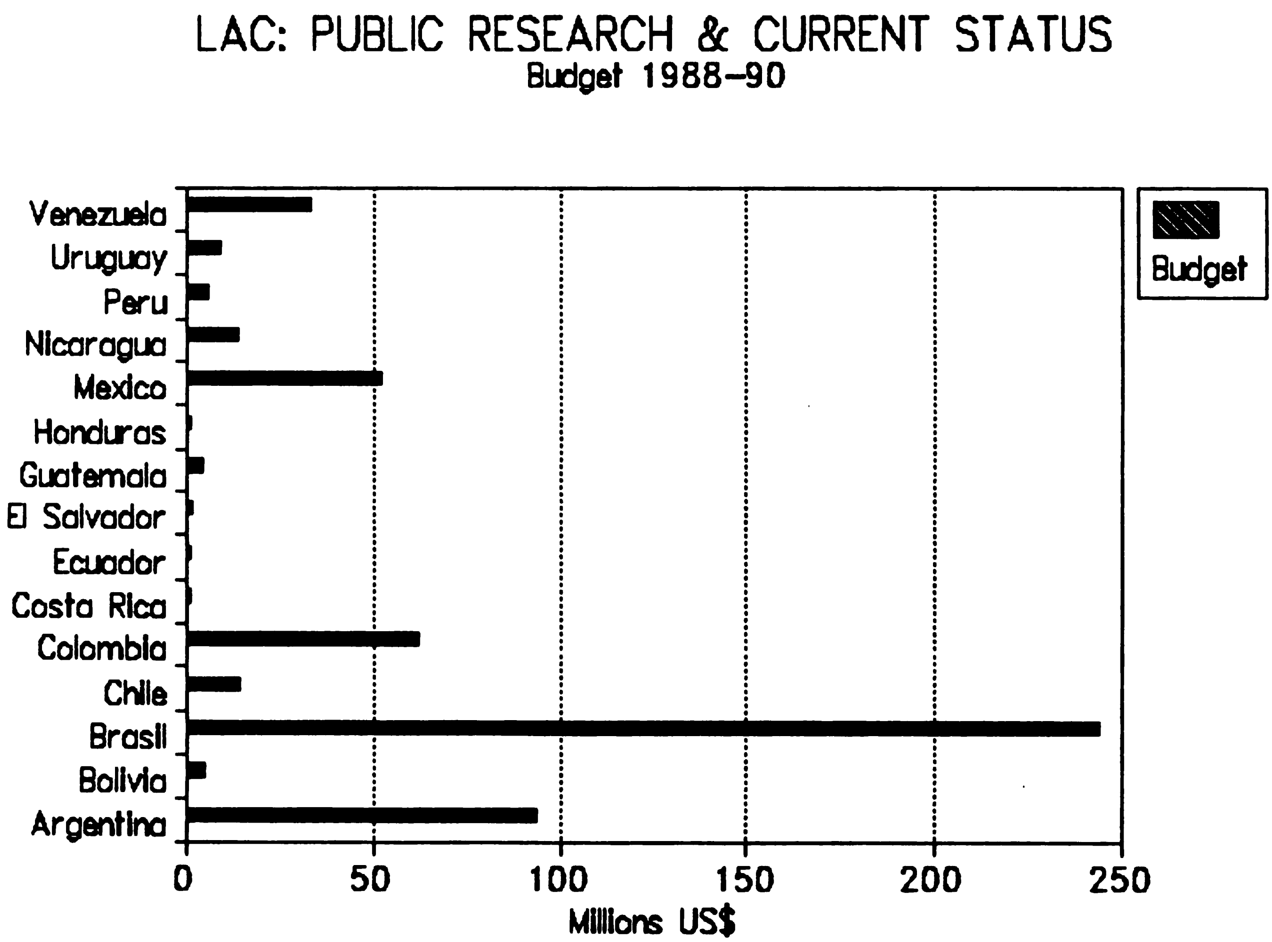
SOURCE: Methodogical Appendix

FIGURE 9



SOURCE: Methodogical Appendix

FIGURE 9-A



APPENDIX: Table 10

B. AGRICULTURAL RESEARCH AND TECHNOLOGY CAPACITY IN THE REGION

The organization of research and extension in LAC has evolved into a multilevel, dysfunctional system. The process of institutional development can be basically characterized as a supply-driven process: the priorities of international donors, and the research lines represented in universities of developed countries have tended to prevail, rather than the specific needs of farmers in the region.

Hopes for enhanced food sufficiency were raised by the development and adoption of improved varieties of staple crops in Asia and LAC. Experience with adoption of these technologies, however, indicates that not only is the technology much more site specific than originally thought, but that differences in risk, access to credit and lack of appropriate, profitable technologies can affect the rate of successful adoption.

1. National and Regional Agricultural Research and Technology Transfer Systems

a. Public and private research institutions

The LAC region after World War II saw the systematic organization of research centers and experiment stations in many countries. Often the stimulus for their establishment and political support was the need to develop technologies for staple foods, namely corn, wheat, beans, rice, potatoes and cassava. Stimuli were both internal, food pressures related to expanding population, urbanization and import-substituting industrialization, and external, international conditions and institutions (both private and public) favoring economic growth. Another force behind the political support was the conviction that agricultural productivity could not be raised just by technical assistance and technology borrowed from foreign sources.

The semi-autonomous research institutes were considered an institutional innovation of great importance for carrying out research without much of the political interference observed in the old research divisions of Ministries of Agriculture. These institutes with decentralized research achieved acceptance in the late 1950s and with their broad mandates and political constituency were able to command additional resources and grow at a rapid rate.

Table 1 shows the growth of research funding for the region. While it is true that since the mid-70s that remarkable growth has slowed down, it could be said that the LAC region has now built a system of research which is mature enough both to develop closer partnership with international centers of the Consultative Group for International Agriculture Research, (CGIAR) and other research institutions, and to establish networks for cooperative research and information sharing among different countries (Figure 9-A).

In LAC today there is great potential, with four types of actors: the National Agricultural Research Systems (NARS), a set of regional programs and networks for reciprocal cooperation in the exchange of experience and joint research, two regional research and education centers, Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and Caribbean Agricultural Research and Development Institute (CARDI); and the three CGIAR international centers located in LAC, International Maize and Wheat Improvement Center (CIMMYT), Centro Internacional de Agricultura Tropical (CIAT) and Centro Internacional de la Papa (CIP), which have linkages with other centers based outside of the region. These four actors have constant interactions in the different regions of LAC, providing mechanisms for discussion of research priorities, allocation of resources and identification of opportunities. A system like this can effect a better division of labor in agricultural research, introducing a more efficient utilization of resources and the comparative advantages of each institutional actor.

Examination of the Latin American and Caribbean NARS reveals a certain loss of institutional strength in the traditional national research programs, particularly after the mid-70s. Other private and non-government efforts have entered the arena, particularly in adaptive experimentation and extension. Even allowing for diversity across countries in that transformation and taking into account the heterogeneity among different national programs in size, funding and organizational structure, there are two arguments often used to explain the relative loss of institutional strength in national research programs one is that institutions such as the CGIAR Centers (CIMMYT, CIAT and CIP), and other organizations are now also producing technologies as public goods, and have became practical alternatives to and competitors of national programs; the other is that research is increasingly becoming a private good serving particular interests in the agricultural sector.

National programs in LAC are gradually modifying their structures and working modalities to take these facts into account and develop greater integration and partnership with those additional efforts.

National Agricultural Research Extension Systems (NARES) should be seen as mechanisms to develop improved technologies that are consistent with the economic and social circumstances of the countries, and transfer them to farmers for adoption, to design agricultural policies that will favor incorporation of such technologies into production systems, and to establish institutional structures and organizations to carry out agricultural research and extension in an efficient and effective manner.

The basic model used in developing semi-autonomous public research organizations was the technology converter, i.e., a mechanism that would take internationally available technologies and facilitate their dissemination and adoption (Trigo, Piñeiro and Sabato,1983:133). The risks of providing technology for largely unknown agroecological conditions, the lack of trained staff and facilities for research activities, the high costs of technology efforts under such conditions, the scarcity of funds available, and the absence of other willing and capable organizational actors meant that only governments could undertake such a responsibility and that this might best be done through concentrating efforts and resources.

The development of extension activities in the region also received a strong institutional boost in the postwar period through joint agreements between the US and country governments which established "servicios" in a dozen countries between 1947 and 1958: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, Bolivia, Chile, Paraguay (Rice, 1971b: 47). The "servicios" sometimes provided early extension programs with a research component. After a few years the "servicios" were terminated and the extension function usually transferred as a line unit or program to the Ministries of Agriculture. A trend toward institutional and practical separation of research and extension functions seems to have evolved within the "servicios" in some cases and with the transfer to a separate Ministry structure in others (Rice, 1971b: 53-55).

In most instances the new institutions were given a relatively unfocused mandate, in terms of products, regions and clienteles, to develop agriculture. Beginning from coverage of a few products and regions, research programs tended rapidly to diversify their efforts. In the absence of other traditions, an effort was made to follow prevailing international research orientations. Research products, patterned largely on the capital-intensive technology development trends of the DCs, mostly tended to be suitable and applicable to the more enterprising groups of large and medium-scale agriculturalists.

With land reform efforts in the sixties, and with integrated rural development programs in the seventies, political attention and mandate turned primarily to smallholders. At this point it became evident that a suitable pool of improved technology for this clientele was missing and that, in addition, support facilities for transfer and adoption were inadequate. Furthermore, it was generally realized that, both for agroecological and socioeconomic reasons, technical change, especially with smallholders, was far more complex and difficult than originally anticipated.

The public research organizations had to face an initial staffing problem. This was managed in three ways. First, large numbers of trainees were sent abroad to American and other universities to obtain master's and doctoral level degrees. AID and foundations such as Ford, Rockefeller and Kellogg played an important role in this funding. Second, national graduate training programs at the master's level were set up jointly with local universities in a number of countries such as Argentina, Colombia and Peru (Trigo, Piñeiro and Ardila, 1982). Third, early staffing often relied heavily on foreign and expatriate personnel.

Most public research programs expanded very quickly, and diversified activities along a number of dimensions. The number of commodities with some degree of research coverage increased rapidly. By the early eighties, a number of institutes and programs were engaged in research in over 80 commodities, although with variable intensity. The institutes tended rapidly to increase their regional infrastructure of experiment centers, stations, and fields, and with it their coverage of agroecological variability. Some degree of disciplinary diversification began to occur with a limited number of agricultural engineers,statisticians, biologists and social scientists joining a majority of agronomists and veterinarians. Research staff expanded over time despite an often high turnover, at faster rates than funding in real terms.

A number of consequences have resulted from this expansion. Average spending per researcher has tended to decline in real terms over time, both for operational expenses and for salaries. Although in overall terms the number of researchers with graduate degrees,especially at the master's level, less so at the doctoral level, has grown, this fact tends to obscure substantial turnover rates. During the last three decades, real government spending on agricultural research declined in the context of stabilization policies and a global reduction in government expenditures, thus aggravating research conditions. Donor and external funding assume a larger role in research funding, as public funding declines. Consequently, government expenditures on agricultural research remain a very modest percentage of total government expenditures, below one percent of the gross domestic agricultural product in most cases. Managerial conditions for agricultural research tended to decline with decreasing autonomy and discretion following as a result of coping with diminished funding, greater internal complexity of research programs and efforts, and the absence until very recently of administrative technological modernization.

Second, a number of attempts to bridge the gap between technology generation and its adoption took place in countries such as Mexico, Colombia, Honduras and Guatemala, in which international and regional research centers, particularly CIMMYT and CATIE, participated. On-farm and farming-systems methodologies gave rise to an approach to technology generation which stressed both the influence of local need identification and local conditions, through farmer participation and feedback to research planning. Currently, most research institutes have developed, or are in the process of developing, some form of on-farm or farming-systems research capabilities or program.

Third, a number of non-governmental actors began to engage in technology related activities either directly or through the funding of these. These have included commodity associations (cotton in Peru or rice in Colombia), regional groupings (Patronato de Sonora in Mexico), private companies (tomato processors in Panama), industry-wide groupings of processors (FUNDASOL in Venezuela), foundations sponsored by donors (AID in the Dominican Republic, Ecuador and other countries) and nongovernmental organizations either performing or funding research or technology transfer activities. Despite all these, private sector efforts remain small in comparison to their potential contribution.

b. Research coverage of staple foods vs. nonstaples

Despite the overall growth in research funding, there are still great inequalities among commodities. Funding of research for basic food staples still lags well behind that for export and industrial crops. This is particularly true when we take into consideration local or indigenous crops such as quinoa, some Andean roots and tubers and floury maize. Food aid, for example the P.L. 480 program, has brought changes in consumption patterns in which maize and other sources of energy intake have been replaced by wheat. This has caused not only a growing dependence on an imported food, but also a lack of stimulus for agricultural research oriented to ward local crops, some of which in particular environments are significant in terms of sustainability.

The fragmented and heterogeneous nature of the production systems for food crops in LAC has meant that staples lack the political base that characterizes crops such as sugar, coffee or cotton. Pressures from politically and socially more powerful sectors, both rural and urban, have biassed the focus and rate of technological change toward exportables and created patterns of institutions and funding in which some of the basic food staples remain underrepresented.

Table 2 shows research spending by commodity (percentage of value) highlighting the low relative investment for the most important staple foods.

c. Adequacy of extension services and other mechanisms for technology transfer

Extension services in LAC have developed under a quite different paradigm than that which has guided research. With the exception of INTA in Argentina, agricultural research and extension are placed in different institutions in the rest of the countries. Extension and technology transfer services have in most cases remained in the Ministries, lacking the necessary support and institutional continuity for better performance. This is not to say, however, that placing both activities (research and extension) in the same institutions is a necessary and sufficient condition for effective coordination or for improved institutional performance.

Extension tends to have a weak integration with research activities, even where both have been placed in the same organization, although the development of on-farm and farming-system approaches at research agencies and special integration efforts offer some promise of gradual improvement. A top-down view of the role of technology transfer and extension has been linked to this. Differences in the institutional acculturation of academic research personnel and extension service employees and conflicting perceptions of status and the appropriate clientele may also be a factor.

The Ministries are unable financially to support a staff large enough to ensure coverage of most smallholders, yet alternative strategies to individual and group extension approaches have only been explored minimally. The Ministries face administrative difficulty in organizing and controlling the activities and performance of a large staff engaged in only partly standardized field activities. The difficulties experienced have produced an internal concern with extension methodology per se, rather than efforts to face directly the more structural problems of ensuring suitable linkages with both researchers and farmers, of dealing with the difficulties experienced by the latter on their farms, and of seeking strategies to expand coverage and impact.

Associated difficulties and problems include lack of operating funds, low staff morale and high turnover, frequent reorganizations that increase discontinuity without improving on structural problems, and administrative rigidity.

Current conventional wisdom says that extension agents should help in the definition of researchable problems at the farm level, providing technical as well as socioeconomic information for orienting research toward the need of farmers, and giving feedback on how research-generated technologies perform in the field when compared with local used alternatives. However, extension services in most of LAC countries are not involved in providing input to research. The absence of appropriate functional integration among farmers, researchers and extensionists has meant inadequate problem-solving processes, on the one hand, and an unsatisfactory basis for tailoring science-derived innovations to the conditions of specific clienteles, specifically smallholders.

Despite the fact that at the conceptual level there is agreement that technology development, transfer and use are all part of a mutually reinforcing continuum, the fact that most LAC have a functional gap between research and extension (Ruttan, 1987) has meant that maximum potential advantage has not been realized from technological advances.

There have been some donor-funded programs to improve extension services and make research effective in meeting farmers needs, for example the introduction of the training and visit system and the Farm Systems Research and Extension Projects. In the case of T and V success has not been great, as in the majority of the situations efforts tended to dilute once external funds main out the "On-farm research" approach to technology generation, which stresses both the influence of local need identification and local conditions, through farmer participation and feedback to research planning, has also had a positive impact in bridging the functional gap between technology generation and its adoption. In a number of countries, including Mexico, Guatemala, Honduras, Panama, Ecuador and Colombia, specific efforts involving local and internatural institutions (CIMMYT, CATIE) have been implemented and institutionalized in some degree since the mid-1970s Merrill, Sands and Mc Allstor, 1988). Currently, most research institutes have develop, or are in the precess of developing, some "on-farm"/farmer systems research capacities as integral components of their research and technology development strategies

On-farm research is not a substitute for extension, but projects with that orientation have made important contributions toward improving the process of defining the research needs of resource-poor farmers, and involving extension agents in the process. Recommendations tailored to location-specific circumstances have been developed, with a significant improvement over the blanket technology packages that extension services often promote.

In addition to the problems mentioned above, there are others associated with research and technology transfer. One difficulty arises from the pattern of growth of technology institutions. The generation of systematic technology for more than one hundred commodities, produced over a wide range of agroecological and socioeconomic conditions, amounts to a very large workload to manage in a relatively short period under current conditions of current arrangements. Not only is simply too much being expected in too short a time, it is also far too heavy a burden to assign mainly to government institutions. The present model was highly successful originally but its assumption of technology as a public sector responsibility has clearly proven inadequate for dealing with the explosive growth of technology requirements. Developing and diffusing the amount and diversity of technology currently and prospectively being required in the region will demand, among other changes, a redistribution of efforts to include greater participation by other actors, mainly the private sector. Although nongovernmental and private sector efforts are on the rise, they are clearly insufficient in relation to the magnitude of the requirements.

A second problem is limitations for pooling efforts and resources and for capturing externalities. Despite substantial increases in commodity, disciplinary and institutional networking, much research still results in duplication and inefficiencies, not only between countries but even within them. In the face of scarce, diminishing resources for research, responding to expanded requirements would make it necessary to minimize duplications and improve the use of existing resources. In turn, this highlights the need for enhancing cooperation,collaboration and networking.

A third difficulty concerns adapting to future trends in agricultural science. Often, the staff of research institutes lacks the disciplinary composition required for successful engagement in agricultural biotechnology, although universities are in a somewhat better position. Removing this difficulty calls for substantially improved linkages and new mechanisms to develop science-based capabilities not only among institutions within and between countries but inter-regionally as well.

A fourth concern is the stagnation and/or decline of public technology institutions, particularly over the last decade. Research organizations suffer from administrative rigidity, staff turnover, underfunding and the absence of institutional forms and capabilities for linking with specific clienteles and other non-governmental research actors. Extension services also face problems of methods, of the political environment of the ministries in which they are located, and difficulties in triangulating appropriate functional relationships with specific targeted clienteles and research organizations and programs.

