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CIAT in the 1980s

A long-range plan for the Centro Internacional de Agricultura Tropical

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Contents

Preface

This indicative plan projects the activities of the Centro Internacional de Agricultura Tropical (CIAT) throughout the 1980s. The plan focuses specifically on the three biennial budgetary periods between 1982 and 1987, with more general projections for the rest of the decade.

The plan was developed during the two-year period from mid-1979 to mid-1981. It was prepared by an interactive process involving CIAT's management and staff, its Board of Trustees and leading representatives of collaborating national agricultural research institutions in the Western Hemisphere. The first version was prepared with the active involvement of CIAT management, research staff and members of the Board of Trustees. The second version, responding to comments on the first by the Program Committee of the Board, CIAT staff and selected individuals, was presented to twenty-four leading representatives of collaborating national research institutions in twelve countries who convened in a special three-day workshop for this purpose at CIAT. The comments from the national representatives, plus comments on the second approximation received by the Executive Committee of the Board, were incorporated into the third version submitted to the Board of Trustees at its May 1981 meeting. At this meeting, the Board authorized publication of this final document.

Summary of the Plan for CIAT in the 1980s

As a basis for future planning, this document examines CIAT's role in relation to global needs of the developing countries, the total agricultural research and development framework, and the family of international agricultural research centers.

ROLE OF CIAT IN RELATION TO FOOD AND INCOME

Within the gamut of institutions and functions addressing the needs of the developing world, CIAT is considered a development-oriented agricultural research and training institution. Its major product is food production technology which can contribute to three basic goals:

(a) Improving the production, quality and stability of supply of basic food commodities in the developing countries;
(b) Improving the nutritional status of those segments of the urban and rural population still below minimal nutritional requirements; and,
(c) Improving the income levels of the rural, and indirectly, the urban low-income population.

Within the context of improving food production in the tropical developing countries of the world, CIAT gives special emphasis to Latin America. This emphasis has important implications for the selection of commodities on which the Center is to concentrate its efforts. The Center's commodity mix – or "mandate" – has evolved during an interactive process among CIAT's management, the Board of Trustees, the Technical Advisory Committee (TAC) of the Consultative Group for International Agricultural Research (CGIAR) and the sister centers.

The three factors most important in this commodity selection have been: first, the importance of the commodity in people's diets and in production systems of farmers, especially low-resource farmers in the developing countries; second, the division of labor between international centers; and finally, application of the principle that it is advantageous that global responsibility for research on a particular commodity be assigned to a center located in the region of genetic diversity for that species.

The plan begins with an analysis of the socioeconomic situation in Latin America to assess whether the commodity mix that has evolved during the first decade of CIAT's activities is still valid. In this context it is evident that a food production strategy for the South American continent must consider three areas of need: large farm intensification, expansion of the agricultural frontier, and small farm intensification. For socioeconomic considerations, and also considering that the large farm sector is already relatively well-served with agricultural production technology, the conclusion is that CIAT should concentrate on the latter two components of the overall food production strategy. An analysis of the comparative advantage of the major food commodities under different production conditions in Latin America clearly indicates that maize, cassava, potatoes, plantain, beans and dual-purpose (milk and beef) cattle have the greatest advantage for the small farm sector. Upland rice, beef production and cassava offer the most potential for expansion into frontier areas. Food consumption patterns vary so much across Latin America that no staple food can be singled out as the major source of calories or protein in the region.

When nutritional requirements, rural incomes and demand projections are considered, the commodities that stand out as most important are sugar, rice, maize, wheat, sorghum, potatoes, cassava, field beans, soybeans, beef, and milk. Taking into consideration the work of other institutions with these commodities, it becomes clear that CIAT's current mix of crops—beans, cassava, rice and tropical pastures—represents a reasonable selection to contribute toward meeting both production and nutritional goals of Latin America.

The rationale for making an international research and development effort varies with each commodity. Beans are an important small farm crop and a major low-cost protein source. Cassava is also an important small farmer crop with great potential for expansion on the frontier. It is an important low-cost caloric source in a limited number of Latin American countries. It offers great opportunity for increasing incomes of small farmers if technology to utilize its potential as an animal feed can be generated. Cassava's importance as a food is greatly accentuated when considering consumption patterns for it in Asia and Africa. Rice is a major staple in many countries of Latin America and is increasingly important in the diets of low-income consumers. In some countries it is a primary crop on small farms. Upland rice is another promising crop for frontier expansion. Tropical pastures—with the focus of the CIAT program on the acid, infertile soils—have a particularly important role in the frontier expansion strategy. To the extent that improved pastures contribute to beef and milk production, CIAT's efforts in tropical pastures will have a major impact on the availability of protein in all countries where this technology is appropriate.

These socioeconomic analyses indicate that there is no reason to suggest that any of the current CIAT research programs should be discontinued or that new ones should be added at this time. This, of course, does not preclude program deletions or additions during the decade which cannot be foreseen at present but which may be recommended after future internal or external reviews.

ROLE OF CIAT IN RELATION TO OTHER INSTITUTIONS

CIAT's activities are viewed as being complementary to other institutions involved in agricultural research and development. The plan emphasizes the key role of national research systems and defines the modalities for strong complementary, cooperative relations with national research programs. The complementary relationship between CIAT and basic, or strategic, research activities of the more specialized research institutions and universities in developed and developing countries is also acknowledged, and continued cooperation with such institutions is envisaged.

CIAT is expected to make a significant and unique contribution to overcoming some of the technological constraints on the strength of its focus on basic food commodities, and its emphasis on technology development for low-resource farmers and on the expansion of the agricultural frontier. CIAT also can help overcome some of the institutional constraints in Latin America by helping build the reservoir of scientists and trained technicians, by stimulating better orientation of research and training, and by strengthening links between research and extension at national levels.

HISTORICAL PERSPECTIVE

The plan for the 1980s is placed in historical perspective by reviewing the accomplishments made during the Center's first ten years. Institutional achievements principally relate to the sharpening of focus and organizational refinement. Over the past decade there has been a marked reduction in the number of food commodities covered, a clarification and sharpening of the program strategies and priorities, and a narrowing of the geographical and ecological foci.