2. Achievements of Applied Biological Science in Staple Food Production

For the last 35-40 years there has been a directed effort, particularly for the Third World, to use science-based technology as the dominant strategy to alleviate "the food problem." Rapid technological progress was considered the key to maintaining the food population balance in developing countries, particularly in a situation where cultivable land was increasingly limited.The stock of knowledge accumulated until the fifties in the field of agronomy, particularly in soil preparation, fertilizer application and irrigation, and in germplasm development, the main forces of what became known as the "Green Revolution."

In Latin America and the Caribbean (LAC) rates of growth in production of major food crops have been consistently better over the last 25 years than for other regions and developing countries. From 1962 to 1972 total food production grew at a rate of 4.2% in LAC, compared to 3% for all developing countries. In the following decade the LAC growth rate was equal to the overall average. In the 1960s growth in yields per hectare accounted for 35% of increased food output, while in the 1970s this contribution had risen to over 60%.

Despite the initial successes, food sufficiency has remained a regional concern. Growing incomes, greater urbanization, increased labor force and population growth all combined to continually increase demand for food. Overall, growth of food consumption in LAC has exceeded the growth of production since the 1970s, with a consequent heavier reliance on imports. Cereals and vegetable oils account for a very significant part of the rise in food imports for LAC.

Both non-economic and economic factors have contributed to the poor agricultural performance of the last 15-20 years. Civil and political upheavals have created a discouraging environment for production. Changes in world production and distortions in international trade for agricultural foods and in financial markets have worsened the terms of trade for traditional agricultural exports. Perhaps most important, early industrialization policies of import substitution discriminated strongly against agriculture in many LAC countries.

A long period of industrialization disequilibrium and rapid debt accumulation, plus other unfavorable internal and external factors, have created problems in LAC with no precedent in modern history. Probably no other region was as hard hit by the international debt crisis. By the end of this decade the crisis had caused a realignment of exchange rates, gradual improvement of domestic competitiveness of the agricultural sector (in which the LAC region still enjoys significant comparative advantages in a number of agricultural products), and stimulated exports.

a. Lessons of the Green Revolution

The Green Revolution started when semi-dwarf wheat and rice varieties, developed by CIMMYT and IRRI, spread rapidly in response to the food crisis in Asia. Although Asia received more media attention, research on these two crops had important predecessors in LAC, first in 1943 when a joint program was initiated by the Rockefeller Foundation and the government of

Mexico, and later in 1950 when a similar program was established in Colombia.

First products of the Green Revolution were released in 1962 for wheat and in 1966 for rice These superior varieties spread rapidly in large rice and wheat growing areas of Asia, and the research programs exceeded the expectations, as the time needed to produce these first commercial varieties was shorter than anticipated. However, this pattern of success was not repeated for other species.

The "Green Revolution" euphoria caused by the rapid growth of wheat and rice production in many developing countries, for example in Colombia and Brasil for rice and in Argentina and Mexico for wheat, has been replaced since the beginning of the 1970s by growing fears that Green Revolution-type technologies, or more simply modern varieties (MVs), were enriching large-scale farmers at the expense of small scale ones, landowners at the expense of laborers, and were being developed only for the most favored environments, neglecting many other less endowed regions.

Donor agencies began to pay increasing attention to issues such as the nutritional requirements of less advantaged groups, equity in the distribution of the benefits of research, and the special needs of the resource-poor farmer. With this came a reformulation of the CGIAR Centers policies for the generation of technologies oriented toward the poorest segments of society. This change in orientation is reflected in the wider variety of staple crops on which research is being conducted. By the year 1983, IARCs-related varieties released by national programs is LAC were as follows: wheat (bread and durum)-127; rice-129; maize-126; beans-90; potatoes-12; cassava--32; pasture species-12; sorghum-5; and cowpeas-12.

It is not clear so far how the consideration of the social component by the IARCs affected the efficiency of their research effort, since many of the social problems are political in nature and technology can hardly solve rural problems rooted in long-standing social inequalities.It has been clear, however, that agricultural technology is much more site-specific than thought at the beginning of the Green Revolution after, and the early successes of new wheat and rice varieties. In fact, one of the main conclusions of several adoption studies carried on between 1970 and 1980 was that "the most pervasive explanation of why some farmers don't adopt new varieties and fertilizer while others do, is that the expected increase in yield for some farmers is small or nil, while for others it is significant, due to differences (sometime subtle) in soils, climate, water availability, or other biological factors" (Perrin and Winkelmann, 1976).

Specific study cases for LAC. Perhaps one of the best advertised cases of an attempt to bring the Green Revolution into what otherwise would have been a "neglected area" was the Puebla Project in Mexico. The Project, located in the state of Puebla in Central Mexico, began its activities in 1967. This was a rainfed area where most small farmers cultivated corn using traditional methods, obtained very low yields and used most of the harvest for home consumption. Technical support was given by CIMMYT and the Postgraduate College at Chapingo. The Rockefeller Foundation covered a substantial portion of the operating cost of the project.

A package of technological and institutional practices designed to increase corn yield was developed and disseminated among peasants. The package included technical information about fertilizer doses, time of application, and plant density, plus institutional arrangements to facilitate access to credit and fertilizer. The use of fertilizer was already known by farmers of the area, but very few of them were using it. Because of the relative high yield potential of the local corn varieties, new seed was not introduced. In addition to the technological inputs, a 30% increase in labor was required for fertilizer application, increased plant density and extra-output.

After several years of work with the project, the rates of adoption of recommended technologies were considered relatively low, in spite of the fact that, according to cost-benefit analysis , participating farmers could nearly quadruple their net return per hectare by following the project recommendations. Table No. 1 shows estimated input-output coefficients of corn production for some areas of the Puebla Project.

Researchers from various social sciences have produced many explanations for the patterns of adoption of the Puebla Project farmers. It is very probable that risk aversion, particularly in the form of safety-first behavior for this type of small holders, explains quite well the discrepancies between peasants' demand for fertilizer without risk and actual demand under risky conditions (Moscardi, 1997). When the model is expanded to include the true opportunity cost of the family labor and imperfect information, additional explanations are found for different adoption patterns (Benito, 1975).

TABLE No. 1

PUEBLA PROJECT INPUT-OUTPUT COEFFICIENTS

VARIABLE	TRADITIONAL TECHNOLOGY	IMPROVED TECHNOLOGY
Family labor (days/ha)	41	53
Nitrogen (kg/ha)	22	115
Phosphorus (kg/ha)	15	40
Plants (thousands/ha)	33	60
Yields (kg/ha)	2.000	3.500

SOURCE: Benito, C.A. Peasants' Response to Modernization Projects in Minifundia Economies, AJAE, May 1976.

Table No. 2 shows data associated with maize adoption studies in Colombia, El Salvador and Mexico (Veracruz) by farm size and percentages of adoption. Some correlation between farm size and adoption decisions is apparent, although further data has indicated that when equilibrium levels of adoption appear to have been realized very little correlation is shown.

Table No. 3 shows a summary of results from multivariate analyses to explain farm-to-farm differences in adoption behavior in areas where equilibrium adoption levels have not been realized. For each factor included in the analysis, "yes" means that the factor was significant statistically, and a "no" otherwise. It is evident that productivity factors, agroclimatic zones and topography are the most consistent in explaining why some farmers adopt new varieties and others do not.

Distribution of benefits. The distribution of benefits of the Green Revolution raises several issues: modern varieties and the poor; farm size and adoption; employment and nutrition. The impact study carried out by the CGIAR has shown that Green Revolution technologies have done rather well in regard to those concerns. These findings are consistent with several studies that can be summarized as follows: in MV-affected areas the poor appear to have gained absolutely but lost relatively; small farmers adopted after larger ones, but they did adopt, and raised yields; farm workers found that the effect of MVs in boosting the demand for their labor seldom brought much higher wage rates, but employment rose; and poor consumers gained as food prices fell (Lipton, 1985).

b. Access to new technology

There is an increasingly accepted view that technically appropriate technologies and profitable MVs, by being wides pread, will everywhere help the poor. The problem is that these technologies are not available everywhere.

In many modernization projects of LAC, and in particular within the integrated rural development (DRI) strategy for transforming traditional farming into commercial agriculture, there has been a common denominator of rapid availability of superior technologies. When these were not available, the necessary additional income streams to sustain those projects did not occur and many of them have failed.

Where a new variety or new technology is marginally profitable, the subsidy implied by government credit programs, or solidarity actions to reduce uncertainty and transaction costs, or better extension programs, could be expected to affect many farmers' decisions to adopt it. But there is no substitute for technically appropriate and profitable technologies when a high rate of irreversible adoption is desired.

TABLE No.2

FARM SIZE AND PERCENT OF FARMERS ADOPTING NEW VARIETIES

Crop and Area		Number of Farmers	Farm Size	Percent of Farmers Adopting by Farm Size				
				Limits (ha)	SMALL	MEDIUM	LARGE	
Colombia maize								
1 low-valley			203			19		65
hillside	49		2.6		0		16	
2 med-valley		50		2.6		19		30
hillside	170		2.1		10		15	
3 high-valley		135		1.0		5		12
hillside	126		1.5		4		4	
Salvador maize								
1 valley	177		1.4-3.5		34	46	71	
2 hillside	126		1.4-3.5		26	13	36	
Veracruz maize								
1 valley	42		1.0-3.5		27	37	55	
2 hillside	69		1.0-3.5		18	32	36	

SOURCES: Gerhart, Colmenares, Cutié, Perrin, Vyas, Demir and Gafsi

TABLE No.3:

FACTORS EXPLAINING WITHIN-REGION VARIABILITY IN FARMER'S DECISIONS TO ADOPT IMPROVED VARIETIES

Country: Crop: % Adopters:	Kenya Maize 67%	Colombia Maize 20%	El Salvador Maize 36%	Veracruz Maize 34%	Tunisia Wheat 31%	Turkey Wheat 64%
Productivity						
Agro-climatic zone	YES	YES	--	--	NO	YES
Topography	--	YES	YES	YES	YES	YES
Information						
Schooling	YES	YES	YES	--	NO	NO
Extension visits	NO	YES	--	--	--	--
Demonstrations	YES	--	--	YES	--	NO
Age	NO	--	--	--	--	NO
Tenure	--	NO	--	--	NO	NO
Inputs						
Credit-use	--	YES	NO	NO	YES	NO
Credit-availability	YES	--	--	--	NO	--
Co-op membership	--	--	--	--	--	YES
Product Market						
Variety discounts	--	--	--	--	YES	NO
Market sales of crop	--	--	--	NO	--	NO a/
Risk						
Perceived yield risk	--	--	NO	NO	--	YES
Use of drought Crops	YES	--	--	--	--	--
Off-Farm Income	NO	--	--	NO	NO	NO
Farm Size b/	NO	YES	NO	YES	NO	YES

SOURCES: Gerhart, Colmenares, Cutié, Perrin, Gafsi and Demir

a/ Market participation was important in one of four Turkish regions

b/ Farm size was important in one of three Colombian, two of four Turkish regions.

C. POLICY ISSUES IN STAPLE FOOD RESEARCH AND TECHNOLOGY TRANSFER AND ADOPTION

Effectively mobilizing the full potential of science and technology contribution to food security requires careful consideration of a number of issues, as well as placing technological policy instruments in the overall policy and institutional framework. How to take better advantage of the new institutional developments affecting private sector interest in technology development without compromising the needed participating of public institutions in critical aspects of the process; the need to correct past biases against smallholder agriculture and fully exploit the potential of the better agricultural lands; the appropriate use of the region's biodiversity weath effectively linking the region to the biotechnology revolution; and building upon the existing horizontal and regional cooperation experience, are some of the specific issues to be considered.

1. The Overall Policy and Institutional Framework

It is important to treat food security policy and institutions in the region holistically. A food security approach should look at food not simply in terms of a traditional sectoral perspective on agriculture but take instead a broader view. "Food" in this definition includes industrially grown or produced edibles, e.g. broilers and mushrooms, processed foods, and production for intermediate uses such as animal feed. When this approach is taken, food security issues extend beyond on-farm concerns with production to encompass postharvest, marketing, processing and industrial production issues. The difference is important because food consumption patterns in the region are changing to include a growing component of processed and industrially derived foods. Omitting these would seriously distort consideration of the composition of final demand for food in which product attributes such as packaging, pre-preparation and convenience become relevant in addition to availability and prices. Evidence of these changes is apparent from nutritional surveys in both urban and rural areas, and from changes in the added value of food industries which show a rising share of the off-farm contribution.

The food industry has proved to be among the most resilient industrial subsectors in the general industrial decline taking place since the mid-1970s. Yet its chances seem increasingly to depend on improved ties with agricultural product suppliers and on its capability to identify, negotiate, adapt and innovate technologically under competitive cost conditions.

Holistic analysis reveals major problems in current food policy. No single policy framework deals with the different stages and aspects involved. Serious discontinuities, both of infrastructure and of institutions, disrupt the integration of different functions such as postharvest management, conservation, packing, distribution and marketing.

The greatest problem of agricultural technology is the absence of functional links. Whereas on-farm production is supported by formal research and technology transfer organizations, postharvest management, processing, distribution and marketing functions often lack adequate sources of technology and innovation. In other instances, technology sources exist without links among the various functions. Yet for successful overall performance these functions need to be closely articulated. For instance, commodities are composed of living, metabolizing tissues having a variety of characteristics, including their capacity to withstand the stresses of time, temperature, physical handling, and transport, to resist infection and/or spoilage by decaying organisms, and to develop and maintain quality. These characteristics constitute the basis for determining the requirements for successful storage, handling, and distribution. All the care taken in producing a crop may be lost through poor postharvest handling practices (AID, 1990:12).

At the farm production level, certain policy impacts are discernible. A low price policy for staple foods has prevailed historically, enforced by discouraging exports, through the selective use of imports to contain prices, and in some instances through direct attempts to regulate prices. The net impact to have been variable, but their thrust is to discourage the production of staple foods. Conversely, number of inputs--machinery, oil, fertilizers--tended to be subsidized either directly or through overvalued exchange rates. This primarily favored export crops and presumably had little direct effect on staple production except through pressures on lands used for these crops. The net effect of interventions on credit has probably caused a reduction rather than an increase in the amount of credit available to the smallholder. (Vasquez et al., 1989:51).

Since the seventies and especially the eighties, policy has been dominated by structural adjustment and instabilities of various sorts. The general direction of these has been toward removing subsidies, increasing market influence in setting prices and linking domestic with international economic activity. As these policies take effect, domestic output and real GNP will rise, but the real wage rate will not necessarily increase. Thus, while these policies tend to raise the real prices of staples, and therefore their production, the net effect needs to take into account possible impacts on food demand due to income decline. Also, higher prices for imported inputs militate against smallholder modernization, yet could potentially encourage improved adaptation of existing technologies through changes in relative factor prices. Other negative effects on food-production follow from the decline of public sector spending on agriculture and its infrastructure.

The crisis and the short-term orientation of structural adjustment and macroeconomic management have impaired possibilities for carrying out consistent and sustained agricultural policy and have led to a "disempowerment" of Ministries of Agriculture. Consequently, little if any progress has been made towards developing science and technology policies for agriculture within their framework, a difficulty further compounded because many of the relevant institutions are outside the purview of the MOAs. In some countries, progress has been made by way of national general policies for science and technology, in which the agricultural sector fits , but in general these efforts lack effective instruments and implementation.

2. The Relative Roles of the Public and Private Sectors

The contribution of public sector research and extension organizations has been extensively discussed earlier in this paper. However, until recent years the important role of the private sector in agricultural technology development and transfer in LAC was not properly recognized. The last 10-15 years have seen a remarkable growth in participation of the private sector in applied and adaptive research, input supply (in particular fertilizers and pesticides) and technical assistance. This participation goes beyond the classic case of multinationals in hybrid corn.

There are two important factors behind the growing importance of the private sector in technology generation and transfer: first, science-based technology results in increasing possibilities for private appropriation of the benefits of technical change, making private investment in R&D activities more attractive; second, each year agricultural universities in LAC produce a substantial number of professionals who in the past were absorbed by public sector services, but now are increasingly employed in the private sector for technical assistance in farmer's associations, input supply stores and consulting services.

Farmers' associations are the best example of private participation in adaptive experimentation and technology transfer. Those organized around commodities, such as the Federation of Rice Producers (FEDEARROZ) in Colombia, and others in Brasil and Argentina, as well as the traditional, coffee, cocoa and banana growers, have developed a wide range of activities covering research and technical assistance and integrating efforts with national research programs and even with international centers. Farmers cooperatives have also been quite active in developing technical assistance schemes in LAC.

A parallel development of increasing importance in recent times is concerned with the creation of a number of independent research and extension foundations oriented to provide funding support for research and technology development such as FUNDAGRO in Ecuador, ADF in Dominican Republic, FUNDEAP in Peru and FUNDASOL in Venezuela, or actually assume direct responsibility for implementing research in specific areas such as Fundacion Chile in that country, FHIA in Honduras or FUSAGRI in Venezuela. The majority of these initiatives have been donor-driven, mainly through USAID, but they have also been able to generate counterpart funds of some magnitude from local public and private sources. To date, experience with this type of institution is still limited as must of them have been slow starters, concentrated on providing complementary funding helping in attracting and retaining scientists, promoting training, and serving as "mentors" of a science-dependent agricultural sector. However, their development should be closely monitored as they provide a flexible and effective administrative mechanism for complementing the traditional components of the NARS and generating additional funding support for its activities.

They could prose to be quite relevant in the context of the budgetary restrictives confronting the majority of the countries and offer an important alternative for providing continuity to the research effort and over all institutional sustainability to the traditional research organizations.

A large number of NGOs operate in LAC. Most of them are oriented to community development and social welfare, but some collaborate with rural development projects, simultaneously providing technical assistance.

A word of caution is in order now that many countries of LAC are going through adjustments to reduce the size of the respective state budgets. Strengths and limitations are found in the public as well as the private sector when trying to generate and transfer optimal technologies from a social standpoint, and when deciding issues such as the optimum level of investment in agricultural research, or the need for sustainable agricultural growth. Both private and public efforts are needed, and care must be taken to ensure an appropriate balance, so that coverages of relevant clienteles, crops and agroecologies are properly maintained or developed.

Despite the growing importance of private sector participation in agricultural technology, there is still considerable debate on the proper role of those efforts. Issues such as natural resource conservation, environmental contamination, distortions in the rate of technological change, or bias in favor of commercial large-scale farmers against small farmers, are mentioned as areas of concern when discussing the role of the private sector in technology generation and transfer. There is no doubt that the public sector will always have an important role to play, but neither is there doubt that coordination and integration of public and private efforts could yield a better final performance.

3. Issues Specifically Related to Size of Production Units, Particularly Small Ones

Should technological change be induced or tailored to fit the farm size and even the production and consumption patterns of peasant farming? Should peasant farming, instead, evolve or dissolve into farming structures, say commercial or cooperative farms, with sufficient land and resources to benefit from available and emerging technologies? This has been, and still is, a key question for agricultural technology systems in most LAC countries.

One outstanding pattern in the history of new knowledge, and hence of technological change, has been its relative autonomy with respect to existing organizations of production and trade. In the long run, organization of production has tended to adapt to technological changes. On the other hand, technological innovations, such as changes in factor ratios, have been induced by changes in the relative scarcity of resources. The relative prices which explicitly convey those scarcities, however, do not convey with the same transparency information about the relative opportunities of social groups. In addition, while profit-making has been a driving force for overcoming resource scarcities, it has been weak in reducing differences in opportunities. Fears of social unrest or compassion (if any), have been the real driving forces in reducing unequal opportunities.

Uneven distribution of opportunities has tended to induce institutional changes rather than technological changes. The agrarian reforms of the 1960s and early 1970s were institutional changes aimed at incorporating some peasants into farming systems which could adopt modern technologies. Collective and cooperative farming, for example, were complemented with investment in irrigation and mechanization, with free technical assistance, and with subsidies of modern inputs. This was the case in the Dominican Republic, where agrarian reform became functional in the production of rice with modern technologies. It was even the case in the most recent agrarian reform of Nicaragua, since 1980.

The large quantities of peasant farms in LAC have always represented a challenge for the organization of research and extension in the region. The community of agricultural scientists, communicators, and social researchers has responded with different approaches to this agrarian dilemma. On one hand is the ***adoption debate***, which investigates the neutrality of agricultural technologies with respect to farm size. On the other hand is the ***farming system debate***, which investigates the adaptation of technologies to the production and consumption patterns of peasants. In between these two paradigms have evolved numerous alternatives, from home economics, through gender-oriented systems, to agroecology for small farms.

a. Adoption of technologies among peasants

What explains the low rate of adoption of Green Revolution technologies among peasants? How does diffusion of Green Revolution technology affect social differentiation in rural areas? These are the two major questions within the adoption approach. They are also two different perspectives, one based on partial-static equilibrium, the other based on general-dynamic equilibrium.

Peasant characteristics, recommendation packages, and low adoption rates. Different rates of adoption among LAC peasants are explainable by two major sets of factors: the characteristics of peasant farming and the nature of the technological recommendations.

Different rates of adoption among peasants are explained by diverse behavior under conditions of uncertainty. They are also explained by their different information about the technology, by their different access to credit, and by the different opportunity cost of their labor (Benito, 1978).

Green Revolution technologies create two additional sources of risks for peasants. Improved seed varieties combined with higher doses of chemical fertilizers have higher mean yields than traditional varieties, but at the cost of higher variability. These technologies, in addition, induce single cropping in place of the traditional multiple crop pattern of peasants. Under conditions of rainfed farming a poor rainy season may thus imply lower yields with improved seeds than with traditional ones. Since most peasants farm under survival conditions, they tend to follow a "safety first" rule. They try to minimize the probability of falling below a survival level of real income (Benito, 1976b). As a consequence, poor peasants will tend to adopt technologies at a lower rate than commercial farmers. The attitude of peasants under uncertainty in turn depends on factors like farm size, family size and others (Mosrcardi and de Janvry, 1977).

Communicators and rural sociologists have explained the low rate of adoption as a result of the imperfect information of peasants and the lack of organizations providing access to credit and input markets. An additional explanatory factor for the low rate of adoption is the opportunity cost of peasant labor. Green Revolution technologies are more labor intensive. Some advocates of agricultural modernization used to assume that the opportunity cost of peasant labor was near zero, the underemployment hypothesis. This is not always the case. For example in Puebla, Mexico, for some groups of peasants the additional benefits of the new practices did not offset their additional labor costs (Benito 1978; Villa Issa, 1977).

Many studies on peasants' adoption assume the existence of profitable technologies, or that researchers and extensionists provide appropriate recommendations to farmers. This may not always be the case, however. The farming practices of peasants, as far as they deviate from recommendations of researchers, should not be interpreted as a lack of adoption, but rather adoption of more appropriate practices (Baldwin, 1978). The real reason for low rates of adoption of new seed varieties and fertilizers in some countries or areas of LAC is explained by the technology itself. Given the specific site of peasant farming, some recommendations are able to increase yields, but are not able to increase the net income of peasants in a significant way (Perrin and Winkelmann, 1976). Without a substantial increase in income, net additional costs and risk, some groups of peasants do not have the incentives to change their farming technique and their production patterns.

The perspective which explains adoption by peasant characteristics calls for rural development projects which reduce transaction costs in credit and input markets. Plan Puebla pioneered the organization of credit-buying groups and communication systems where by peasants taught themselves. The perspective which explains adoption mainly by the adequacy of the technological package suggests tailoring recommendations to specific areas or crop patterns. This is the current approach of CIMMYT in the region.

Green Revolution and social differentiation. The diffusion of Green Revolution technologies has been objected to because they reinforce the process of social differentiation in rural areas (Griffin, 1974; Feder, 1976). They are not neutral with respect to farm size. The rate of adoption of Green Revolution technologies has been larger among commercial farms than among peasant farms. This differential access to new sources of income sped up the process of social differentiation between commercial farmers and peasants. In addition, small groups of peasants with the right characteristics to adopt profit-increasing recommendation, have differentiated rapidly from traditional peasants. They became commercial farmers, suppliers of transportation services, middle men, lenders, or migrated to towns and cities. The success of adopting peasants has allowed them to join commercial farmers in reaping the rents created by government interventions in prices, such as subsidized credit, irrigation, mechanization and other subsidized inputs.

The promotion of the Green Revolution among peasants in LAC to a large extent represented the concern of the research community trying to prove the neutrality of yield-increasing and high-input technologies. This was one of the major thrusts of Plan Puebla and the subsequent replications in Mexico and many other countries. During its first stages Plan Puebla had the technical support of CIMMYT and the financial support of the Rockefeller and Ford Foundations.

The most relevant factors affecting social differentiation in the region were not technical changes per se, but rent-seeking policies. The ultimate causes of rural poverty in LAC are inappropriate institutions and excessive population growth. In many countries there are no institutions nor affirmative action to induce equal access to human capital formation. Neither are there institutions nor financial programs to promote peasants' access to land via ownership or secured tenancy. Direct and indirect government interventions in macro and micro prices made possible social differentiation via technological change or other external shocks (de Janvry, 1981).

b. Farming systems for small farmers

The farming system approach has promoted the adaptation of technology to the specific production and consumption patterns of peasants. This approach uses on-farm research to develop site-specific techniques and to communicate with peasants.

Farming system approaches had some political and financial support during the 1970s. CATIE is a regional institution developing these types of technical packages. IFAD, in Rome, has shown a preference for financing rural development projects which include farming system approaches.

The implementation of this approach in the region is today facing major challenges. In the first place, the generation and transfer of specific recommendations for millions of farmers is a very expensive strategy. In the second place, political and financial support have decreased since the fiscal crisis. The approach was more justified within the previous models of industrial-import substitution and cheap food policies. Under such models most peasants were *de facto* producers of non-tradable commodities. Therefore, one strategy for reducing chronic food insecurity was the path of self reliance, a rural way of development (Benito, 1976a). Under the evolving conditions of structural adjustment, if prices are allowed to reflect relative scarcities, many peasants will benefit from the higher prices induced by increasing real exchange rates. The elimination of subsidies for commercial farmers will increase the competitiveness of peasants in relation to that group. The correct incentive system will benefit both producers of exportable and importable crops. Some groups of peasants, then, have economic incentives to adopt modern technologies.

4. Technology for Rainfed Agriculture

Land currently under cultivation in the LAC region represents only 22% of all potentially cultivable land. However, the most favorable land is already under cultivation and most of the "reserve" is found in areas with heavy rains, acid soils and other sustainability problems, plus high transportation costs to distant consumption centers.

The necessary technological developments for different land types can be seen by analyzing the likely prototypes of agricultural development paths (CIAT, 1990), as follows.

a. Intensive -urban farming

Highly labor-intensive development path which will expand close to urban centers. It requires either large urban markets for fruits and vegetables, or an export demand. Regions need good infrastructure, land typically under irrigation and high standards of production quality. This path is oriented to the development of non-traditional agriculture.

b. Marginal land farming

Farming occurs on less fertile land which is more distant from major markets, generally by small-to medium-sized farms. These agroecozones are characterized by serious sustainability problems, low incomes, pressure on fragile resources, erosion, and similar problems. Hillsides in the Andean Region are examples of regions on this development path. Niches with better soils closer to markets will develop with intensive crops and high labor use or with rurally based agroindustries. An important share of the consumption basket of Andean countries--floury maize, potatoes, beans, broad beans, quinoa and a variety of vegetables--is provided by these systems.

c. Commercial farming on fertile land

This development path is relevant for large areas of the hemisphere which currently produce basic grains for urban populations. It involves increased mechanization and tends toward less diversified systems. The challenge will be to increase efficiency in a sustainable manner, avoiding present problems of specialized agricultural systems such as excessive use of agrochemicals, weeds, soil compaction and erosion.

d. Intensification on environmentally low-value land with agricultural potential

A very important agroecozone of the LAC region is the "acid savannas." Intensification of agriculture in the savannas offers scope for increasing staple-food production from currently low levels of productivity. Promising production systems are being developed with combinations of new acid-tolerant rice varieties and pastures. The critical issue for this development path is whether the production will be competitive as increasing energy prices affect transportation and input costs. This also depends on research in developing varieties and new production systems which can efficiently use these environments.

e. Intensification on environmentally valuable land with low agriculture potential

Use of the humid forest for cropping and livestock in the past has had a markedly land-exploiting nature, due to a relatively free access to this resource. The significant negative environmental externalities of this system and questions about sustainability of crop and livestock production on these lands have led governments to question its validity. There is a growing consensus on the need to better understand this ecosystem and the trade-off involved so as to design more appropriate technology for its use.

In summary, commercial farming on fertile land and intensification on environmentally low value land with agricultural potential are the two development paths where most of the increased production of staple food is expected for the LAC region. Most of the areas apt for these two systems are rainfed lands.The most important challenge for technology development is to obtain long-term gains in output while preserving the resource base.

5. Applied Biological Research in the Forefront of a New Agricultural Revolution

The advances in molecular and cellular biology achieved in the last two decades, coupled with improved biological and biochemical engineering, have given rise to a group of new and revolutionary technologies, collectively known as biotechnologies, which currently or potentially permit the precise planned manipulation of basic biological functions, such as reproduction, propagation, growth and tissue differentiation, resistance to diseases, metabolism, production of secondary metabolites and photosynthesis.

Biotechnology is not an unitary entity; it is an enabling technology which has extensive applications in industry, agriculture and the service sector. At its heart are the processes to manipulate the genetic basis of organisms. These genetic engineering techniques, the most important being the recombinant DNA techniques, make it possible to transform reproduction and genetic change, that is, essentially, the evolutionary process, from an aleatory process to a planned one. It is in this sense a true "engineering" because it permits rational design of biological agents and substances and their production processes.

There is no doubt whatsoever that these technologies are going to replace traditional ways of obtaining, producing and using biological productive agents, such as plants, microorganisms, animals and enzymes. The agricultural sciences and technologies, in particular, are now and will be affected by these new molecular and cellular approaches.

Currently only the phenotypic traits based on one gene can be manipulated with available techniques. Traits and functions based on many genes must wait for the elucidation of their control, expression and functioning, as well as the development of efficient cloning and transferring techniques. It is estimated that these advances will be achieved in the next 10 to 20 years.

a. General prospects and time frame

Significant economic impact of biotechnology on agricultural production is not expected before the year 2000. After that it will be an increasingly important component of new products and processes for crop and livestock production, forestry, aquaculture and agroindustrial processing. This forecast is based on the time needed to develop new products, about 10 years.

Biotechnology is being, and will be, applied to the following goals in agriculture and related industries:

Improved propagation and breeding of plants and animals. Through tissue culture and embryo technologies it is already possible to accelerate substantially the breeding of improved plants and animals. Genetic mapping of crops and livestock will further increase the efficiency and possibilities of breeding.

Design of products adapted to processing and market requirements. Novel traits related to the quality and processing characteristics of plants and animals will be incorporated genetically. Tomatoes with new ripening characteristics better suited to harvesting and handling are already available.

Improved animal disease and pest resistance and control. Diagnostics based on monoclonal antibodies and DNA probes, as well as genetically engineered veterinary vaccines, are already commercially available. In the medium term, genetically engineered livestock incorporating disease resistance will be produced.

Manipulation of animal metabolism. Though the use of hormones (growth hormone or somatotropin) its is already possible to manipulate animal metabolism to obtain higher production of milk and improved meat characteristics. This will affect the dairy and pork industries substantially in the short to medium term.

Improved plant disease and pest resistance and control. Genetically engineered plants, incorporating pest and disease resistance, will be available very soon commercially, since a significant number of them are currently in the regulatory approval process. Two traits have been manipulated in many different plants: resistance to herbicides and incorporation of insecticidal toxins. In the short term, genetically manipulated biological pest control agents such as bacteria, viruses and other organisms currently under development will be available commercially.

Industrial production of secondary metabolites. Large-scale tissue culture processes to produce high value substances from plants are already developed and in some cases in commercial production. This will reduce the price of these products substantially and replace imported materials.

Increased stress resistance. The resistance to cold, heat, salinity, excess water and toxic soil components, among other environmental stresses of plants and animals, will be manipulated to suit specific production needs. The genetic bases of these resistances are complex and they will be improved only in the medium and long term. But other strategies are already in the field test stage, such as the use of genetically manipulated bacteria to reduce the damage of freezing to plants.

Manipulation of plant nutrient adsorption and metabolism. Biotechnology offers the long-term prospect of transferring more efficient photosynthetic pathways and the capabilities of fixing nitrogen to crops. This would reduce dramatically the use of fertilizers as well as increase productivity beyond the current biological barriers.

Several commodities important in the Third World have been examined recently to assess current constraints to their productivity and the likely availability of new biotechnologies to aid their resolution. Substantial progress may be expected in the short term (0-5 years) for potato, rapeseed, and rice; in the medium term (5-10 years) for banana/plantain, cassava, and coffee; and only in the long term (10+ years) for cocoa, coconut, oilpalm and wheat.

b. Trends in biotechnology generation and use

Biotechnologies were born in the molecular biology laboratories of universities in the U.S. and Europe. Commercial interest in biotechnology was encouraged by the possibility of obtaining patent protection for these innovations. This was established by a few landmark legal decisions, principally in the U.S., which for the first time accepted the patenting of living beings. The commercial potential led to the creation of many small companies by researchers with the support of venture capital, mostly in the U.S. The great expectations of the general public and the investment community in this new field made raising capital through public offerings possible, but the longer and more costly processes of developing commercial products led, in most of these startup companies, to severe capital shortages, and needed research could not be sustained. Many small companies were bought by the big pharmaceutical, agrochemical and energy corporations.

These corporations were initially slow to engage themselves in biotechnology, but when its commercial prospects became clearer they began to invest heavily, developing their in-house research capabilities, establishing linkages with academic institutions and research groups and buying up or establishing strategic linkages with small startup companies. Uncertainties about the risk for public health and the environment of the recombinant DNA technologies have produced regulatory responses by many countries. These regulations are a significant element in the cost and time needed for the development of commercial products and therefore have accelerated the trend toward the concentration of the commercial development of biotechnology in large corporations able to sustain these increased costs.

Today the commercial development of biotechnologies is dominated by these multinational corporations. As a result, the role of the private sector in agricultural research in general has increased substantially in the industrial countries during the last decade. Corporations involved in the agricultural industry have developed channels for the commercialization of biotechnology products by absorbing independent seed companies.

The use of biotechnologies in basic and applied research institutes worldwide has diffused quite rapidly. Most countries in Latin America, especially Mexico, Brazil, Argentina and Cuba, have scientific capabilities in this field. These capabilities are heavily constrained because of declining investment in research in general and lack of linkages with industry. The capabilities to develop commercial products are very weak since only a small biotechnology industry exists. This reflects both the weakness in traditional industries able to exploit biotechnologies, such as pharmaceutical, agrochemical and plant and animal genetic industries, and the scant interest existing industry shows in it. The ultimate reason is the uncertain business climate caused by the severe economic crisis which many of the countries of the region are experiencing.

c. Effects of biotechnology on agriculture

The level of investment needed to make a significant contribution to biotechnology and to develop commercial products is beyond the possibilities of most LAC countries. The integration of regional markets for these products and the pooling of scientific and productive resources between countries and firms is a requisite for any meaningful strategy for the development of biotechnology.

The general effect of biotechnology on agriculture will be to accelerate the trend towards its industrialization. The increased use of inputs, albeit biological ones, and the better control of the production process will make agricultural production processes more independent of climatic and ecological constraints and therefore more adaptable to industrial organization. In some cases, for example the production of high-value products by tissue culture, production could be transferred completely to factories.

The most important general effects of biotechnology on agriculture will be to increase dramatically the efficiency of production of traditional and new plants and animals, as well as the range of possible variations of the organisms to be obtained. This will permit acceleration of breeding activity and broaden the range of organisms available for use in special production situations. The increased knowledge on the physiology and ecology of plants, microorganisms and animals will result in more energy and environmentally efficient production processes, through the use of new biological inputs which will replace for current inputs based on fossil fuels.

In this way it will be possible to sustain and increase the productivity growth of agriculture in existing production areas by the provision of higher output, cheaper-to-grow, higher quality products, and the incorporation of new production areas which for climatic and ecological reasons have not been used to date. The ecological impact of agriculture, both locally and on a global scale, will be reduced. Through improved biochemical engineering processes these products will be refined, modified and reconstituted into foods designed to meet specific needs and demands. As a consequence of these effects, the historical trend toward lower agricultural product and food prices will continue.

The potential of biotechnology for the development of a low chemical input or high biological input agriculture is in the medium to long term. In the short term, biotechnology will actually strengthen the use and extend the lifetime of agrochemicals, as the extensive development of herbicide tolerant crops through genetic engineering shows.