Organizationally, procedures for program review and modification have been firmly established, providing for strong involvement of collaborating countries in the development of the Center's policies and operational procedures.

CIAT staff and management involvement in setting priorities and program planning have been enhanced through the development of annual program reviews and occasional position papers. At the same time, the Board of Trustees has established a mechanism for effective involvement in program and policy decisions through its Program Committee.

Program accomplishments during the first decade include the development and refinement of methodology and setting priorities of research activities. In addition, each of the commodity programs has made significant advances in getting improved varieties and associated agronomic practices to national programs, and through them, to the farmers. In the case of rice, national production levels already have improved significantly in virtually all countries of the region.

CENTER-WIDE OBJECTIVES AND PRINCIPLES

Based on the foregoing analyses of the socioeconomic, institutional and historical conditions and achievements, CIAT's projected strategies for the 1980s are defined, for the Center as a whole and for each commodity program. The overall objectives of CIAT are reconfirmed as follows:

> *To generate and deliver, in collaboration with national institutions, improved technology that will contribute to increased production, productivity and quality of specific basic food commodities in the tropics—principally countries of Latin America and the Caribbean—thereby enabling producers and consumers, especially those with limited resources, to increase their purchasing power and improve their nutrition.*

This statement of objectives emphasizes the technology development orientation of the Center. While it is recognized that many institutional, social and political developments are important for improved human welfare, the statement clarifies CIAT's contribution as one of applying modern science and technology to the problems of food production. The objectives statement also recognizes the collaborative nature of CIAT's activities with various national, regional and international agencies, and it indicates a strong orientation towards the American tropics. However, in the case of beans and cassava, CIAT has been given global responsibility among the international agricultural research centers. The Center thus has important worldwide roles to play, particularly with beans in eastern Africa and with cassava in Asia. While stressing that CIAT will not shirk these international responsibilities, the plan also acknowledges the special advantages to be gained from establishing and maintaining working relationships in the Western Hemisphere, and the dangers of spreading scarce resources too thinly. The objectives statement also emphasizes CIAT's basic orientation to low-resource farmers as well as to low-income urban consumers. This orientation is reflected in the research strategy of the Center.

In order to accomplish the overall objectives, the plan delineates the Center's operational principles relating to relevance, complementarity, technology design, and international cooperation.

Cassava

The objectives of the Cassava Program are:

(a) To develop germplasm and associated cultural practices that require low input levels and that are responsive to improved management, as a means to increase cassava production per hectare in areas where cassava presently is grown.
(b) To develop germplasm and associated management practices which under intermediate levels of inputs will lead to profitable cassava production on the underutilized, acid and infertile soils of the lowland tropics.
(c) To develop systems to improve the utilization of cassava and allow for more efficient use of cassava for direct and indirect human consumption.
(d) To strengthen national cassava research and development programs so that they may more effectively carry out their roles.

During the coming decade, the Cassava Program anticipates that its germplasm improvement activities aimed at the production of finished varieties for testing and release by national agencies will diminish in favor of increased emphasis on the production of germplasm for use in national breeding programs. Research on production practices will increasingly emphasize cropping systems and long-term fertility, while research related to management practices for cassava in existing production systems will decline. A gradual expansion in utilization research is anticipated; initial emphasis will be on storage and quality of fresh cassava, and the proportion of utilization efforts devoted to integrated production and utilization systems will increase later. Germplasm will be developed for six production environments. While five of these can be covered adequately by research and testing within Colombia, the sixth environmental system – represented by subtropical conditions of Mexico, southern Brazil, Paraguay, Bolivia, the northern islands of the Caribbean and southern China – will be dealt with by placing a breeder in a location representative of this ecosystem. Regional cooperation activities of the Cassava Program will be strengthened by outposting a regional cooperation scientist in each of three regions: Asia; the Caribbean, Central America and Mexico; and Africa.

Beans

The Bean Program objectives for the 1980s are:

(a) To develop improved technology for beans (*Phaseolus vulgaris*) – particularly higher and more stable yielding germplasm – which will lead to increased national production and productivity in those Western Hemisphere countries where beans are an important food source.
(b) To assist other regions – particularly eastern Africa – in achieving the same objectives through institutional arrangements in which CIAT can provide technological input based on its work in Latin America and the Caribbean.
(c) To strengthen national research programs in beans through training and by establishing a bean research network for scientists working on crop improvement.

The staffing pattern for the Bean Program is forecast to remain reasonably stable through the decade. However, research directions of the multidisciplinary team are expected to change considerably as emphasis in bean improvement is shifted in accordance with evolving priorities. The strong emphasis on disease resistance – currently representing about 80% of the improvement crosses – is expected to be reduced to approximately one-half this level by the end of the decade. The proportion of crosses related to insect resistance will remain relatively constant, while there will be considerable expansion in crosses designed to improve plant structure, yield potential, adaptation characteristics, and quality factors.

Inter-institutional transfer of the improved bean technology will be strengthened through the addition of an outposted regional cooperation scientist in each of the following areas: Central America, Brazil, the Southern Andean Zone, eastern Africa and the Middle East.

Rice

The objectives of the Rice Program in the 1980s are defined as follows:

(a) To continue to develop germplasm-based technology designed to overcome constraints to increasing production of irrigated rice.
(b) Through a new initiative, to develop, in collaborative research with national institutions, new germplasm-based technology to improve productivity and stability of supply in the more favored upland rice environments of the region.
(c) To continue active collaboration with the International Rice Research Institute (IRRI) in rice research, with particular emphasis on the International Rice Testing Program (IRTP).
(d) To continue to help strengthen national rice research programs in the region through training and consultative visits, and to further support the active network of rice researchers established during the 1970s.