The increased complexity of the agricultural production processes incorporating biotechnological products calls for greater managerial and technical capabilities, which, even if these products were scale neutral, will cause agricultural production to further concentrate in larger production units. This could be one important barrier to the widespread adoption of these technologies by small-scale farmers in the Third World, aggravating the current dual structure of agriculture.

Biotechnology is likely to change the comparative advantage between countries and between commodities, particularly export commodities. The application of new and emerging technologies to export commodities will improve their competitive position in the international marketplace. In general, the competitive advantage derived from geographic or environmental factors will be reduced. This will dramatically affect many Third World countries, whose exports and economic basis will be weakened or even destroyed. These potential negative substitution effects should be identified beforehand and compensatory action be taken by the countries benefitting from them.

World-wide diffusion of agricultural production models based on large-scale use of improved varieties and races of plants and animals has increased the genetic vulnerability of agriculture and threatened the loss of valuable genetic resources. Biotechnology has the potential to change this negative trend, offering new methods of germplasm characterization and conservation and methods for the in-vitro increase of genetic variability. But natural genetic diversity, produced by evolution, is the most important prime material for the exploitation of the potential of biotechnology, which makes genetic resources a strategic input to the future agricultural revolution. This calls for national and international efforts for the conservation and characterization of these genes, within a legal and commercial framework, which recognizes the strategic importance of agriculture and food for all countries, as well as the costs and contributions of farmers, scientists and firms to the productive use of these resources.

The scientific and technological development of biotechnology is mostly controlled by a relatively small group of multinational corporations. Their role in the transfer and use of these technologies and products in Third World countries will depend on the existence of intellectual property protection mechanisms and of adequate biosafety regulatory frameworks. Governments and local industry have to learn to harness the technological and productive potential of these corporations for local development purposes. Without an adequate macroeconomic environment and appropriate industry and technology development policies, it is unlikely that this goal will be achieved. A strong local scientific and engineering community, competitive local firms and a government capable of creating and maintaining a general support to competition and development of local technological capabilities are essential elements in this strategy.

Some countries in the region have formulated biotechnology policies, national programs and certain financial resources related to agricultural biotechnologies. The development of a well-defined national biotechnology strategy and a plan of activities are critical steps in the implementation of an effective national biotechnology program. Public sector investment and creative partnerships between public and private sector interests are equally important in establishing a competitive strategy in biotechnology.

6. International Horizontal Cooperation and Technology Transfer

Horizontal technical cooperation, either by information exchange or improved coordination and development of joint research activities, is one of the most important elements in augmenting resources and increasing the effectiveness of national research and technology transfer institutions. This is particularly so in the case of the smaller countries where there are economic limitations for the development of full-sized NARS able to attend to all their research needs. Some recent studies (Trigo, 1988) indicate that in most of the Central American and Caribbean countries the levels of investment required to maintain a minimum research program exceed by far what would be considered "reasonable" research investment standards calculated as a percentage of the value of the commodities, even in staple crops such as cassava, beans, rice and maize. Within Latin America and the Caribbean there exists considerable experience of this kind of mechanism; several particularly successful cases include the Program for Cooperative Agricultural Research in the Southern Cone (PROCISUR) and the Program for Cooperative Agricultural Research in the Andean Subregion (PROCIANDINO), among others.

Both PROCISUR and PROCIANDINO are flexible coordinating mechanisms for cooperative research and information exchange in which each country retains its management responsibility and programming independence in accordance with its respective capability. Their structure includes a number of specific crop networks (PROCISUR: winter cereals, summer cereals, oil-seeds and cattier; PROCIANDINO: maize, potatoes, food legumes, and oil-seeds) operating under an integrated secretariat provided by IICA. Overall priority setting, resource allocation and supervision of activities are responsibilities of the directors of research of the participating countries who meet at regular intervals, usually twice a year.

Both Programs have been in operation for almost a decade now, and even though initially they were externally funded by the Inter-American Development Bank and IICA, they now have substantial direct financial support from the member countries themselves.

In addition, there are several other important regional programs with more specific foci. Briefly, these include the Program for Regional Cooperation on Potatoes (PRECODEPA), the Research Network on Animal Production Systems in Latin America (RISPAL), the Regional Network for Cacao Technology Generation and Transfer (PROCACAO) in Central America and Panama, the Cooperative Program for the Protection and Modernization of Coffee Cultivation in Mexico, Central America, Panama, and the Dominican Republic (PROMECAFE), and the Caribbean Research Network on Rice. At this time a Cooperative Program for the Basic Grains (maize, beans, rice and sorghum) involving the Central American countries and Panama is being initiated with donor support from the EEC.

All of these programs represent important mechanisms to resolve or at least to reduce the problems and deficiencies in the national programs by facilitating better use of available resources. For example, horizontal cooperation programs allow the relatively more capable national organizations to share resources and enhance their international influence and credibility. Likewise, these programs provide a mechanism for the smallest countries and organizations, that lack the necessary critical mass of human resources and financing to access valuable resources and support. Similar needs in the private sector are addressed by these cooperative efforts through research and technical assistance activities.

Although a quantitative evaluation of these efforts is difficult because of the natural lag time that exists in the enhancement of national research programs, some recent studies analyzing the case of PROCISUR show the investments returns of these types of activities to be extremely high. Evenson and da Cruz (1989) have found the internal rates of return for PROCISUR to be 191 percent for corn, 110 percent for wheat, and 179 percent for soybeans, levels that exceed most indexes of national investments in research at the commodity level, and even those estimated for the International Agriculture Research Centers (IARCs). From a more qualitative perspective, it is important to emphasize that the cooperative programs and networks have also had an impact in strengthened relations between the international agricultural research centers and the beneficiary NARS, and in fact it can be said that some sub-regional networks are becoming effective substitutes for the Centers' out-reach programs. They are also making a significant contribution to the improvement of priority-setting mechanisms of the IARCs: by establishing the basis for a permanent and structured discussion and operational contact, they make it easier for the centers to reflect national needs and priorities in their program development processes.

Parallel to these initiatives, the region also has long experience with Subregional Research and Development Centers, particularly in Central America and the Caribbean, where the Center for Tropical Agriculture Research and Training (CATIE), serving Central America, Panama, and Dominican Republic, and the Caribbean Agricultural Research and Development Institute (CARDI) in the CARICOM countries, represent key elements of their agricultural research systems. CATIE is mandated to conduct research and training in the areas of small-scale agriculture sciences and natural resources appropriate for the region of Central America. The major programs are structured as tropical crop improvement, crop production technologies, integrated natural resource management, and postgraduate studies. CARDI is oriented toward agricultural research and development throughout the Caribbean in programs for livestock production, fruit and vegetable production, and technology transfer. Within these mandates, CATIE and CARDI constitute the research nuclei for the subregions and are the technical foundation for long-term development strategies. Further, they serve to complement activities of the international research centers while strengthening national research programs that are more oriented toward adaptive and applied research in direct support of their extension services to farmers.

There is no doubt that horizontal cooperation programs have produced outstanding benefits for advanced developing countries as well as the smaller, underdeveloped ones. In the former, there exists great potential for development of industries of agricultural inputs as well as for joint ventures in agro-biotechnology to exploit the local advantages while strengthening technical and institutional capabilities.

In order to assure that these initiatives achieve maximum success, it is essential that they have substantial and consistent support. This aspect has been traditionally the role of the international finance and technical cooperation organizations. Nevertheless, support is generally directed toward projects which experience many of the same problems as the national institutions that are the beneficiaries of the regional cooperative programs. It clearly would be in the donor agencies' interest to foment a policy of collaboration and long-term support for regional cooperation programs that strengthen specific projects.

7. Assessing the Value of Genetic Resources in LAC

a. Use of germplasm resources

Maintaining availability of foodstuffs requires assessing the value of the wealth of germplasm for agriculture throughout the world, not only in Latin America and the Caribbean (LAC). Despite other sources of production and productivity, most progress has occurred through production of superior genotypes for increasing yields, facilitating adaptation to the environment and improving the quality of final products. Between 50-60% of production increases in economically important crops in LAC originate primarily from work carried out with genetic resources.

Improving species requires having access to adequate genetic variability. Natural evolution has given rise to an enormous genetic diversity expressed, at the molecular level, in the polymorphism of the different genes making up individual genomes. Unfortunately, many useful species are disappearing today due to the increased use of a few varieties and superior breeds that are replacing a broader range of more traditional ones. This development, known as genetic erosion, has made production increasingly vulnerable to changes caused by biotic and abiotic factors of the production environment.

Historically, humanity has exploited only a few of the enormous number of existing species. Approximately two million living species have been classified; of these, 440,000 are plant species and 47,000 are vertebrates. Ninety percent of food production has been based on approximately 20 plant species, and only four (wheat, corn, potatoes and rice) supply an estimated one half of the total foodstuffs consumed (Wilson, 1985). This shows a dramatic imbalance between the existing biodiversity and the utilization of a few species. This is of concern because biodiversity and the ready availability of strategically important genes make it possible, through new biotechnology, to provide the raw materials needed to surpass existing physiological limits of productivity. Many physiological functions can be manipulated and enhanced with genes that have developed naturally through the process of evolution, thus improving production without harming the environment.

Genetic resources have become a strategic element for agricultural and industrial development in the countries that possess them.

b. The region as a strategic source of genetic resources

Latin America has important centers of genetic diversity, as well as of several crops native to the region, and it is also the source of a great variety of plants and animal species. It is well known that the humid tropical forests contain the greatest genetic diversity in the world, and although these forests represent only 6% of the earth's surface, they contain almost one half of the known species (Lebel and Kane, 1987). Latin America and the Caribbean contain almost 40% of the species, more than Asia or Africa. In the late 1980s, the Smithsonian Institute found that the Pacific region of Colombia was the most biologically diverse area in the world (Latin America and the Caribbean Commission on Development and the Environment, 1990).

This wealth is increasingly threatened by the destruction of the ecosystem and by the increased use of a limited number of varieties and species. The exchange and "marketing" of genetic resources with other regions has been unequal, with the balance being tipped against Latin America and the Caribbean. Frequently, species and genotypes native to the region have been taken out, only to be reintroduced a few years later as commercially improved cultivars.

Institutions of the countries of the region have developed important capabilities for technology generation and transfer, including the breeding of plant and animal species. Nevertheless, they have not fully exploited existing germplasm resources, due primarily to the poor organization and operation of germplasm banks. Most germplasm banks are not adequately characterized, nor are they suitable for conserving and manipulating the potential of existing resources, with a few exceptions such as CENARGEN of EMBRAPA in Brazil and CATIE in Costa Rica. This represents a threat to the results of long years of work.

c. Strategic priority actions

The world agenda for the 1990s focuses on achieving sustained agricultural development and a concomitant stable production of foodstuffs and raw materials. Diversity is essential to achieve these goals and a close link between stability and diversity is generally recognized. A great diversity of germplasm exists in the region (Brush, 1989). One of the top priorities on the agenda is to make use of the region's diversity of ecosystems and genetic resources.

On the one hand, this involves the urgent need to increase the use of the genetic potential of the region and, on the other hand, to establish policies and programs to develop greater capabilities to characterize, properly use, manage, and conserve these resources. It is also essential to establish criteria for the region with regard to the legal protection of species, varieties, breeds and germplasm. The interests of the region need to be balanced with opportunities for sharing this wealth. Actions should be designed not only to improve current species, but also to develop the production potential of others. Likewise, duly characterized genetic resources must be re-evaluated in economic terms. Strategies pursued can give germplasm a high value, as a source of wealth, negotiating power, socioeconomic agreement, and potential for greater technological stability and independence. Last but not least, research should also consider long-term issues relating to the environment and conservation through germplasm resources.

Strategies should be designed to strengthen national and regional efforts and capabilities to seek, gather, characterize, conserve and use genetic resources. These need to promote the establishment and implementation of joint regional policies and strategies on the subject. Recently, several international organizations are giving high priority to developing an institutional framework for promoting and coordinating efforts on a worldwide basis.

D. ACTION PRIORITIES AND STRATEGIES FOR THE 1990s

1. The Role of Agricultural Technology and Transfer

During the 1990s and the initial years of the next millennium, a relatively weak food security situation will likely prevail in the Latin American and Caribbean countries. Food demands will continue to grow, even if an anticipated slowing in the population growth rates takes place. As the economies of the region get back on a positive growth trajectory, increases in per capita consumption may be expected; some recent estimates suggest that in the current situation relatively modest increments in income would have significant impacts on food demand. Furthermore, in the present environment with its opening of regional and world economies, liberalization of international trade, and progressive elimination of international subsidy programs, the era of meeting domestic food demands through highly subsidized food imports from the developed countries may be coming to an end, with the possible exception of the poorest countries and in specific catastrophic situations.

On the production side, the possibility of a sustained increase in production through area expansion will certainly be smaller than in the past. Even assuming that new areas for agricultural production continue to be available, and this seems to be one important factor differentiating Latin America from the other regions of the developing world, net effects will tend to be smaller due to an increased concern over natural resource conservation, the need to take out of production some of the poorer lands presently used, and advancing soil erosion and deserts.

The opening of economies and macroeconomic adjustment processes will also affect production possibilities. These processes will bring a realignment of input-output price ratios, particularly through an increase in the cost of capital vis-a-vis other inputs, which will speed up the economic obsolescence of a large part of the present stock of production technologies. In parallel, the development and application of the technologies required in the new context will need to confront the problem of research and technology transfer institutions much limited in their scope of action due to budgetary and other restrictions emerging from the fiscal crisis of the 1980s and ensuing efforts to reduce the role of the State and public institutions.

In searching for an action strategy to meet the food production challenges of the 1990s, it is also essential to place food production in the broader context of both the international situation likely to prevail during the decade and the role of agriculture in reactivating the economies of the region. Current events point toward a future of significantly increased and diversified international trade at the global level, and accelerated processes of political and economic integration at the regional level. The 1990s will introduce a significant change in the direction of development strategies followed by the countries of the region, as the protectionist import-substitution industrialization schemes that have prevailed since the 1950s begin to be dismantled and replaced by market-oriented open-economy policies designed to reincorporate LAC into the international economy.

The import substitution model in fact reduced the agricultural sector to the production of cheap food and foreign exchange for industrial and urban development, and established a pattern of integration with the world economy essentially based on the participation of the region within commodity markets. By doing so, it exacerbated the structural dualism of the sector and failed to take advantage of the region's comparative advantages deriving from the quantity and quality of its natural resources. The shift to a market oriented open economy approach highlights the need for competitiveness which in turn enhances the importance of natural resources as a source of comparative advantages and of agriculture as a strategic sector for economic growth. In this new context, however, it becomes important to emphasize that the traditional approach to agriculture as a producer of raw materials and commodities is not the one that offers the greatest possibilities. In an international trade environment increasingly characterized by oligopolistic competition in differentiated product markets, opportunities are associated with the capacity to create and exploit market niches by way of transforming natural comparative advantages into dynamic competitive advantages through a rapid process of technological advancement. This implies looking at the agricultural sector with a broader comprehensive perspective that goes beyond the farm-production level to include post-harvest and marketing phases in the agrifood chain. Furthermore, the strong backward, forward and final demand linkages that characterize the agrifood sector create large multiplier effects throughout the rest of the economy, as well as a number of direct positive income effects for the rural poor. Agroindustrial developments provide an important opportunity for decentralizing economic activities and for generating rural area non-agricultural employment. This, added to the price effects associated with an improved agricultural production outlook, could have a significant impact on food security both through the increased availability of food and, perhaps more importantly, through improving income conditions for the rural population, and consequently their access to food.

In an even broader perspective, decentralizing economic activity, by easing conditions that fuel rural-urban migration processes, will also bring relief to the already dramatic situation of many of the cities in the region, and will set the basis for a more rational allocation of investments that seek to improve decaying urban infrastructure and bring about a more effective management of environmental concerns.

In this context, agricultural research, technology transfer and their application become crucial instruments in meeting the food security challenges of the 1990s and beyond. In summary, this covers not only the obvious implication that for increasing production and food availability new technologies are a necessary condition, but also that a strong innovative capability in the agrifood sector is essential for reactivating the economies of the region, a necessary condition in generating the purchasing power that Latinamerican and Caribbean populations require to benefit from such increased food production.

The above does not imply that food security problems can be solved merely through a technological strategy. The dimensions of the problem go far beyond what technology on its own can achieve. They involve the broader policy and institutional dimensions of the framework necessary for technological efforts to produce results, and if they are not in place there is little that new technology can accomplish. Nevertheless, research and technology transfer are very powerful instruments as shown by past experiences of success with Green Revolution technologies. Also, the fact that we are currently in the initial phases of a new scientific and technological revolution--increasingly being referred to as the "gene revolution"--and one which opens a whole new set of possibilities for creating a more efficient and benign relationship of mankind with his natural environment for productive purposes, further highlights the relevance of increased efforts in this field. This, however, will require a profound revision of both the nature of technology development to promote and of the institutional framework to make it possible.

2. Priorities and Strategies-Research and Technology

Four key elements arise in defining research and technology priorities. First, discussions of the topic need to consider the effects of changes in relative prices deriving from economic adjustment processes and the liberalization and opening of the Latin American and Caribbean economies. Second, changes arise from the new role of the agricultural sector in economic development. Third, technology development needs to fully consider the growing concern with sustainability, natural resource conservation and environmental issues relating to agricultural production. Finally, in terms of opportunities, priority consideration should fully exploit the potential offered by new advances in biotechnology, as well as the potential contributions that other components of the new technological paradigm, such as microelectronic and information technologies, can make to agricultural and rural development.

Present research investments reflect conditions prevailing in the scientific and economic contexts of the 1960s and 1970s. In the 1990s, both product and technology-orientation priorities in research call for revision.

* At the product level, changes in relative prices between tradable and non-tradable products will increase the importance of indigenous and traditional agricultural crops vis-a-vis those of commercial agriculture. National research efforts have concentrated greatly on cereals (wheat), to the detriment of roots and tubers (potatoes, yams and cassava) and other traditional crops, particularly in tropical areas (plantains). In the future, these latter production alternatives should receive a stronger emphasis as they become more competitive staples in the basic diet.

The new export orientations will also need to be recognized in the shaping of research agendas for the NARS. Export diversification in its early phases can draw upon imported technology packages, but as the new production efforts mature they will generate an increasing need for local research, particularly with regard to plant protection and variety adaptation.