The major changes anticipated for the Program will be a modest expansion in staff and a considerable shift in research emphasis to develop technology for favored, upland rice production. About one-half of the plant improvement work in upland rice will be directed to adaptation characters related to drought, low phosphorus tolerance and high aluminum tolerance, while about 30% of the breeding activities will be on disease resistance. Other research activities for upland rice will involve work on architecture for yield potential, quality factors and insect resistance. It is anticipated that over the decade the present predominance of work on disease resistance can be decreased with more concentration directed to adaptation to soil stress, lodging resistance and early maturity. Current levels of work on quality factors and insect resistance should remain about the same over the decade. The increasing emphasis on upland rice will require, in addition to the upland rice breeder joining the Program in 1981, a rice economist in 1982 and a rice physiologist in 1983. Much of the work of the rice agronomist will also shift from work in irrigated to upland conditions.

Tropical Pastures

The overall objective of the Tropical Pastures Program is to develop low-cost, low-input pastures technology to increase beef (and milk) production on the acid, infertile soils of tropical America. The strategy to achieve this objective is:

(a) To select pasture germplasm adapted to the environmental conditions (climate and soils) of the region and resistant to pests and diseases.

(b) To develop persistent and productive pastures and management practices for their profitable utilization.
(c) To study the role of improved pastures in production systems and to develop complementary animal management and animal health components.

Specific activities of the Tropical Pastures Program will evolve as progress is made toward these objectives. Gradually, more emphasis will be on advanced stages of pasture evaluation and on outreach. Also, better knowledge of the area of interest and of germplasm performances will enable systematic organization of the Program's germplasm strategy within each major ecosystem.

Emphasis will continue throughout the 1980s on the well-drained savannas. However, this will be slightly reduced over time to enable some work in the poorly drained savannas and the humid tropics. Principal importance will continue to be assigned to germplasm evaluation. Some increases in evaluation of pasture production systems is anticipated. A considerable increase in the number of trials with associations in the pasture components is planned.

It is anticipated that five additional staff positions – three in regional cooperation and two in research – will be required during the decade. Two positions will be adjusted for by phasing out current positions, leaving three actual staff additions. Regional cooperation staff are expected to be outposted in three areas: Central America and the Caribbean; the Cerrado region of Brazil; and subtropical South America.

INTERNATIONAL COOPERATION

Strong and expanded activities in international cooperation are planned for the decade. The goal is to provide for collaboration in research and inter-institutional technology transfer. Training will continue to be the major component of international cooperation, but much emphasis also will be placed on germplasm exchange, technical consultation, information services, and consultation on national program planning within CIAT commodity areas. The relative emphasis of different aspects of each of these components will vary considerably from country to country and commodity to commodity, depending on the stage of development and level of interest of the national research systems for each commodity. The plan presents a scheme defining relative emphases of these various types of activities in relation to different circumstances at the country level.

Training activities will continue to center on CIAT's commodity programs, to help build the capability of the national research systems to cooperatively, as well as independently, conduct research on these commodities. An increasing proportion of the training activities will be at higher professional levels, including increasing opportunities for thesis research in collaboration with cooperating universities and greater emphasis on postdoctoral fellowships. While CIAT does not plan to work actively in training extension agents, it will assist national programs to do so by providing training materials and assistance in planning and conducting in-country training programs.

NEW INITIATIVES

Two modest sets of new activities are projected for incorporation into the overall Center services to CIAT's commodity research programs. These will be in seed production technology and in agroecosystem analysis.

The exact nature of the activities and staffing pattern of the Seed Unit remain to be defined after further consideration by the Board of Trustees. General objectives of these activities will be to help overcome problems related to the lack of trained personnel in national seed programs; unclear and inconsistent policies by governments; limited supplies of breeder and basic seed for transfer to the seed industry; problems in producing, processing and storing of good quality seed; inadequate marketing systems; and the lack of effective mechanisms for the transfer of improved seed to small farmers. Strong national seed programs and local seed industries will greatly complement the crop improvement programs of CIAT and other centers by helping make improved seed available to farmers.

It is also planned that an agroecosystem analysis capacity will be added to the existing functions of the Data Services Unit. This will serve all of CIAT's programs by helping to characterize the climatic, edaphic and socioeconomic conditions of the existing and potential regions for production of beans, cassava, rice, and tropical pastures in CIAT's area of influence. Such characterization will help each commodity program to better focus its research priorities. A data bank on climatic, ecological and edaphic factors will also assist in selecting sites for regional testing, as well as extrapolating results of these trials. Analysis of specific meteorological conditions at the time and location of regional trials will provide better understanding of season-to-season and location-to-location differences, and will assist breeders in producing materials with better yield stability.

BUDGET PROJECTIONS

The implications of all of the foregoing planning considerations on the staffing pattern of the Center indicate a net growth of senior scientific and administrative staff positions from sixty-three in 1981 to eighty-five in 1987, and remaining at that level through the end of the decade. The largest component of this increase is for outposting of regional cooperation staff. While only a modest increase in research staff is planned, it is anticipated that some additional scientific positions may be required as a result of new problems or opportunities which cannot be foreseen. However, it is expected that any such additional staff positions can be provided for by reducing or deleting some current activities.

Overall budget requirements for the plan are projected to increase from U.S.$17.75 million in 1981 to $24.0 million (1981 dollars) in 1988 and thereafter. An extremely favorable return on this investment has been indicated by an *ex-ante* cost/benefit analysis based on conservative assumptions regarding the rate of adoption of new CIAT-generated technology, and equally modest estimates of the values of resulting increased production and the proportion of that increase which can be attributed to CIAT's efforts.