* In terms of the type of technology, input price realignments (traded/non-traded, domestic/imported), together with concern over sustainability and natural resource conservation, point toward assigning a higher priority to the development and application of management technologies --ecosystem, farm, cropping systems, crops, resources-- vis-a-vis input-based technologies. Sustainability concerns highlight the need for new technologies integrating crops, livestock, and forestry, and emphasizing the global efficiency of resource use rather than achieving maximum productivity strategies typical of the Green Revolution. Some specific research areas such as biological nitrogen fixation, soil conservation/management techniques, minimum tillage, integrated pest management, and the recycling of residues will increase in importance; at a more general level, fields such as agroecological zoning studies and watershed management technologies should also be considered.

a. Making use of the region's biodiversity wealth

Taking advantage of the region's great genetic diversity should be of foremost importance to any future agricultural strategy. As stressed above, this diversity offers one of the most important differentiating factors and resources for the future development of the region and for meeting the food challenges of the 1990s; however, only a very small proportion is currently being used, and the majority of food production and consumption comes from introduced species. In part this has occurred because most of the stock of research and technologies available, at the time when domestic research efforts started in the 1950s and 1960s, was related to these (temperate climate) crops; but it also derives from the absence of concrete and specific efforts to exploit the potential of indigenous species, both for food and other purposes, since then. In this respect it is urgent to begin a formal wide-scope inventory and evaluation program. Mounting evidence shows that deforestation processes, particularly in the humid tropic areas, are having a high negative impact on diversity, and important numbers of species are being lost; however new advances in the field of biotechnology make such an inventory evaluation more viable now.

Some needed regional actions include: a) a search for resources and financial mechanisms for initiatives to conserving genetic material; b) encouraging reciprocal horizontal cooperation programs among the countries, for research and technology transfer related to the conservation of genetic resources, with the new biotechnologies, and for the joint use of germplasm resources; c) designing policies, strategies and systems to integrate the region with other regions carrying out similar work; and d) promoting and supporting efforts to develop the use of non-traditional species.

b. Exploiting opportunities in the area of biotechnology

Biotechnology holds a tremendous potential both for generating new ways of exploiting agriculture through improved products and processes, and for addressing sustainability and environmental concerns. Genetic engineering targeted to specific characteristics or environmental stresses, improved breeding programs through the combination of traditional methods with different tissue and cell culture techniques, more efficient methods for the large-scale production of virus-free planting materials, new biological insecticides and pesticides, more efficient methods for the treatment of effluents or the recycling of agricultural by-products, and improved fermentation processes are just a few of the new areas where increased activities could be of great impact for food production. However, in most developing countries, NARS biotechnology capacities are at best incipient and they urgently require the strengthening of human resources, installations and equipment in areas such as greenhouses, laboratories for biochemistry, molecular biology, virology, and fermentation processes. Given the relatively large investments that would be required, this should be done in the context of a careful analysis of priorities and in close collaboration and co-ordination with universities and other science and technology centers to avoid unnecessary duplications. Regional horizontal cooperation through research networks and cooperative programs will be of special importance in facilitating developments in this area and in ensuring that the region develops the necessary capacities.

c. Modernizing technology for the food chain.

The challenges to be confronted, as well as the new strategy of economic reactivation through agri-food development, requires technological modernization of all phases of the food-chain. Yet however important more efficient farm- level technologies may be, ensuring access to technologies and information dissemination for the post-harvest phases of the food production process will also prove a necessary condition for success. This implies moving away from the current conception of vertically segmented technologies to an integrated approach that fully considers interactions among different levels and seeks technologies designed to improve the efficiency of processes as a whole rather than the maximum productivity of any individual phase.

d. Technological improvement for the smallholder.

Smallholders comprise an important segment of the farm population and have played a strategic role in the production of staple food. The better endowed and more competitive segments of this sector will continue to do so in the new context. Current adjustment processes, with their dismantling of longstanding policies of bias against traditional agriculture, raise a number of favorable prospects, including the possibility of higher prices for smallholder products, a more favorable situation for producers with a factor bias against capital-intensive technologies, and a potential for new market development, such as for products from organic agriculture. Technology improvement for the smallholder will entail a close interaction among researchers, farmers and technology-transfer agents seeking improvements for specific clienteles in specific agroecological zones through low-capital, low-risk technologies. It will require greater attention to technologies suited to sustaining and improving production on fragile land such as hillsides and humid and semi-dry tropical areas. It will also require an important emphasis on farm-management practices and agronomic technologies for individual farmers as well as for groups and communities. It is important to stress that in addition to technological services, an adequate strategy for smallholders will also need to emphasize investment in other complementary services and infrastructure such as credit, electricity, roads, and access to markets and supporting institutions.

3. The Need for a New Institutional Environment

Over the last quarter of a century, institutions in the developing world that generate and transfer agricultural technology have grown dramatically, and it may be said that they have had a tremendous impact on agricultural improvement and economic growth. Public sector institutions have been at the center of this successful effort. At the same time they have been instrumental in creating the conditions that permit non-public organizations to become increasingly involved in technology development and application processes.

More recently, however, dramatic changes in relevant scientific, economic and institutional environments bring forward the need to review the nature of the institutional model required to confront the challenges of the new context. Biotechnology has produced a new situation in which public developed-country universities and research centers are no longer the main providers of basic scientific and technological knowledge, but rather share the stage with a large, increasing number of other institutions, mostly in private industry. At the same time, the new conception of a broader agri-food sector as the core of an economic reactivation strategy draws attention away from the isolated consideration of agronomic techniques and toward aspects relating to post-harvest handling, processing, packaging, storage, etc., and, consequently, toward the question of how to link with relevant sources of research and development information in these areas.

The debt crisis of the 1980s severely limited the financial viability of many of the NARIs in the region, and, as we move into the 1990s, the effort of modernizing the public sector underway in most of the countries has placed on the bargaining table the issue of what should be the role of the State in technology development and the shape of organizations responsible for implementing it. Following are some of the strategic issues to consider in shaping the new institutional context for technology development and application in the 1990s.

a. Redefining the role of the public sector

Under conditions of increasing resource scarcity and given a technological processes increasingly subject to the rules of market behavior (technologies subject to proprietary protection, private sector investments in technology research and development activities, etc), public sector emphasis should move away from the global perspective that mandated a responsibility for covering all --or at least a majority-- of a country's technology needs in agriculture. A more strategic role will involve assuming responsibility for (i) some key basic research areas, essential to assure a minimum level of national technology independence; (ii) certain components of the technological package --non proprietary technologies in the management and agronomic fields, where it would be impossible to fully recover R&D costs; and (iii) a service function for those segments of the agricultural community which are unable to answer their demands through market mechanisms (smallholders, small or remote regional production situations, etc.).

This redefinition of the role of public institutions should be accompanied by a number of additional legal and organizational reforms making them more flexible and setting the basis for a more effective and efficient use of available resources. These should include decentralization processes, to facilitate clientele participation as a means for increasing responsiveness, as well as greater opportunities of mobilizing local resources for funding specific activities; and the development of mechanisms to link public and private technology organizations and on-farm technology generation with post-harvest off-farm requirements.

b. **Facilitating and encouraging private sector participation.**

Ensuring the region's food security in coming years will demand a great effort and large amounts of resources, since an adequate supply of technologies must be developed for a wide range of commodities spread over an enormous diversity of agroecological conditions, to which must be added the post-harvest, handling, packing, transportation, processing, distribution and marketing of food products. Policies, institutional arrangements and mechanisms need to be established for encouraging and channeling a broadened participation of the private sector in technology generation and transfer.

c. **A renewed role for the universities.**

Increasing the role of universities in technology development becomes an essential element in the context of the new demands to be confronted. A key area in this regard concerns biotechnology. Universities are better prepared than NARIs to respond to the challenges posed by biotechnology because their staffing composition fits the requirements of such research to a greater degree. University faculties include more genetic engineers, molecular biologists,virologists, enzymologists, fermentation engineers, and other related fields than the research staff of the NARIs. Universities also offer greater possibilities for working on some forms of basic research and on problems related to post-harvest phases. On the other hand, NARIs have strong complementary capabilities in related fields. NARIs and universities have interacted to a very limited extent in the past and bridging that gap is an important priority for the future. This would strengthen not only research programs in biotechnology but also the development and expansion of graduate education for agriculture and food production in general, and would help develop biotechnological and other related technologies for smallholders and other farmer groups not likely to be targeted by private- sector efforts via the market.

d. New funding sources and mechanisms.

The increased participation of the private sector in agricultural R&D activities will help to solve some of the overall funding restrictions; however, the critical need for more stable funding mechanisms other than traditional national budget allocations for public institutions still remains. Some countries as noted above, already have important experience in terms of developing R&D foundations to facilitate channeling private and non-governmental funding toward activities not related to the generation of non-proprietary technologies, but these initiatives are still at the experimental level and need further development.

A related funding need arises with respect to providing venture capital for technology development and its exploitation through joint ventures between public and private organizations. This requirement will prove crucial to increasing competitive capacities, not only of on-farm production, but also in supplying technology for agroindustrial development. Many national institutions and universities have scientific and technological capabilities that, combined with entrepreneurial abilities, could provide a sound basis for such development. However, national firms in most cases are too small to have access to the levels of capital needed for the R&D and market development stages, particularly given the high interests rates that prevail in local capital markets. Facilitating the flow of this type of capital could prove an important strategic element in making appropriate use of past investments in human capital and infrastructure development.

e. The Role of External Financial Assistance

Despite the expected greater diversification of regional funding sources for technology activities mentioned above, this alone will not suffice. The magnitude and diversity of technology challenges faced by the region in attending to its future food security requirements are such as to require additional external sources of funding over the coming years. Donors and the international community will need to play an enhanced role if the region is to achieve a sustainable management of its technology needs. In the absence of such a contribution, the risk of regression, with ultimately higher costs and suffering, becomes very likely.

Placing the above on the agenda will require that the region identify the global order of its priority financial requirements for technology over the coming years as a means for assessing the potential contribution of the various actors--governments, private sector and the international sector-- and working out a suitable financial strategy.

4. Priorities and Strategies-Modernizing the Technology Transfer System

Technology transfer mechanisms in the region have evolved from a traditional extension-service approach to technical assistance mechanisms, mostly of a private nature. This evolution has tended to sever research system-clientele relationships, and by so doing in many cases it diminished the relevance and applicability of the research effort. The introduction of client-oriented research methodologies becomes a high priority for ensuring a greater impact of research investments in the future. This approach offers a direct way for internalizing client concerns as well as for improving the other linkages of the research-technology transfer-farmer triangle. Client-oriented research can promote massive technology transfer by ensuring the relevance and fit of research solutions to farmers' needs and conditions by providing a clear focus for joining research, transfer and farmers' concerns. Besides offering the opportunity for training participating extension agents, it may also help increase the awareness and responsiveness of on-station researchers to the complexities of farmer-need identification and the necessary restrictions that workable solutions must consider. Improving the relevance and functional integration of staple-food research will require efforts aimed at strengthening and institutionalizing client-oriented methodologies.

A second issue with regard to the technology transfer system is its adequacy for dealing with sustainability concerns. Most technologies for natural resource conservation and sustainable agricultural development are management-based and many cases, such as integrated pest management, involve action not only by the individual farmer, but also at the group or community level, if they are to be effective. The current trend away from technology transfer approaches of the traditional extension systems-type and toward private technical assistance runs counter to these needs, and would demand a profound revision of current policies and investments in this field.

5. International Co-operation as a Way to Make Better Use of Existing Capacities.

Several reasons make international cooperation mechanisms a strong instrument for meeting the food challenges of the 1990s. First, many of the problems to be confronted are of a common nature. This makes joint efforts to solve them a logical and efficient alternative in terms of a better use of the diminished resources the countries can invest in technology development. Furthermore, in several country groupings at the sub-regional level --particularly Central America and the Caribbean-- countries are too small to be able to maintain completely developed independent research systems. Second, fully exploiting the new technologies will require levels of investment that go beyond the expected economic capabilities of most of the countries of the region, including some areas in the larger ones. Also the speed of changes in these fields and already existing gaps render autonomous capacity development strategies inefficient, especially in the region's present climate of political and economic integration.

At we have stressed in a previous section, LAC has a long tradition of cooperation and a strong institutional infrastructure which differentiate it from other developing world regions, and is an important factor in meeting the challenges to be confronted. It this infrastructure is to be fully effective, it will be necessary to solve some weaknesses which limit its effectiveness. Stable funding is probably the most serious limitation. Both sub-regional centers, such as CATIE and CARDI, and cooperative programs (PROCIS) and networks depend almost entirely on special projects for their operation. This has prevented them from developing all their potential and in many cases is forcing them to undertake low-priority efforts for the sake of generating, through overhead recovery, enough funding to cover their fixed costs. Overcoming this limitation is probably one of the highest priorities in a strategy for technology development.

IARCs are the other important actors in the international cooperation dimension, and as noted above, their contributions have been significant. They are also entering a new era and need to adjust their relationships with NARS and their integration in the regional R & D system. Two areas in need of review concern the way that national institutions participate in their priority-setting processes and how to make a better use of their comparative advantages vis-a-vis NARIs which are now, particularly in the larger countries, capable of assuming many of the functions that

IARCs have performed previously. In this latter area, initiatives are already underway by which NARIS are assuming some of the more applied "downstream" efforts, freeing IARC resources for the "up-stream," more strategic concerns.

6. The Need for a Renewed Human Capital Effort

Human resources are a critical element in technological development. LAC countries have, since in the mid-1950s, carried out major efforts to develop cadres of agricultural scientists, initially at developed country universities and later at graduate schools within the region. International assistance, both though grants and loans, played a crucial role in funding this effort.

Toward the end of the 1970s and during the 1980s this tendency came to a halt and training programs were reduced to levels insufficient to cover even the replacement needs of the NARS. In the 1990s, human resource deficiencies will be felt strongly. First, many of those receiving training in the 60s and 70s will be approaching the end of their productive cycle. Second, local training mechanisms (universities and graduate schools) have declined in their capacities as a consequence of the debt crisis and it would not be an over statement to say that they are currently unable to meet the region's human capital demands in terms of either quantity or quality. Third, the biotechnology "revolution" is quickly rendering obsolete much of the existing stock of scientists at agricultural research institutions. Last but not least, these institutions are finding it increasingly difficult to retain their best staff; as technology acquires more and more a proprietary nature, and as budgetary and other restrictions make it difficult for them to pay competitive salaries, they find themselves at a disadvantage, as the private sector entering the new agricultural technology development and exploitation markets. In this context, the recreation of human capital development programs becomes a necessary condition for any strategy oriented to strengthening technological capabilities for agricultural development. These, however, should be of a broader nature than the ones implemented in the past and should consider not only the training of researchers for the NARIs but also the demands of the new actors now participating in agricultural technology development and utilization processes.

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METHODOLOGICAL APPENDIX

Explaining and Predicting Food Flows in LAC

An aggregative framework. The basic propositions of this report are based on an aggregative framework of food flows for LAC. It is not a substitute for micro and country-specific investigations of food security issues in LAC. The diversity of the region will call for specific studies at the time of selecting and designing projects for generating and transferring technologies. An aggregative approach, however, is a more cost-effective method for generating the information necessary to identify the magnitude and overall nature of food sufficiency and insecurity in the region.

Model specification. This model is specified for the purpose of investigating the technical changes required to maintain an average level of food sufficiency. Average food sufficiency is defined by the consumption level determined by population and income levels in the region for a given relative price of food. This is an adaptation of the sufficiency standard based on consumption trends (Valdes, 1981). The model explains and predict food consumption, food production, food exports, and food imports. All these variables, except imports, are determined by behavioral functions. Imports are considered as an adjustment variable.

Food consumption is a direct function of total population and the per capita level of total consumption expenditures. It is also an indirect function of the relative price of food. Food production is defined as the product of agricultural land times average food yields. Agricultural land and average yields are direct functions of time. Time here is a proxy for long-run development of land and technological changes for yields.

Food exports are a direct function of the relative price of food exports and of food availabilities. Food production is used as a long-run proxy for food availability. Food imports are defined as food consumption minus food production, plus food exports minus changes in food stocks.

Data Sources. The flow variables are represented by the food indexes of FAO. They are weighted averages of physical quantities of food, where the weights are their prices. The FAO indexes are food production, total and per capita, food exports and food imports (FAO, 1988). The food consumption index (or total food availability index) was estimated for the purpose of this study using the FAO food indexes and our estimation of weights. The food consumption index is defined by the FAO production index plus the FAO food import index, minus the FAO food export index. The weights are the importance of production, imports and exports with respect to total food consumption.

For lack of information, changes in food stocks are used in a implicit way. Therefore the index of food consumption interpreted as net change in food stocks. This is a plausible assumption for the purpose of this study, which is to project long-run or trend values of food sufficiency. Studies of temporary food insecurity will need to consider changes in stocks in an explicit way.

Population is measured by the implicit index of population of LAC contained in the FAO food production indexes, that is, by the total food production index divided by per capita food production index. The implicit index of population was used to estimate per capita food consumption.

Total consumption expenditures per capita are based on World Bank data for the region as a whole (World Bank, 1989). The FAO index of food export prices, transformed into constant U.S. dollars, was used both as an indicator of relative prices of food exports, and of relative prices of food consumption.

Estimations. The parameters of the above relationships were estimated by means of a single-equation regression, using linear squares and restricted least squares. This last method was used to incorporate **a priori** information about price elasticities in the food demand function and the supply functions.

Two additional functions were estimated to predict future levels of food production and imports. This was necessary because the flow variables are represented by indexes. The production index cannot be obtained by multiplying the land index by the yield index as when operating with absolute variables. In this case it is necessary to estimate appropriate weights, or rather the parameters which relate the food production index with the land and yield indexes. For the same reason, it was necessary to estimate the parameters relating the food import index with the consumption, production, and export indexes.

Specification and measurement errors. The parameters estimated with this model were used for conditional and *ex-ante* forecasting. The value of the explanatory variables are not known with certainty. The value of the explanatory variables, say population, consumption expenditures per capita, food prices, and even future expansions of land and changes in yields, are based on expert opinions and statistical trends.

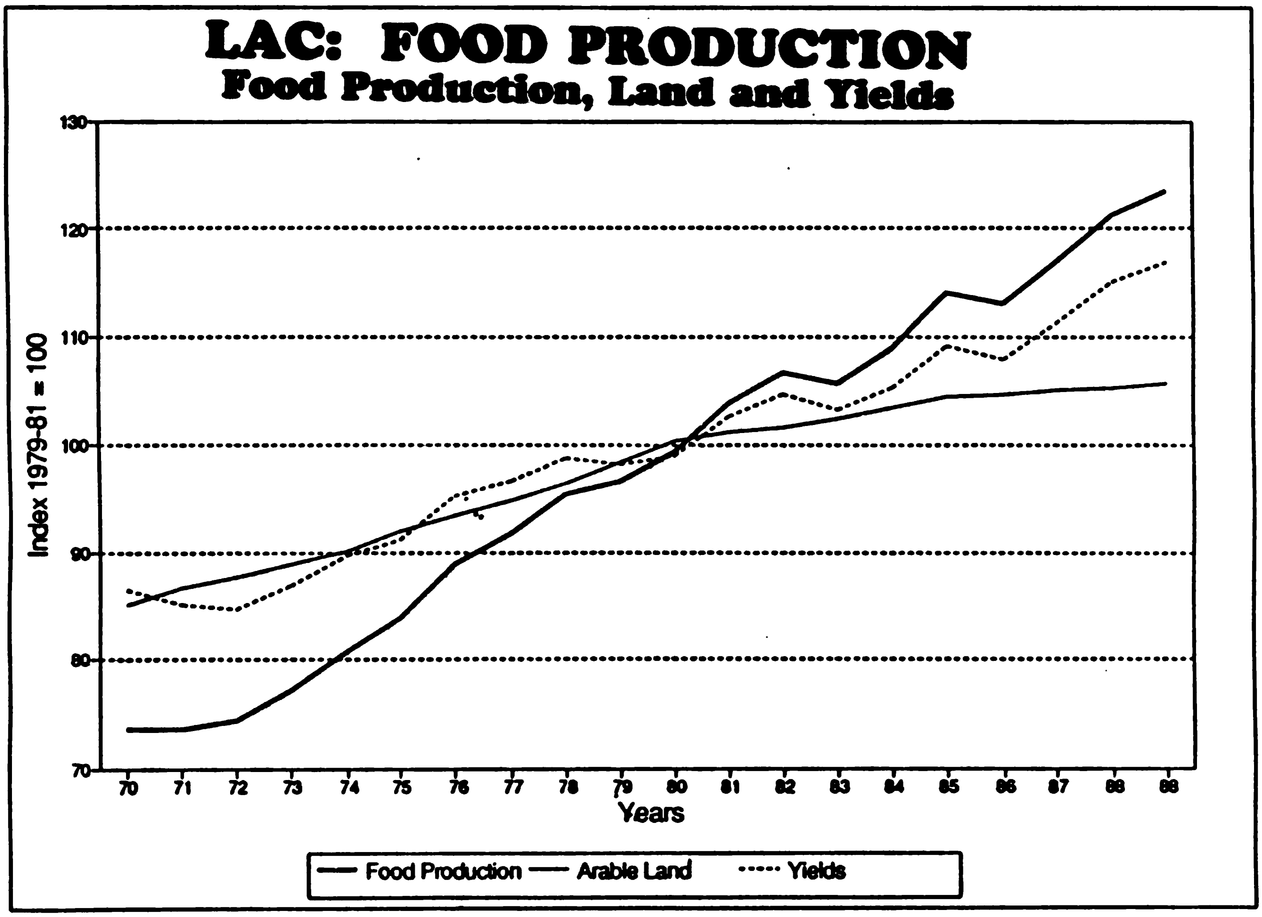
The estimated parameters, however, have the expected signs according to the conventional price theory and most empirical studies. Alternative specifications of the model which account for other explanatory variables and for simultaneity may produce alternative parameter values (Two-stage least squares, for example). More complete specifications are more useful for testing hypotheses. Prediction power, however, is seldom higher than in a model which already includes the fundamental explanatory variables.

The FAO food index is the only source of information available. It incorporates the measurement errors of the national statistical systems. This is an unavoidable fact, but does not invalidate the study, if the only purpose is to identify basic behavioral patterns and some significant trends.

An additional limitation of the FAO indexes is the continuous process of revision of values. Constructing diachronic series for the purpose of this study, therefore, required numerous interpolations during overlap periods. Overall, the model and the estimated parameters capably illustrate food trends in the region as a whole.

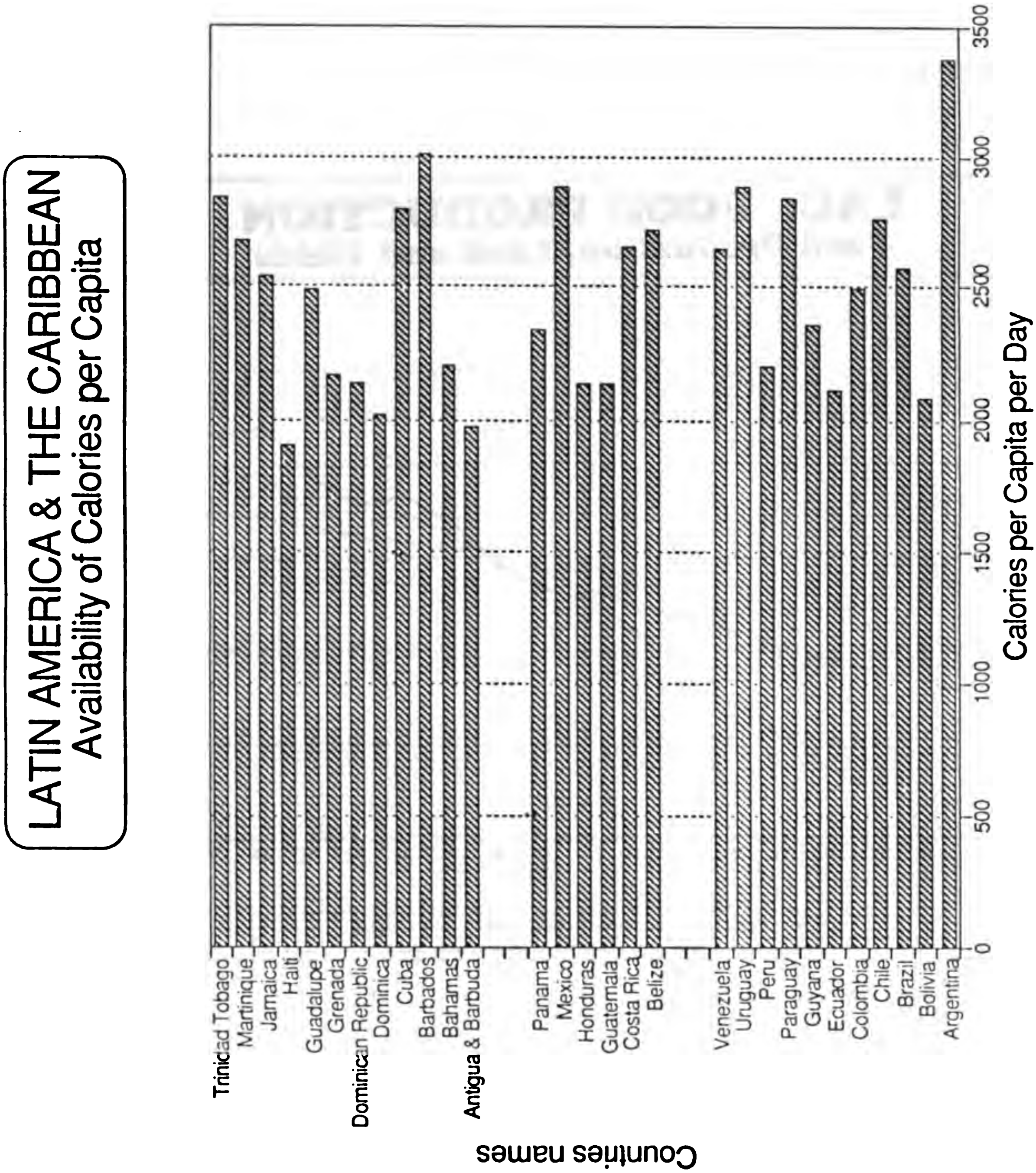
APPENDIX OF FIGURES

FIGURE 10



SOURCE: FAO, Yearboocks, several years

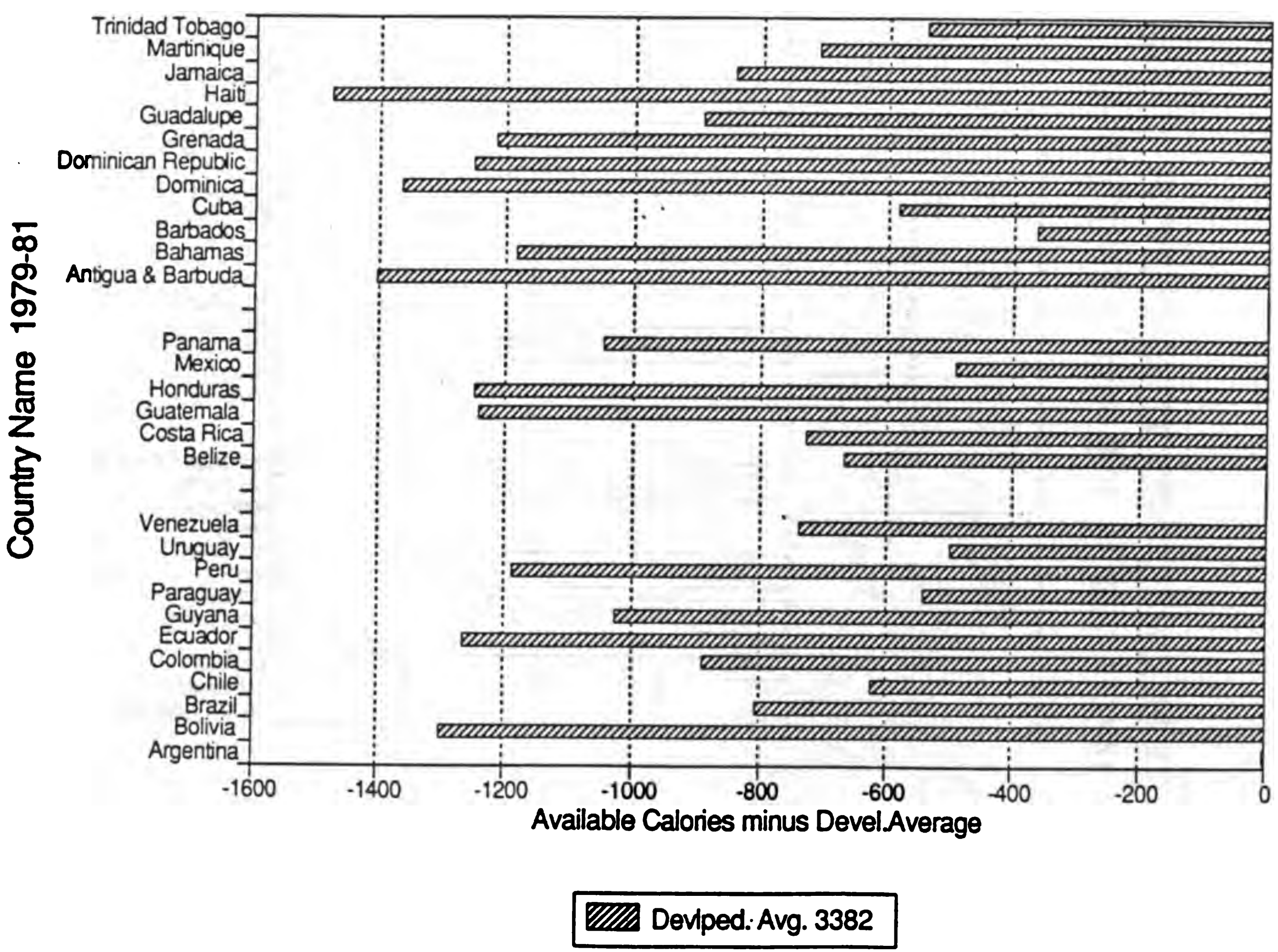
FIGURE 11



APPENDIX: Table 5

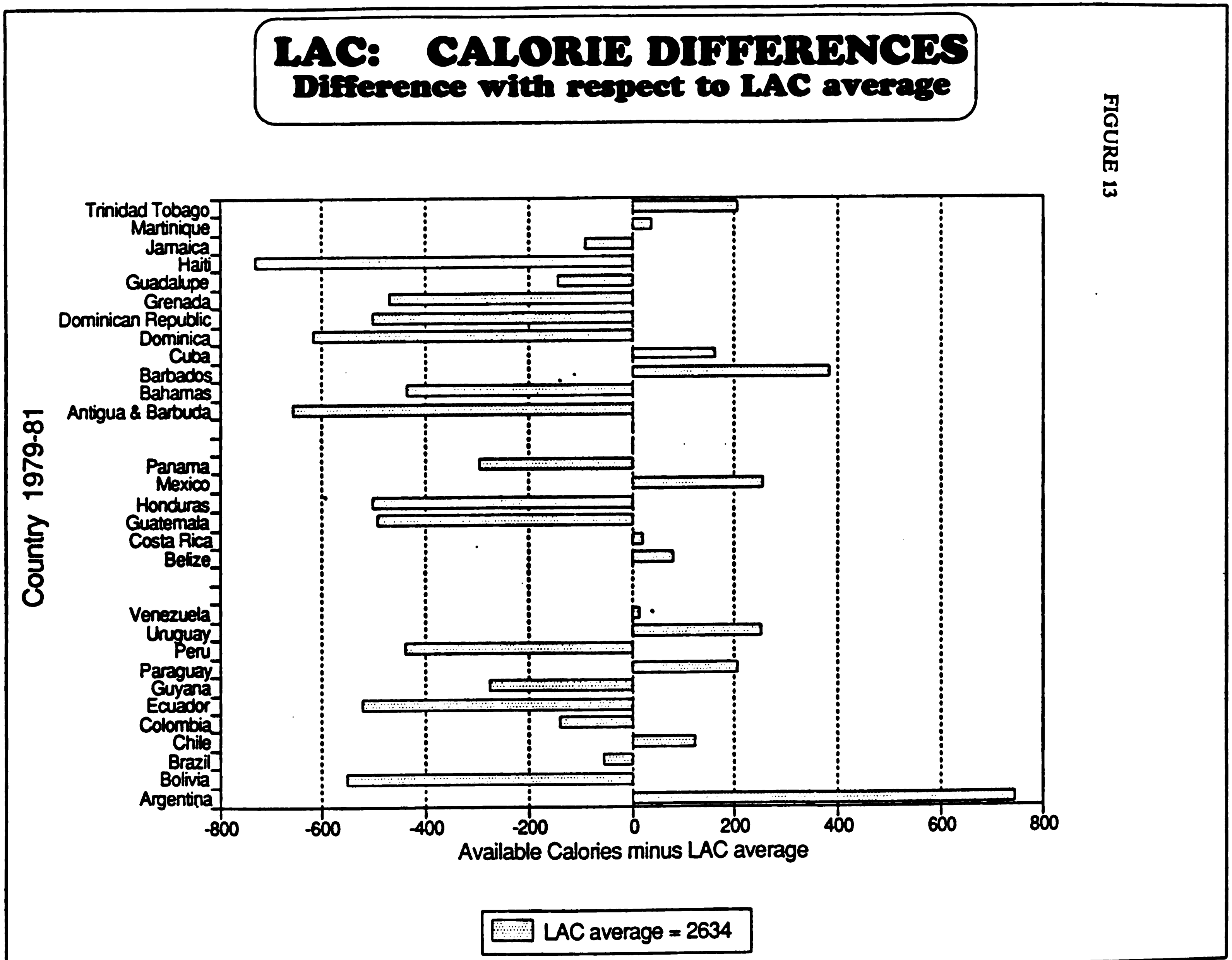
FIGURE 12

LAC: CALORIC DEFICIENCY
With respect to Developed Market Econ.