Part I

The Planning Context

1

The Socioeconomic Environment in Tropical America

Over 400 million people in developing countries are estimated to be malnourished, causing a substantial reduction in human capacities.[1] While some of the contributing causes of hunger in many countries are insufficient food production or resources to import food, the more basic cause is poverty and the lack of sufficient income to purchase food for an adequate diet. A solution of the world food problem, while dependent on producing more and cheaper food staples, in the end relies on raising the income levels of the poorer segments of the population. Accordingly, "hunger is as much a political, economic and social challenge as it is a scientific, technical or logistic problem."[2]

Improved agricultural technology adapted to the socioeconomic and agroclimatic conditions of the developing world is a necessary, but by no means sufficient, component of a world food strategy. In recognition of the key role of agricultural technology in increasing food production in the tropics, the Consultative Group for International Agricultural Research (CGIAR) system was formed in 1971. In addition to CIAT the system now includes nine other international centers and three related activities. While improved production technology is the final product of these centers, the CGIAR system recognizes this technology can be a means of achieving more basic socioeconomic goals, namely:

(a) Improving the production, quality and stability of supply of basic food commodities in developing countries;

1. Food and Agricultural Organization of the United Nations, *The Fourth FAO World Food Survey,* (Rome, The United Nations: 1977)

2. Presidential Commission on World Hunger, *Overcoming World Hunger: The Challenge Ahead,* (Washington, D.C., March 1980).

(b) Improving the nutritional status of those segments of the urban and rural population still below minimal nutritional requirements; and,
(c) Improving the income levels of the rural population with limited resources and, indirectly, of the low-income urban population.

The direct impact of the introduction of new technology is on increased food supplies. The flow of these supplies through systems of food production, distribution and consumption and their impact on nutrition and income distribution are complex and never fully corrective. Improved technology alone will never solve the problems of income distribution and nutrition but some agricultural technologies will undoubtedly have a greater impact than others on these two related problems. Choosing and developing the most appropriate technological alternatives thus require an understanding of the socioeconomic structure and how technology might be designed that is compatible with that structure and the three basic goals.

Although CIAT has a global role within the CGIAR system, it has a particular comparative advantage in the Latin American region. CIAT began with no fixed crop mandate or unique ecological orientation. Major changes in the Center's research activities have generally followed a horizontal approach (i.e., addition or deletion of staple food crop programs). A vertical approach that embraces any expansions into more basic research will be considered, when needed, in research areas where CIAT has a particular expertise. Circumstances affecting the Latin American agricultural sector will, therefore, continue to influence most research planning at CIAT.

SOCIOECONOMIC GOALS AND THE AGRICULTURAL SECTOR

The Production Gap

Food production in Latin America has grown at a sustained rate of 3.6% annually since 1950, a rate consistent with growth in aggregate demand (Appendix 1). The regional aggregate is highly deceptive, however. Food production has kept pace with demand growth in only five of twenty-one Latin American countries in the last decade. Only in Argentina have consumer food prices increased more slowly than overall consumer price levels.[3] All Latin American countries, except Argentina and Uruguay, are net importers of food staples. If current production growth rates are projected to 1990, food deficits in all tropical countries, except

3. Food and Agriculture Organization, *The State of Food and Agriculture in 1978* (Rome: The United Nations, 1978).

Brazil and Paraguay, are expected to increase by 50%.[4] Increases in the agricultural production growth rate will be necessary in most countries to keep food prices constant in real terms and to maintain current levels of self-sufficiency in food.

Land, Labor and Growth

Agricultural production can be increased either by mobilizing more land and labor resources or by using current resources more efficiently. A major means of improving the efficiency of resource use is through technological change. In order to most contribute to growth, technical change should increase the productivity of the resource in most limited supply. In the case of Latin America, land is highly abundant. Studies comparing potentially arable land to land currently under the plow estimate that Latin American agriculture utilizes only 18-35% of its potential land resource (Appendix 2). Moreover, the average farm size of 112 hectares is very high by developing country standards. In the aggregate there appears to be a surplus of land relative to labor. Such a situation implies that the most efficient growth strategy would be to increase labor productivity while expanding arable land. Increased farm mechanization would be one logical result of this strategy.

Nevertheless, past growth has not followed such a path. Except for Argentina, Uruguay and Venezuela, Latin American countries have been increasing productivity of both land and labor. During the 1960-78 period, tractor use increased 5.6% annually and fertilizer use grew at an 11.2% rate. This intensification of land use appears to be inconsistent with the concept of a land-surplus economy.

This apparent inconsistency arises from the very heterogeneous nature of Latin American agriculture. While an agricultural frontier does exist in most tropical South American and Central American countries, expansion at the frontier competes with intensification of farms presently in production. The high costs of bringing new frontier land into production using existing technology make it less profitable than intensifying land already in production. Competition between extensive and intensive development is complicated further by the very skewed distribution of land, a particular characteristic of Latin American agriculture. The majority of farmers have access to very limited land resources and must concentrate on yield-increasing techniques in order to increase production. Large-

4 International Food Policy Research Institute, *Food Needs of Developing Countries. Projections of Production and Consumption to 1990*, Research Report No. 3 (Washington, D.C.: International Food Policy Research Institute, December 1977).

scale farmers, on the other hand, control most of the land resources and face relatively high labor costs. As farm size increases, costs for obtaining and managing large numbers of seasonal laborers rise. Thus, large farmers invest in labor-substituting mechanization or specialize in extensive production activities, such as pasture beef systems.

An agricultural growth strategy for Latin America that efficiently utilizes both land and labor resources is not only complicated by the distribution of these resources but also by very marked differences in land quality. Three very different growth strategies emerge:

(a) Intensification of production by large farmers who control the more fertile areas, primarily through mechanization and higher input use;
(b) Expansion of agricultural production on the less fertile frontier land; and,
(c) Intensification of production by small farmers through higher, more stable yields.

Some areas, especially much of Mexico, Central America and the Caribbean, do not have large, underutilized frontier areas (Appendix 3). For these countries (a) and (c) are the major options.

Each growth strategy implies a different research focus. In a planning context, the issue is not only to decide which areas of research promise the largest production gain but also to determine the areas in which CIAT has a comparative advantage, especially in relation to the three socioeconomic goals defined earlier. Latin American agriculture has a dynamic large-farm sector that relies on mechanization research easily transferable from more developed countries. Rapid growth in a large-farm agriculture coupled with a very skewed land distribution can produce an accelerating treadmill effect, with "less efficient" farmers moving out of agriculture. With insufficient employment opportunities in the urban sector, large social stresses develop. The rest of this section addresses the issue of whether there is potential complementarity between the three strategies, which will help define research requirements.