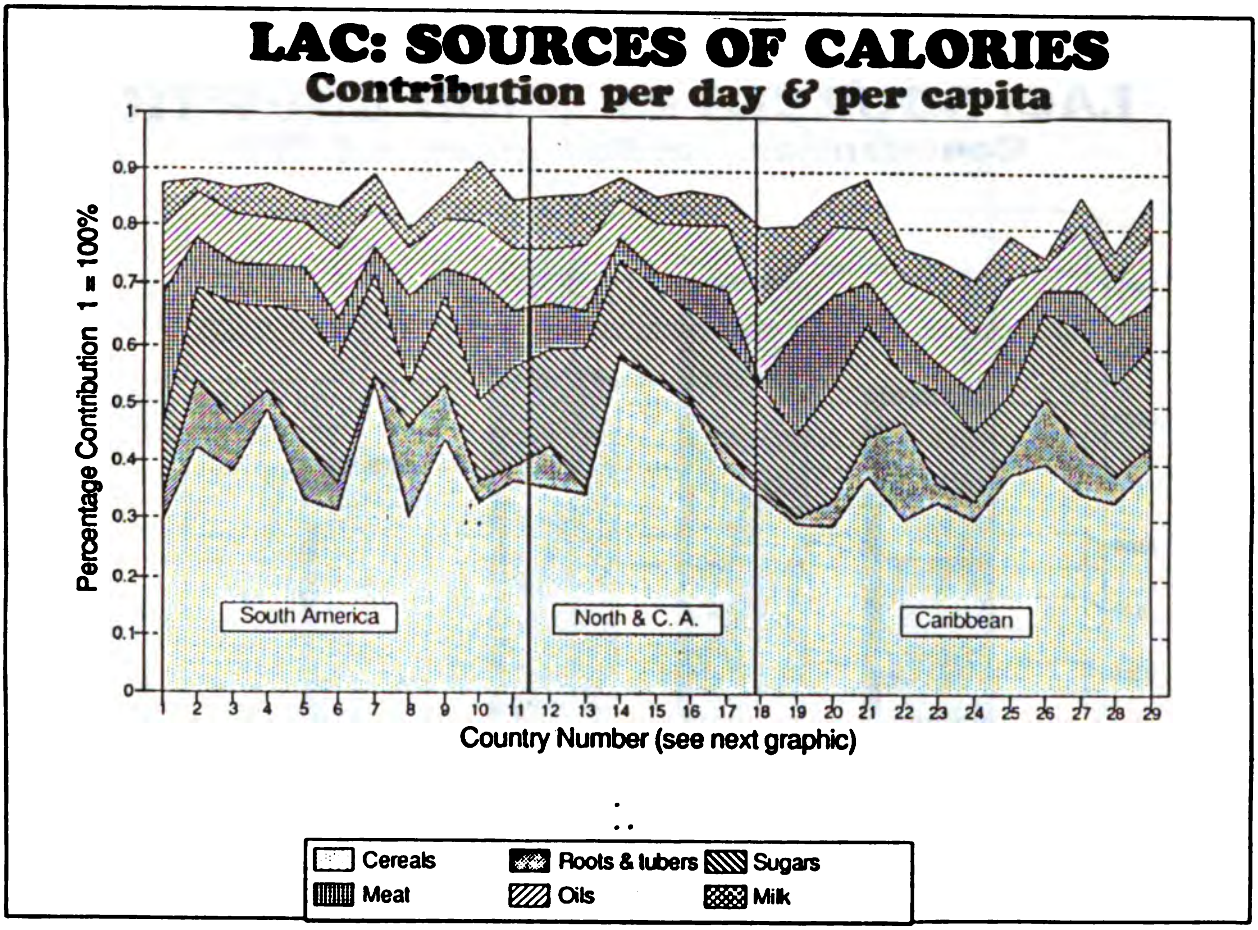
APPENDIX: Table 6

FIGURE 13



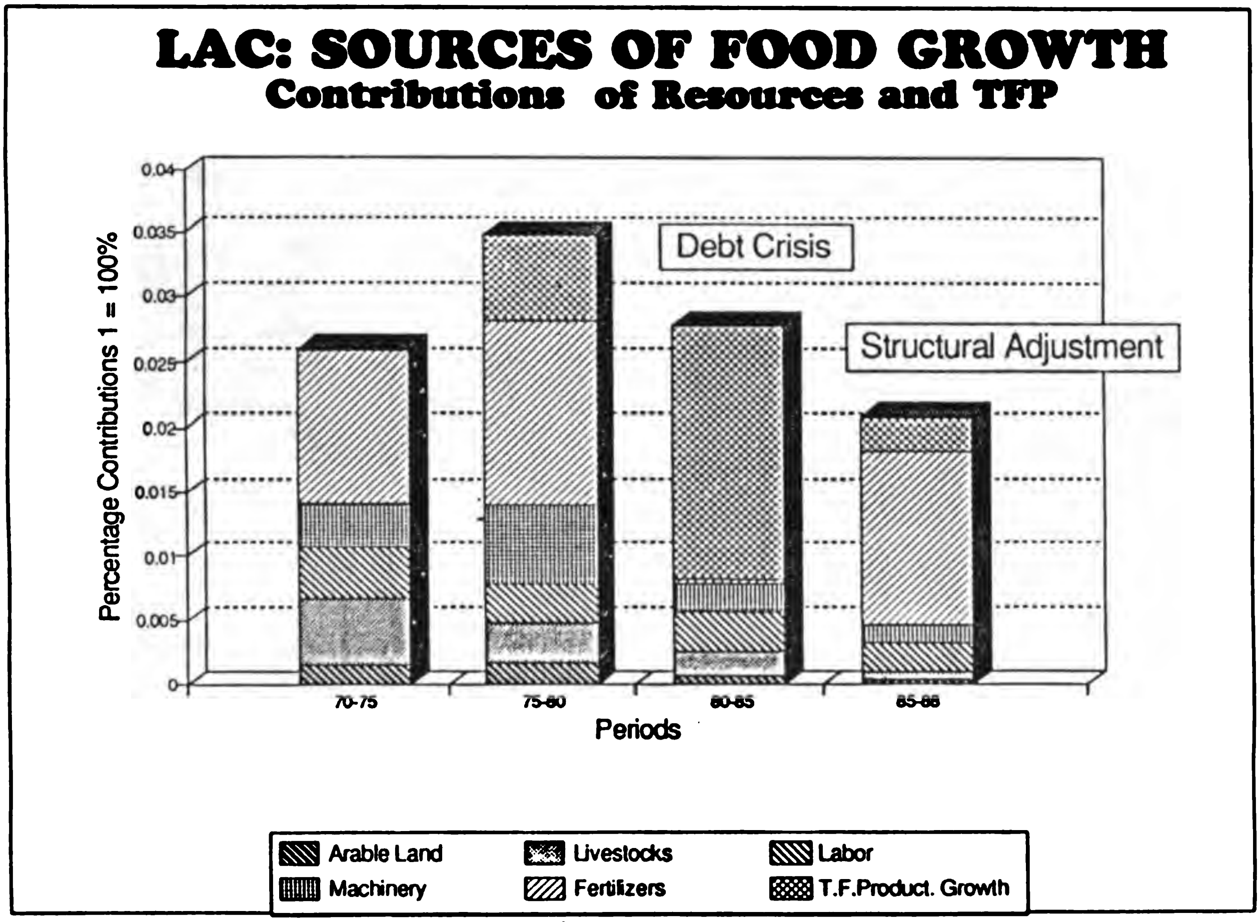
APPENDIX: Table 6

FIGURE 14



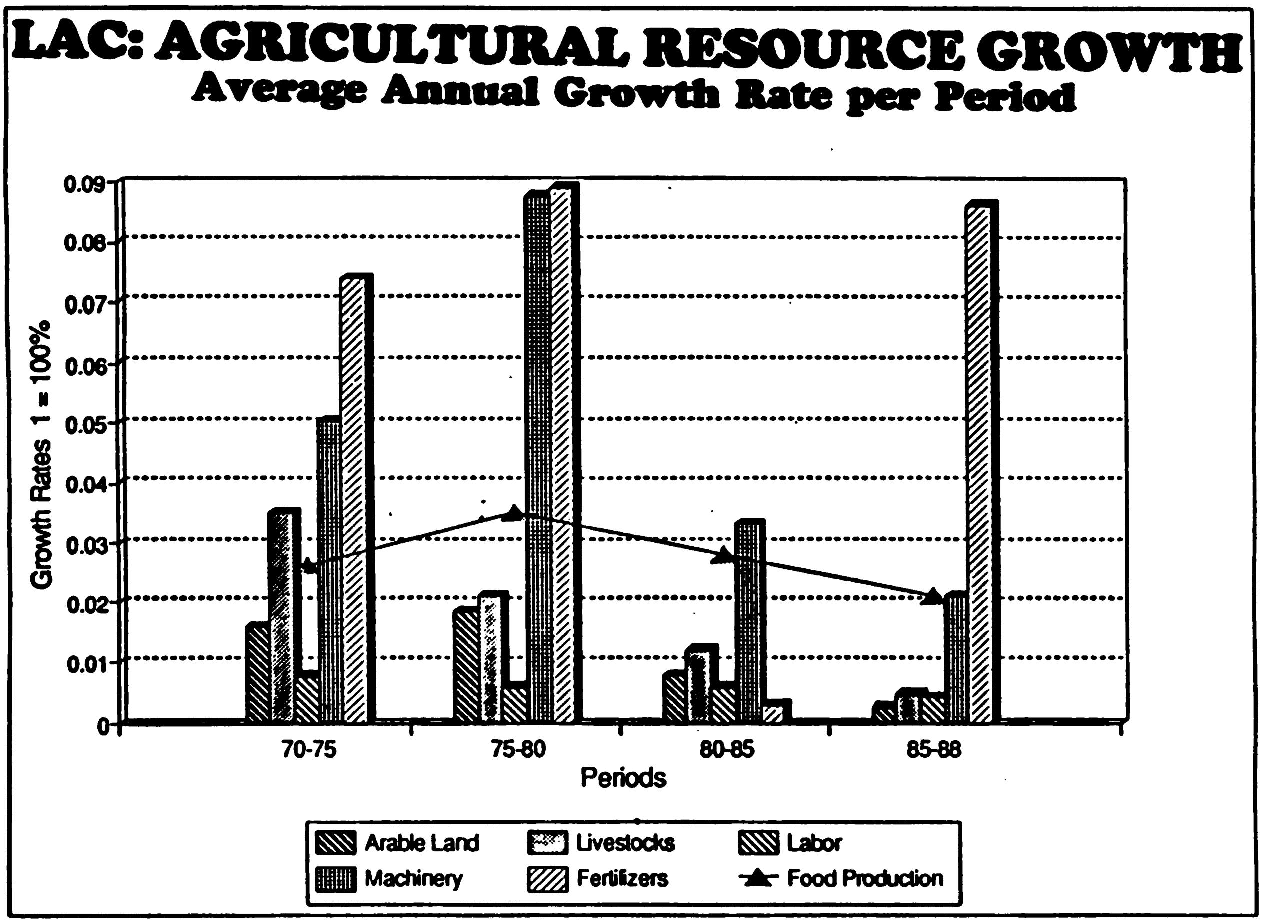
APPENDIX: Table 4

FIGURE 15



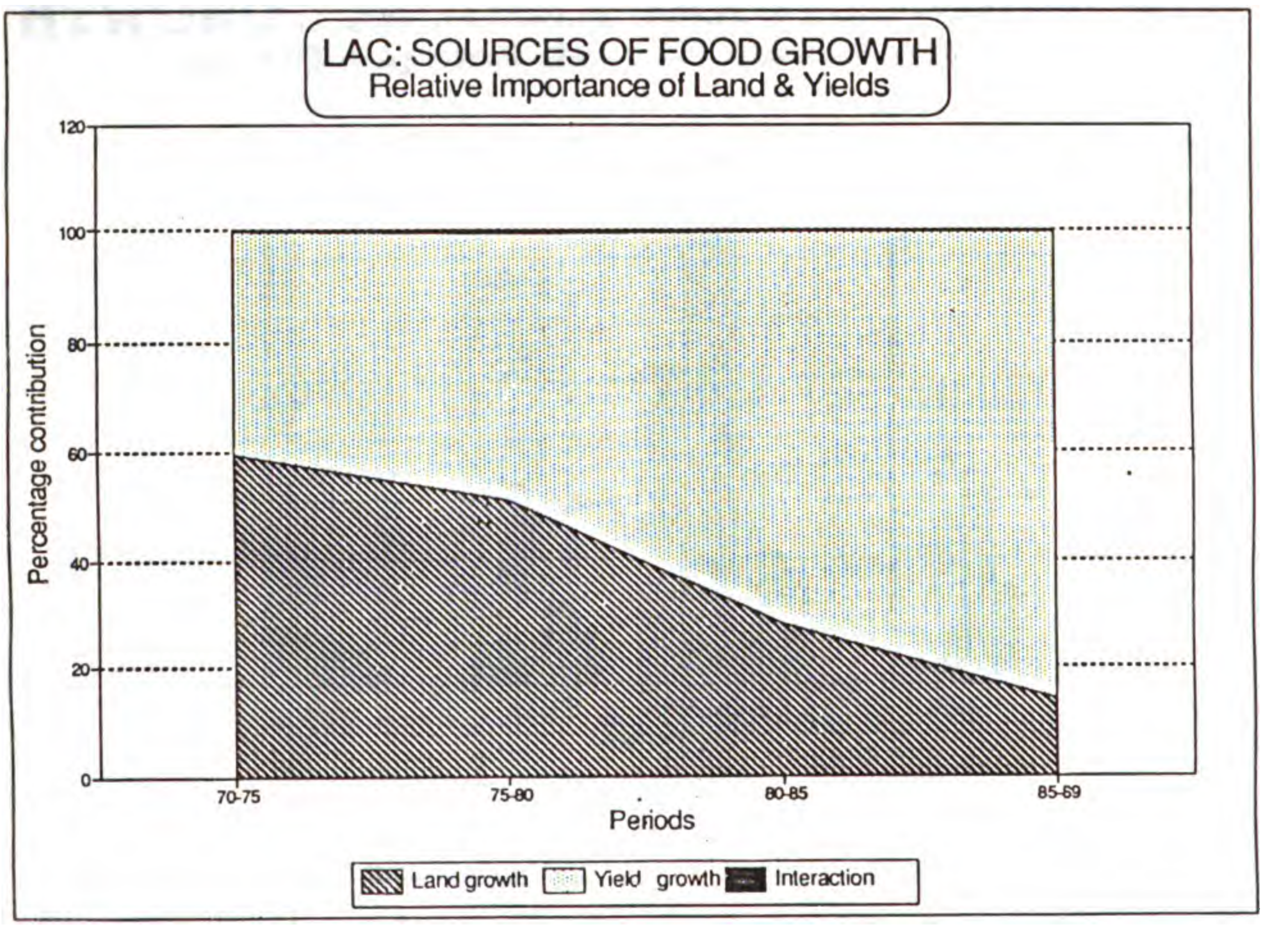
APPENDIX: Table 8

FIGURE 16



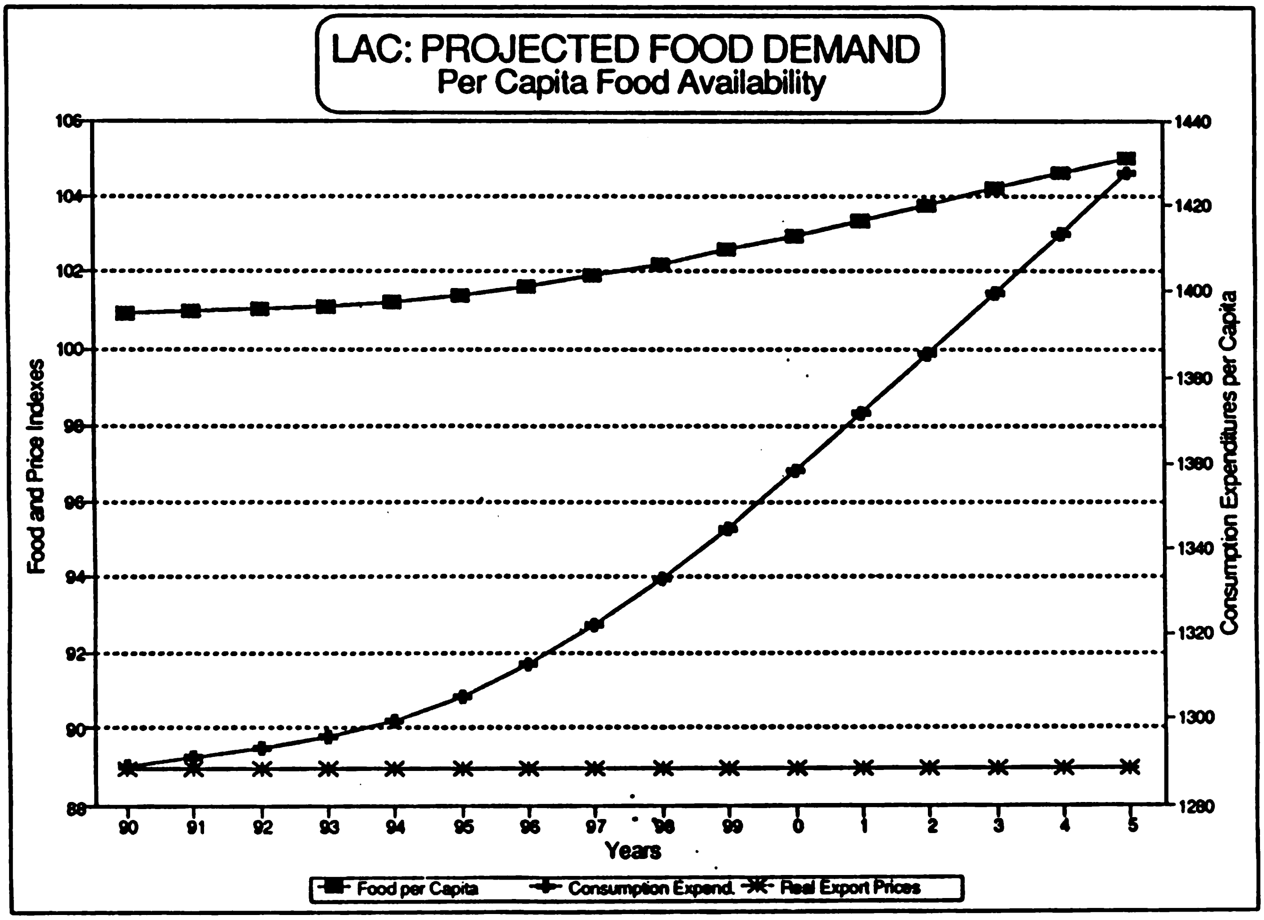
APPENDIX: Table 8

FIGURE 17



APPENDIX: Tables 7, 8 y 9

FIGURE 18


LAC: PROJECTED FOOD DEMAND
Per Capita Food Availability
106
104
102
100
98
96
94
92
90
88
Food and Price Indexes
1440
1420
1400
1380
1360
1340
1320
1300
1280
Consumption Expenditures per Capita
90 91 92 93 94 95 96 97 98 99 0 1 2 3 4 5
Years
Food per Capita
Consumption Expend.
Real Export Prices

APPENDIX OF TABLES

TABLE 1

LATIN AMERICA
FAO Production Indices
1987-81 = 100

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
LATIN AMERICA												
Total Production												
Agriculture	95.45	97.01	98.68	104.32	104.82	104.89	107.93	113.46	110.62	115.83	119.40	121.23
Food	95.27	96.70	99.42	103.88	106.58	105.62	108.93	114.00	112.94	116.83	121.31	123.51
Per Capita Production												
Agriculture	99.86	99.24	98.71	102.45	100.31	98.19	98.86	101.71	97.08	99.35	100.46	99.92
Food	99.68	8.92	99.46	101.62	101.98	98.87	99.78	102.2	99.11	100.38	102.07	101.79
WORLD												
Total												
Agriculture	95.71	98.25	99.13	106.62	105.79	105.62	111.6	114.58	115.6	116.24	117.64	121.26
Food	97.58	98.31	99.31	102.38	105.83	105.79	111.4	114.29	116.2	116.25	117.52	121.29
Per Capita Production												
Agriculture	100.95	99.99	99.16	100.85	102.12	100.21	104.07	105.03	104.13	102.9	102.34	103.68
Food	101.03	100.16	100	99.84	98.74	93.22	92.23	96.23	95.71	93.32	94.37	93.14

FAO, Quarterly Bulletin of Statistics, Rome

TABLE 2

LATIN AMERICA
Distribution of Agricultural Production
1000 MT

	1984	1985	1986	1987	1988	1989
TOTAL CEREALS	106768	110658	106026	112281	107837	104508
Wheat	21917	20201	21675	22810	20161	22713
Paddy Rice	16940	16992	17760	18186	19978	19308
Maize	50817	55808	52580	56291	53591	50910
Barley	1331	1262	1291	1592	1224	1579
ROOT CROPS	44030	44945	46971	46085	46002	47632
Potatoes	12161	11602	11253	11662	13494	13121
Cassava						
TOTAL PULSES	5120	5084	4866	4594	5283	5244
Dry Beans						
VEGETABLES & MELONS	19177	19555	19426	20388	21493	21274
FRUITS	65219	65013	64182	69116	68891	71603
Grapes	5093	4876	4762	5730	5564	5564
Citrus Fruit	21618	23212	22396	24402	24565	26242
Bananas	16955	16995	17257	18493	18161	18553
Apples	2239	2208	2059	2629	2618	2784
TOTAL NUTS	182	233	234	192	258	295
OIL CROPS (Oil Equiv)	7405	8647	7970	7935	9165	9685
SUGAR (Centrif.raw)	28879	28147	28422	27761	28450	27184
COCOA BEANS	534	733	726	570	661	679
COFFEE (Green)	3484	3870	3154	4213	3497	3523
TEA	56	63	60	63	49	54
VEGETABLE FIBERS	2249	2524	2068	1828	2499	2380
Lint Cotton						
TOBACCO	721	704	693	696	748	756
NATURAL RUBBER	58	63	54	53	55	58
TOTAL MEAT	15438	16037	16099	16729	17614	18022
TOTAL MILK	36757	38151	38383	40675	41366	42029
EGGS	2899	3099	3426	3470	3377	3188
GREASY WOOL	297	293	311	315	315	318

Source: FAO, Quarterly Bulletin of Statistics, Rome

TABLE 3

LATIN AMERICA Y CARIBBEAN: SOURCES OF CALORIES
Food Sources of Calories per Day per Person
Distribution by Regions and Countries. 1979-81

Country	Total Calories	Mean p/Source	STD p/Source	Diversi-ty Coef*
Argentina	3380	225	287	79%
Bolivia	2082	139	218	64%
Brazil	2578	172	252	68%
Chile	2757	197	333	59%
Colombia	2495	166	226	74%
Ecuador	2115	141	182	78%
Guyana	2359	157	309	51%
Paraguay	2839	203	226	90%
Peru	2195	146	234	63%
Uruguay	2885	192	261	74%
Venezuela	2647	176	246	72%
Belize	2716	181	241	75%
Costa Rica	2656	177	255	69%
Guatemala	2140	143	305	47%
Honduras	2134	142	284	50%
Mexico	2889	193	353	55%
Panama	2338	156	232	67%
Antigua & Barbuda	1980	141	183	77%
Bahamas	2200	147	176	83%
Barbados	3018	201	247	82%
Cuba	2796	186	269	69%
Dominica	2019	135	151	89%
Dominican Republic	2131	142	185	77%
Grenada	2165	144	155	93%
Guadalupe	2490	166	224	74%
Haiti	1906	127	188	67%
Jamaica	2542	169	232	73%
Martinique	2673	178	217	82%
Trinidad Tobago	2840	189	284	67%

* Diversity Coefficient: Mean of Food Sources/Standard Deviation of Food Sources.
Sources: Own estimations, based on FAO, Food Balance Sheets, 1979-81 Average, Rome 1984

LATIN AMERICA AND CARIBBEAN: SOURCES OF CALORIES

TABLE 4

Percentage of Total Calories per Person per Day. By countries. 1979-81

Country	Cereals	Roots	Sugars	Pulses	Oil Seeds	Vegetable	Fruits	Meat	Eggs	Fish	Milk	Oils	Spices	Stimulants	Alcohol Beverage
Argentina	29%	4%	12%	0%	0%	2%	3%	22%	1%	0%	7%	12%	0.1%	0.3%	6%
Bolivia	42%	12%	15%	1%	1%	2%	5%	8%	1%	0%	2%	8%	0.0%	0.3%	2%
Brazil	38%	8%	20%	6%	0%	1%	4%	7%	1%	0%	4%	8%	0.0%	0.2%	2%
Chile	49%	3%	14%	2%	0%	2%	3%	7%	1%	1%	6%	8%	0.0%	0.3%	4%
Colombia	33%	10%	22%	2%	0%	1%	9%	7%	1%	0%	4%	7%	0.0%	0.4%	2%
Ecuador	31%	5%	22%	2%	0%	1%	10%	6%	1%	2%	7%	11%	0.0%	0.2%	2%
Guyana	53%	1%	17%	2%	2%	0%	3%	4%	1%	2%	5%	7%	0.2%	0.2%	2%
Paraguay	30%	16%	7%	6%	2%	1%	8%	15%	1%	0%	3%	8%	0.0%	0.4%	3%
Peru	44%	10%	15%	2%	1%	1%	5%	5%	0%	2%	4%	8%	0.0%	0.1%	4%
Uruguay	33%	4%	14%	1%	0%	1%	2%	20%	1%	0%	11%	10%	0.0%	0.5%	3%
Venezuela	37%	2%	17%	3%	0%	1%	7%	9%	1%	1%	8%	10%	0.0%	0.3%	3%
Belize	35%	7%	17%	3%	2%	1%	5%	7%	1%	0%	9%	9%	0.1%	0.2%	3%
Costa Rica	34%	1%	24%	3%	1%	1%	6%	6%	1%	0%	9%	11%	0.0%	0.4%	3%
Guatemala	58%	1%	16%	5%	0%	1%	3%	3%	1%	0%	4%	7%	0.3%	0.3%	1%
Honduras	54%	1%	15%	4%	0%	1%	8%	2%	0%	0%	4%	8%	0.0%	0.2%	1%
Mexico	50%	1%	15%	6%	1%	1%	3%	5%	1%	1%	6%	9%	0.1%	0.1%	2%
Panama	39%	3%	19%	2%	1%	1%	7%	8%	1%	1%	5%	11%	0.0%	0.4%	3%
Antigua & Barbuda	34%	1%	17%	0%	1%	6%	8%	1%	2%	13%	13%	13%	0.1%	1.1%	3%
Bahamas	29%	1%	15%	2%	0%	2%	4%	18%	0%	1%	7%	10%	0.2%	3.4%	7%
Barbados	29%	5%	20%	2%	2%	1%	1%	15%	1%	2%	5%	12%	0.2%	1.0%	4%
Cuba	38%	7%	19%	4%	1%	1%	2%	7%	1%	1%	9%	9%	0.1%	0.1%	1%
Dominica	30%	17%	8%	4%	2%	2%	7%	7%	1%	2%	5%	8%	0.0%	2.6%	3%
Dominican Republic	33%	3%	16%	4%	1%	1%	15%	5%	0%	1%	6%	11%	0.1%	0.3%	2%
Grenada	30%	3%	12%	4%	7%	1%	8%	7%	1%	3%	9%	10%	0.5%	0.6%	4%
Guadalupe	38%	4%	10%	3%	1%	2%	5%	10%	0%	3%	7%	9%	0.1%	0.7%	7%
Haiti	40%	11%	14%	6%	4%	1%	9%	4%	0%	0%	1%	4%	0.1%	0.2%	4%
Jamaica	35%	8%	20%	1%	3%	1%	5%	6%	1%	1%	4%	12%	0.2%	0.2%	3%
Martinique	33%	5%	16%	2%	1%	3%	6%	10%	0%	3%	5%	7%	0.1%	0.8%	8%
Trinidad Tobago	40%	3%	17%	4%	2%	1%	3%	7%	1%	1%	6%	12%	0.3%	0.3%	3%

Source: Own estimations based on FAO, Food Balance Sheets, 1979-81 Average, Rome 1984

LATIN AMERICA AND CARIBBEAN: SOURCES OF CALORIES

TABLE 5

Food Sources of Calories per Day per Person
Distribution by Regions and Countries 1979-81

Country	Cereals	Roots	Sugars	Pulses	Oil Seeds	Vegeta ble	Fruits	Meat	Eggs	Fish	Milk	Oils	Spices	Stimu-lants	Alcoh Bevera	Total wo/Al	Total
Argentina	987	150	404	14	14	51	108	749	31	10	244	390	3	9	216	3164	3380
Bolivia	877	242	318	26	26	40	105	172	13	7	48	163	1	7	37	2045	2082
Brazil	980	216	516	148	11	21	99	177	20	12	115	211	1	6	45	2533	2578
Chile	1343	93	380	55	3	63	70	186	18	38	159	220		7	122	2635	2757
Colombia	827	239	556	52	8	32	214	184	24	9	108	178	1	10	53	2442	2495
Ecuador	655	103	456	42	10	18	202	132	19	35	150	242		4	47	2068	2115
Guyana	1255	32	394	45	41	6	65	104	16	43	125	176	4	5	48	2311	2359
Paraguay	851	446	212	183	50	22	213	415	27	2	90	223		11	94	2745	2839
Peru	960	210	323	49	13	30	102	99	10	49	92	175		3	80	2115	2195
Uruguay	938	109	399	21	9	31	69	578	17	11	310	281	1	13	98	2787	2885
Venezuela	971	66	446	79	8	18	177	251	25	21	222	264	1	7	91	2556	2647
Belize	958	192	458	95	48	19	138	197	14	10	249	251	2	5	80	2636	2716
Costa Rica	911	26	644	88	21	15	149	157	27	13	230	293	1	10	71	2585	2656
Guatemala	1240	11	335	104	10	14	64	74	19	2	77	145	7	6	32	2108	2140
Honduras	1153	13	320	91	2	11	175	50	10	3	92	179		4	31	2103	2134
Mexico	1443	26	426	169	24	21	91	148	29	19	170	262	3	3	55	2834	2889
Panama	909	80	445	45	30	16	154	183	24	14	106	255	1	9	67	2271	2338
Antigua & Barbuda	678	28	344	7		13	122	151	15	39	255	253	1	21	53	1927	1980
Bahamas	640	27	321	33	7	51	91	402	4	19	153	213	4	75	160	2040	2200
Barbados	869	137	601	72	51	33	43	448	22	59	163	351	6	29	134	2884	3018
Cuba	1050	187	537	121	15	21	69	197	34	34	242	247	2	3	37	2759	2796
Dominica	607	344	157	84	47	43	151	149	11	38	106	165	1	53	63	1956	2019
Dominican Republic	703	73	336	94	27	21	326	102	9	15	132	236	2	7	48	2083	2131
Grenada	649	74	257	77	162	17	172	150	25	70	188	212	11	12	89	2076	2165
Guadalupe	945	105	244	78	13	53	120	247	11	86	168	232	2	17	169	2321	2490
Haiti	766	217	273	121	82	28	164	67	2	5	26	70	1	4	80	1826	1906
Jamaica	882	211	513	33	71	20	125	154	25	37	106	293	4	4	64	2478	2542
Martinique	883	128	420	63	25	79	160	268	8	83	128	193	3	22	210	2463	2673
Trinidad Tobago	1140	86	478	102	56	34	78	191	24	24	181	341	9	8	88	2752	2840

Sources: FAO, Food Balance Sheets, 1979-81 Average, Rome 1984

LAC: CALORIC DIFFERENCES

TABLE 6

With respect to given standards*
Differences per person per day, 1979-81

Country	For LAC Average	For Avg. Requirem.	For Developed ME
Argentina	746	984	-2
Bolivia	-552	-314	-1300
Brazil	-56	182	-804
Chile	123	361	-625
Colombia	-139	99	-887
Ecuador	-519	-281	-1267
Guyana	-275	-37	-1023
Paraguay	205	443	-543
Peru	-439	-201	-1187
Uruguay	251	489	-497
Venezuela	13	251	-735
Belize	82	320	-666
Costa Rica	22	260	.-726
Guatemala	-494	-256	-1242
Honduras	-500	-262	-1248
Mexico	255	493	-493
Panama	-296	-58	-1044
Antigua & Barbuda	-654	-416	-1402
Bahamas	-434	-196	-1182
Barbados	384	622	-364
Cuba	162	400	-586
Dominica	-615	-377	-1363
Dominican Republic	-503	-265	-1251
Grenada	-469	-231	-1217
Guadalupe	-144	94	-892
Haiti	-728	-490	-1476
Jamaica	-92	146	-840
Martinique	39	277	-709
Trinidad Tobago	206	444	-542

Sources: Own estimations based on FAO, Food Balance Sheets, 1979-81, Rome 1984; and FAO/WHO Energy and Protein Requirements, Geneve 1985.

TABLE 7

LAC: CONTRIBUTION OF AGRICULTURAL RESOURCES TO FOOD GROWTH

Eight Periods
Contribution to growth in percentage points

	Production Elasticities	70-75	75-80	80-85	85-88
FOOD PRODUCTION	100.00%	2.62%	3.51%	2.79%	2.12%
RESOURCES					
Arable Land	9.00%	1.61%	1.86%	0.79%	0.25%
Livestock	15.00%	3.51%	2.10%	1.20%	0.49%
Labor	53.00%	0.77%	0.60%	0.58%	0.42%
Machinery	7.00%	5.03%	8.77%	3.33%	2.12%
Fertilizers	16.00%	7.39%	8.90%	0.29%	8.61%

Source: Own estimations, based on production elasticities from
Y. Hayami and V. Ruttan, Agricultural Development, The J. Hopkins
University Press, Baltimore. 1988

TABLE 8

LAC: SOURCES OF GROWTH OF FOOD PRODUCTION

Contributions to growth rate in percentage points

	70-75	75-80	80-85	85-88
RESOURCE INPUTS				
Arable Land	0.14%	0.17%	0.07%	0.02%
Livestock	0.53%	0.31%	0.18%	0.07%
Labor	0.41%	0.32%	0.31%	0.22%
Machinery	0.35%	0.61%	0.23%	0.15%
Fertilizers	1.18%	1.42%	0.05%	1.38%
Total Resource Inputs	2.62%	2.84%	0.84%	1.85%
TOTAL FACTOR PRODUCTIVITY	0.01%	0.67%	1.95%	0.27%
FOOD PRODUCTION	2.62%	3.51%	2.79%	2.12%

Sources: Own estimations

TABLE 9

LAC: FOOD PRODUCTION-PERCENTAGE DISTRIBUTIONS OF GROWTH RATES

	70-75	75-80	80-85	85-88
RESOURCE INPUTS				
Arable Land	5.52%	4.77%	2.55%	1.07%
Livestock	20.06%	8.97%	6.46%	3.49%
Labor	15.65%	9.05%	11.06%	10.62%
Machinery	13.43%	17.50%	8.34%	7.02%
Fertilizers	45.10%	40.59%	1.66%	65.09%
Total Resource Inputs	99.76%	80.89%	30.07%	87.29%
TOTAL FACTOR PRODUCTIVITY	0.24%	19.11%	69.93%	12.71%
FOOD PRODUCTION	100.00%	100.00%	100.00%	100.00%

Sources: Own estimations

TABLE 10

CURRENT STATUS OF PUBLIC RESEARCH AND TECHNOLOGY TRANSFER INSTITUTIONS IN LAC-1990

COUNTRY	NAME	LEGAL STATUS	EXTENSION ACTIVITY	1990, STAFF BY DEGREE LEVEL					BUDGET (CURRENT US$ 000)	
				B Sc	LIC	M Sc	Ph D	TOTAL	YEAR	THOUSANDS U.S.$
ARGENTINA	INTA	AUTONOMOUS	NO	1757		157	49	1963	1989	93351
BOLIVIA	IBTA	DECENTRALIZED	YES	55.		17		72	1988	4600
BRAZIL	EMBRAPA	DECENTRALIZED	NO	467		1151	548	2166	1989	243766
CHILE	INIA	DECENTRALIZED	NO	141		69	29	239	1988	14634
COLOMBIA	ICA	DECENTRALIZED	YES	320		250	80	650	1989	61950
COSTA RICA	DIEA	MOA UNIT	YES	ND	ND	ND	ND	91	1988	1092
ECUADOR	INIAP	DECENTRALIZED	YES	166		57	3	226	1988	1300
EL SALVADOR	CENTA	MOA UNIT	NO	154		8		162	1990	1638
GUATEMALA	ICTA	DECENTRALIZED	NO	131		27	1	159	1989	4260
HONDURAS	DIA	MOA UNIT	YES	129		16	4	149	1990	775
MEXICO	INIFAP	DECENTRALIZED	YES	569		858	256	1683	1989	52100
NICARAGUA	DGTA/MAG	MOA UNIT	YES	250		28		278	1990	13881
PANAMA	IDIAP	DECENTRALIZED	NO	ND	ND	ND	ND	ND	ND	ND
PERU	INIAA	DECENTRALIZED	YES	623		85	5	713	1990	5728
SURINAME	SRMP	MOA UNIT	NO	16		5		21	ND	ND
URUGUAY	INIA	DECENTRALIZED	NO	ND	ND	ND	ND	88	1990	9380
VENEZUELA	FONAIAP	DECENTRALIZED	YES	244		152	21	417	1988	33399

SOURCE: Information available at IICA's, The Technology Generation and Transfer Program.

TABLE 11

CHANGES IN RESEARCH EXPENDITURES
AND PROFESSIONAL STAFF AT SELECTED NARIS

	EXPENDITURES (000 of 1985 LCU)	STAFF #	E/S (000 of 1985 LCU)
EL SALVADOR: CENTA + GANADERIA			
1978	76.119	153	491
1988	16.885	92	183
HONDURAS: SERN (Crops + Livestock)			
1978	2.613	32	82
1988	2.795	148	19
GUATEMALA: ICTA			
1978	6.876	49	140
1988	7.273	144	50
COSTA RICA: MAG + DIA			
1978	93.598	82	1.141
1988	54.219	101	537
COLOMBIA: ICA			
1970 - 72	2.639.000	500	5.278
1986 - 88	4.004.000	450'	8.898
ECUADOR: INIAP			
1970 - 72	718.206	110	6.529
1986 - 88	514.096	208	2.472
ARGENTINA: INTA			
1980 - 82	573.000	1.493	384
1985 - 87	591.000	1.834	322
BRAZIL: EMBRAPA			
1980 - 82	887.500	1.575	563
1986 - 88	793.900	1.835	433
PANAMA:			
1980	3.941	38	104
1986	5.509	112	49

	EXPENDITURES (000 of 1980 LCU)	STAFF #	E/S (000 of 1980 LCU)
BOLIVIA: (IBTA)			
1970	70.067	61	1.149
1983	33.608	104	323
CHILE: (INIA)			
1970	392.445	153	2.565
1984	922.131	189	4.879
PARAGUAY: (DIEAF)			
1976	128.311	33	3.888
1983	962.815	86	11.195
PERU: (SIPA/INIPA)			
1970	2.845.588	174	16.353
1984	3.402.348	273	12.463
URUGUAY: (CIAAB)			
1972	15.438	64	241
1984	19.818	78	254
VENEZUELA: (FONAIAP)			
1965 - 69	162.067	175	926
1983	128.471	383	335

SOURCES: Data collected by IICA-Program II, IFARD (J.Ardila) and Pardey and Roseboom (1989)-- for last six cases.

NOTES: 1) ICA in Colombia was receiving most of a US$ 60 million loan in 1986-88.

2) GDP deflators and consumer price index values from IMF (1989) were used in generating constant LCU estimates for first 9 cases.

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