Large Farm Intensification

Larger farmers in Latin America, while controlling the major portion of the land resource, tend to utilize their land very extensively. In Brazil, for example, farms of more than fifty hectares make up 85% of the land area in farms but have only 53% of the area in crops. In Colombia, large farmers own 76% of the land but have only 40% of the land in crops.

Latin American policymakers have realized that such land use is inefficient and have tried to induce larger farmers to shift from extensive beef production systems to crop systems. Policies to foster mechanization—credit subsidies, overvalued exchange rates, land taxes, and price supports for mechanizable crops—have been implemented in many countries. These policies have been complemented by investments from multinational agricultural supply firms, which find large, untapped markets with low distribution costs and minimal requirements for redesigning chemical, seed and mechanization technologies.

A very dynamic sector has been created and is reflected in the very high growth rates in mechanizable crops. Since 1960, for example, sorghum production in Latin America has increased 12% annually, and Brazilian wheat production has increased 10% per year. Soybean production growth has been even more rapid. In all cases, over 75% of the growth was due to area expansion. This reflects the extensive nature of crop production on large farms. While these crop yields have remained essentially stagnant, overall land productivity has increased due to shifts from pasture production to crops.

Concentration of agricultural policies on intensifying the land use of large farmers has had two important results. First, production growth of extensively produced commodities, especially beef, has lagged behind demand. Second, in seeking to increase the efficiency of land use on large farms, policies have not dealt with, and in some cases have exacerbated, inefficiencies in labor use. High rates of underemployment exist in Latin American agriculture. Inefficient labor use cannot be ignored because of its obvious links to income and nutrition goals.

Expansion of the Agricultural Frontier

At the agricultural frontier infrastructure development is usually limited and input and marketing costs are high. Labor is scarce but land is relatively cheap. Thus, expansion at the frontier generally is based on extensive production systems, and at the Latin American frontier beef systems predominate. By reducing the price of beef, this expansion can induce the intensification of large farms on more fertile land and thus achieve a more efficient utilization of land resources.

As large farmers on the more fertile land shift into crops, rising land values force the intensification of the remaining pasture land. During the 1960-70 period, improved pasture area increased 3.6% annually, a full percentage point more than crop land expanded. In addition to this growth of 21 million hectares of pasture, 92 million hectares were added at the frontier, representing a growth of 2.2% per year in native pastures. These two processes led to a 3.4% annual growth in beef production, well short of the 5.4% growth in demand for beef. Thus, expansion on the frontier is a necessary complement to large-farm intensification, if demands for food crops and beef are to be met.

Even with rising beef prices, the area sown to pasture has not been expanding fast enough to meet demand. For much of the abundant land area of Latin America – the "llanos," the "cerrado," the "pantanal" and the Amazon jungle – the present production costs with current technology for infrastructure and soil correction appear to be too high to support more rapid expansion of land use at the frontier. Selection of crop and pasture species with markedly reduced fertility requirements should improve the potential profitability of land use in these areas. Increased productivity of adapted crops, such as upland rice and cassava, is needed as a means of paying for pasture establishment. Investment in new technology that increases productivity of beef pasture systems in the infertile Oxisol and Ultisol soils typical of the Latin American frontier should complement intensification of large farms on more fertile land. The effect of rapid beef expansion on price would induce these large farmers to shift to more profitable, and more intensive, alternatives. Thus, pasture technology specifically designed for frontier areas should induce a more socially acceptable utilization of land resources in Latin America.

Small Farm Intensification

A paradox exists in Latin American agriculture. From a social point of view, small farmers in labor-surplus economies are in general the most efficient producers in the combined utilization of land, labor and capital resources.[5] Because they control such a small portion of the land resource, their potential contribution to total food production is somewhat limited. However, increasing the productive employment of labor should be given a priority at least as high as fostering more productive utilization of land, since employment is the principal determinant of income and welfare.

Underemployment in the agricultural sector is a principal cause of rapid rates of migration to urban areas. Conditions of Latin American cities offer ample evidence that rural poverty is not being solved by transferring it to urban areas. Moreover, average nutrition of the low-

5. R. A. Berry and W. Cline, *Agrarian Structure and Productivity in Developing Countries* (Baltimore: Johns Hopkins University Press, 1979).

income strata of the population is affected by migration. Studies have indicated that the nutritional situation of the urban poor, even with higher incomes, is inferior to that of the rural poor.[6]

Latin American urban growth eased slightly during the 1970s but still averaged 3.7% annually; the growth rate was over 4.5% in Brazil and Mexico. This process has put extreme pressure on job creation in the urban sector. Industrial growth has been capital intensive and most of the employment is occurring in the tertiary sector, generally in low-productivity service jobs. The service sector is also the entry point for most rural-to-urban migrants—if they can find jobs at all. In most countries average labor productivity is lower in these jobs than in the agricultural sector.

The employment problem is further complicated by the very young age profile of the population. The labor force growth rate is expected to increase from 2.4% in the 1960-70 period to over 2.9% in 1980-2000. Moreover, in Latin America the rural component is more than 30% of the total population and is over 50% in the poorest countries. Therefore, migration flows will remain large and put even more pressure on urban job creation. International Labor Office studies of representative Latin American countries have stressed that a full-employment strategy over the next decade depends on increased employment in the agricultural sector and maintenance of the agricultural sector's role as a residual employer.[7]

Full employment thus requires some check on rural-to-urban migration for at least the next few decades. However, migration rates are highly responsive to changes in intersectorial income differentials. In Latin America a 10% increase in the relative income between the tertiary sector and the agricultural sector increases the migration rate by 11%.[8] Slowing expected migration depends on improving agricultural incomes, especially among the low-resource and, therefore, more mobile portions of the agricultural population. About 35% of the economically active population are landless laborers. Moreover, approximately 50% of all farms are of subfamily size. The existence of a highly mobile agricultural population that is very responsive to intersectorial income differentials strengthens

6. J. O. Ward and J. Sanders, "Nutritional Determinants and Migration in the Brazilian Northeast: A Case Study of Rural and Urban Ceara," *Economic Development and Cultural Change*, 29 (1980): 141-164.

7. International Labor Office, *Toward Full Employment: A Programme for Colombia*, (Geneva: The United Nations, 1970).

8. J. K. Lynam, "Growth in Latin American Agriculture: A Cross-Country Analysis" in *Trend Highlights of CIAT's Commodities*, Internal Document Econ. 1.6 (Cali, Colombia: CIAT, April 1981).

the argument for an agricultural development strategy that increases rural incomes of small farmers and landless laborers.

One partial solution to reduce rural-to-urban migration rates has been to encourage small- to medium-farm colonization on the frontier. Compared with migration to urban areas, colonization schemes tend to be costly and do not create significant population flows. In the Santa Cruz area of Bolivia and the jungle area of Peru, spontaneous labor flows have been significant but have not solved the rural employment situation in the highlands. In the better soil areas of Parana, Goias, and Mato Grosso in Brazil, frontier settlement and associated infrastructure development have been rapid and effective. In general, however, the potential for expansion of viable family size, crop-producing farms at the frontier is limited by soil constraints, lack of appropriate technology, poor access to markets, relatively high capital requirements and inconsistent land settlement policies over time.

Improvement of small-farm productivity remains the most viable avenue for affecting rural (and urban) employment. In Brazil, for example, 40% of rural employment occurs on farms smaller than ten hectares and almost 75% on farms of less than fifty hectares. To what extent can both labor productivity and employment be expanded on farms of this size? An answer will require further empirical investigation but an effective strategy must minimally include labor-intensive crops, employment-generating production systems and yield-raising technologies.

However, strategies to simultaneously intensify both large and small farms are compatible only under certain limited conditions. If farmers in the two groups grow the same commodity and large farmers continue to have access to the subsidized capital typical of most mechanization policies, small farmers usually will not be able to compete. Any initial positive impact on small farm income would vanish and even become negative as prices fall. The inherent nature of Latin American agriculture argues for crop specialization, with small farmers concentrating on labor-intensive crops and large farmers on mechanizable crops. Such crop specialization already characterizes Latin American agriculture. Research to facilitate mechanization of labor-intensive crops could cause small farmers to lose their comparative advantage. Although such research may be effective in increasing the output of such a crop, any social benefits could well be offset by social costs.

A Combined Growth Strategy

If food is to be supplied at reasonable prices and minimum incomes are to be assured through productive employment, growth in Latin American agriculture will have to come from productive employment of both land and labor. Enough public and private resources are being directed to large-scale agriculture to assure its future dynamism. An efficient growth strategy would also include expansion on the frontier with intensification of production by small farmers. However, the compatibility of the three strategies rests on each group producing those crops in which it has a comparative advantage and, especially, on the lack of competition between large and small farmers in the same product market. Research investment should therefore concentrate on strengthening this comparative advantage by matching crop choice and technology design to the particular resource constraints of each farm group. Table 1 summarizes the comparative advantages of several commodities with respect to farm size and frontier expansion.

SOCIOECONOMIC GOALS, NUTRITIONAL REQUIREMENTS AND FOOD DEMAND

In developing market economics price is a fundamental determinant of food production levels, rural incomes and nutrition. However, improving price incentives for farmers often conflicts with provision of cheap food staples for urban areas. Agricultural technology provides a potential wedge in the market mechanism that allows price reductions to consumers through cost reductions at the farm level. Maximizing the impact of new technology on nutrition will depend on understanding food consumption patterns, particularly of the poor.

Nutritional Deficiencies

Inadequate caloric intake by large sectors of the population is the most pressing nutritional problem in Latin America (Appendix 4). Especially serious protein deficits are also found in vulnerable groups such as children in poorer families and pregnant women.

Caloric deficits must be overcome first or additional protein will be utilized principally – and, therefore, inefficiently – as an energy source. In fact, where calories are limiting in the diet, a percentage change in calories will have a greater positive effect on nitrogen balance than a proportionate change in (more expensive) protein.

The true magnitude of the problem is hidden when one uses national averages of per capita availability of calories and protein. The figures have more meaning when expressed as percentages of the population with diets below minimum requirements. Using such an indicator, the extent of caloric deficits in Latin America appears staggering indeed (Appen-

TABLE 1.
Relative comparative advantage of major commodities under different production conditions.

Commodity	Present production areas: Small farm	Present production areas: Large farm	Frontier land[a]
Wheat	+	+ + +	–
Maize	+ + +	+ +	–
Sorghum	–	+ + +	?
Rice (Irrigated)	+	+ + +	+ +
(Upland)	+ +	+	+ + +
Cassava	+ + +	–	+ +
Potatoes	+ + +	?	–
Plantains	+ + +	–	–
Beans	+ + +	+	–
Soybeans	–	+ + +	?
Sugar	+	+ + +	–
Beef	–	+ +	+ + +
Swine	+	+ + +	–
Poultry	–	+ + +	–
Milk (Dual-purpose breeds)	+ + +	+	+
(Specialized breeds)	+ +	+ + +	–

NOTE: Relative comparative advantage is based on yield potential, labor versus capital intensity, and expansion potential. This classification was developed from subjective evaluations by CIAT scientific staff.

a. Predominantly acid, infertile soils.

dix 5). The range in deficits is from one-third of the population in Chile and Uruguay to over two-thirds in El Salvador, Ecuador and Guatemala. Inadequate calorie/protein availability not only implies reduced energy levels but also can result in permanent damage in vulnerable groups such as growing children. Future investments in human welfare, such as health, education and training, cannot substitute for or undo physical deterioration resulting from inadequate diets in the early years of growth. Hence, improving nutrition of major segments of the population must be a principal concern of most Latin American governments if they are to have a healthy, capable work force in the future.

Increasing incomes is the most direct means of correcting nutritional inadequacies. The problem's magnitude and urgency make it too important to rely solely on longer-term strategies, i.e., employment policies. Shorter-term alternatives are to identify and increase production of cheaper nutrient sources and to utilize appropriate policies to increase calorie and protein intakes of the population strata with deficiencies. Understanding the diversity of the Latin American diet is a necessary starting point in selecting commodities for agricultural research which in turn will have a maximum impact on nutrition.

Subregional Importance of Major Staples

Latin American food consumption patterns vary substantially between regions (Appendix 6). Sugar is consistently a major source of calories in the Latin American diet; it provides only calories but is important because of its low cost. Maize is considerably important in Mexico, Central America and some Andean countries, but is of lesser importance in the rest of Latin America and the Caribbean. Wheat is important in all regions but dominates as the principal caloric source only in the temperate Southern Cone countries. Rice provides over 12% of the calories in the Caribbean, Colombia and Brazil. Cassava provides 9% of the calories in Brazil and Paraguay. Beef, an important source of calories in the Southern Cone and Paraguay, is an important protein source in most of Latin America (Appendix 7). Beans provide over 10% of the proteins in Mexico, Central America, Paraguay and Brazil. In summary, no one staple can be singled out as the major source of calories and protein throughout Latin America.

Diversity in the Diet

In the rural sector major sources of calories vary according to local supplies, which in turn vary widely throughout the region due to the extreme variability in soils and climate. In the urban sector, large variance is found in the food expenditures in the lowest-income strata across cities and subregions (Appendices 8 and 9). Consumer budget data from ten Andean cities showed that 15-30% of food expenditures by families in the lowest-income categories were for beef and milk. Moreover, these percentage allocations were maintained throughout the income categories. Beef was not only a preferred food in the Andean cities but the urban poor spent a major portion of their food budget for this predominantly protein source. Sugar and rice were also consistently important items bought in most Andean cities, but could not be said to dominate in total expenditures on caloric staples. Other subregionally important commodities in food budgets of the urban poor were wheat products, maize, beans, cassava and potatoes, but with none being dominant.

Technology and Nutrition

By affecting food prices, agricultural technologies can have indirect effects on the diet of the low-income urban population. Declining food prices are desirable in this context, but product prices must also give proper production incentives to farmers. New technology can mediate these two conflicting roles of price in the market, but rarely will benefits be shared equally by both consumers and producers. If improved consumer welfare has the higher policy priority, then commodity choices should focus on non-exported, non-preferred foods in which market prices are relatively responsive to changes in quantities. These commodities tend to be the principal food staples of the poor.

Northeastern Brazil, containing one of the largest population concentrations with nutritional problems in Latin America, could illustrate the case. Cassava flour, beans/cowpeas and rice, the principal sources of energy, contributed more than 50% of the calories in the still insufficient diet (Appendix 10). (Beans and cowpeas, close substitutes in northeastern Brazil, are reported together statistically.) Beans/cowpeas were as important as meats and fish together as a source of protein (Appendix 11). Cassava flour, the legumes and rice were among the cheapest sources of calories and protein. The fact that expenditures for these commodities increase with income in this region (Appendix 9) is indirect evidence that more of these specific commodities will be demanded by low-income consumers if prices decrease. Technology for crops such as these has an important role in reducing caloric and protein deficits in a region with acute nutritional problems. Moreover, in this particular case balancing beans or cowpeas with cassava helps offset the lower protein content of cassava.

Policies to stimulate production and consumption of these lowest-cost nutrient sources would be expected to have a much more rapid effect in eliminating nutritional deficiencies than would a gradual shift to higher consumption levels of other high-quality foods that cost more per nutrient.

Demand Growth

As a direct consequence of high rates of population and income growth, aggregate demand for food in Latin America is growing 3.6% per year, a rate consistent with the growth in total food production (Table 2). This balance is only apparent however, because:

(a) food production growth lagged behind demand in sixteen of twenty-one countries (Appendix 12);
(b) in most countries nutritional problems have continued, if not worsened, since growth in production of major staples lagged behind demand; and,
(c) those commodities in which production increased most rapidly (export crops, feed grains and poultry) had more impact on the diets of middle- and high-income strata than on the diets of the poor (Appendices 8 and 9).

Given the skewed income distribution in Latin America,[9] income growth has caused expanded demand for those food commodities most preferred by the middle- and high-income strata. As a response to high demand growth, production of those commodities has increased rapidly, sometimes at the expense of more basic food crops. This is the case with poultry and, indirectly, feed grains. Poultry production grew 9.8% annually from 1970-79 in Latin America, compared with 3% in the United States. Production growth of sorghum and soybeans for feed, exports, and vegetable oil was even more rapid.[10] The dramatic expansion of soybeans in southern Brazil helped push dry bean production into more marginal areas.

In Brazil and Mexico, animal feed accounted for 44 and 32%, respectively, of food crop utilization in 1972-74. Over the period 1961-65 to 1974-76, maize accounted for more than one-half the production growth of food staples in Brazil, whereas sorghum was responsible for nearly one-half the increase in Mexico.[11] From 1961-65 to 1974-76 the Brazilian

9. J. Shail, *Size Distribution of Income: A Compilation of Data* (Washington, D.C., the World Bank, 1975).

10. CIAT, *Latin American Agriculture: Trends in CIAT Commodities*, Internal Document Econ. 1.6, (Cali, Colombia: CIAT, May 1981).

11. K. L. Bachman and L. A. Paulino, *Rapid Food Production Growth in Selected Developing Countries: A Comparative Analysis of Underlying Trends, 1971-76*, Research Report 11 (Washington, D.C.: International Food Policy Research Institute, October 1979) 30.

TABLE 2.

Agricultural economic growth indicators and relative importance of selected commodities in the Latin American food economy, 1960-78.

Commodity	Percentage growth in:						Percentage contribution to total consumption of:		Percentage of food budget spent by lowest income strata in:	
	Demand	Production	Area	Yields	Total production[a]		Calories	Protein	Andean cities[b]	Northeastern Brazil[c]
Wheat	3.4	1.9	1.4	0.6	–	8	18	15	4-17	4
Maize	–	2.8	1.1	1.7	–	40	16	15	0- 6	3
Sorghum	–	12.5	9.2	3.3	–	9	–	–	–	–
Rice	3.5	3.3	2.8	0.5	–	18	9	7	2-14	7
Potatoes	3.3	2.3	0	2.4	–	3	2	2	2-11	–
Cassava	2.4	1.9	2.4	−0.5	–	17	4	–		12
Total pulses	3.0	1.4	1.7	−0.3	–	6	5	13	1- 7	16
Beans	3.0	0.3	1.1	−0.8	–	5	3	11	n.a.	n.a.
Beef	5.4	3.4	–	–	58	–	5	14	9-24	9
Pork	4.5	4.1	–	–	22	–	1	4	0- 2	5
Chicken	6.1	9.5[d]	–	–	20	–	1	3	0- 3	3
Milk	5.5	3.9	–	–	–	–	6	12	6-18	4
Agricultural sector	3.6	3.5	2.0	1.5	100	100	–	–	–	–

SOURCE: Unless otherwise indicated, estimates are from Food and Agriculture Organization (FAO) Production Tables, and FAO Food Balance Sheets for 1972-74

a. Tropical countries only, 1978 data. First column includes only meats expressed by carcass weight; second column includes cereals, grains, roots and tubers, all expressed in cereal equivalents.

b. Ranges for twelve Andean cities for 1968-72. (Source: Appendix 8.)

c. For 1975. (Source: Appendix 9.)

d. For 1970-78

growth rate in the use of cereals for feed was 6.3% and Mexico's was 16.4%. In developing countries with rapid increases in incomes, the total use of cereals for livestock feed has increased considerably faster than the use of cereals for human consumption.

In summary, production of poultry, feed grains and export crops is growing faster than production of caloric and protein staples, essentially in response to the concentration of purchasing power in and the preferences of middle- and high-income groups. Production incentives for staples are thus inferior to those high demand crops. Growth in production is therefore lagging substantially behind demand growth for maize for direct consumption, wheat, cassava, beans and beef.

Priority on Major Staples

Table 3 summarizes the importance of principal Latin American commodities in terms of nutrition and demand growth in Latin America. Both wheat and maize are important as caloric sources and demand for wheat as food and for maize as feed is increasing. Rice, beef and milk are already important in providing calories and proteins in most of Latin America. Moreover, a rapid increase in demand is expected for these commodities, especially beef.

The extremely cheap caloric foods, cassava (in rural areas) and cassava flour, are important in Brazil and Paraguay, which account for 40% of the population in tropical Latin America. Countries implementing nutrition programs for their lowest-income strata could take advantage of the cheap calories from cassava and its production potential on less fertile soils. With technological change in marketing and/or processing, fresh cassava may have potential growth prospects as food and/or feed.

Beans are important subregionally for protein and are the most inexpensive protein source. Beans could be an important complement to a nutrition program aimed at increasing cassava consumption since protein deficits become an important concern once caloric deficits have been overcome. Rising bean prices in many countries indicate that growth in demand has exceeded supply growth in recent years.

COMMODITY CHOICES AND RESEARCH STRATEGY

The impact of new agricultural technology on the goals of growth and equity is almost always mediated by the market mechanism. The setting of prices and quantities in these markets determines farmer incomes, the level of production increases, and improvement in consumer nutrition.

TABLE 3.
Summary evaluation of principal commodities based on nutritional importance and expected growth in demand, in Latin America.

	Important regional caloric source	Important subregional caloric source	Important regional protein source	Important subregional protein source	Cheap caloric source	Cheap protein source	Rapid demand expansion for food	Rapid demand expansion for feed
Wheat	x		x				x	
Maize		x		x				x
Sorghum								x
Rice		x		x			x	
Sugar	x				x			
Potatoes		x					x	
Cassava (dried)		x			x			P[a]
(fresh)		x[b]					P[a]	
Beans				x		x	x	
Soybeans								x
Beef		x	x				x	
Milk		x	x				x	

SOURCE: Adapted from Appendices 1-11.

a. Potentially important.
b. Few countries only.

However, an understanding of goal attainment, within a particular socioeconomic environment, is important in defining research strategy only if this understanding can be translated into a specific set of crops on which to do research and a specification of design criteria to develop technology for each crop.

Because of the heterogeneity of Latin American agriculture, no one crop – like the case of rice in Asia – could contribute significantly to total agricultural production and, at the same time, significantly benefit the rural and urban poor. In choosing to do research on several crops, CIAT attempted to select commodities in which the total contribution of CIAT and other research institutions to socioeconomic goals would be high. A first requirement was that these should be predominantly food staples. Secondly, the choice of crops should be such that some would provide for an increase in the productivity and incomes of small farmers, while others would contribute to the expansion of agricultural production on both good lands and the frontier. CIAT's operating divisions for crop research and land systems research reflect these thrusts. The Center's choice of beans, cassava, rice, and tropical pastures for acid, infertile soils is considered consistent with the above strategy.

Each crop has regional importance as a source of calories and/or protein. In terms of contributing to the major nutritional problem (caloric deficits), maize, wheat or sugar would have been other possible choices. The first two are under the mandate of the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). Sugar is already the cheapest caloric source in the diet; this fact partially reflects the large research investment that has already gone into this crop. Sorghum and soybeans are other possible crops important from the production point of view, but are of lesser significance in achieving the overall socioeconomic goals. These two crops, however, are not staples (except soybean oil) and increased production would tend principally to benefit the middle- and high-income consumers and large farm producers. Nevertheless, both are displacing other crops grown in good soils.

Given CIAT's size and budgetary limitations and the early state of technology development in its four current programs, it is too early to consider adding any of these commodities as Core-funded programs. The Center has and will continue to monitor production trends and economic conditions in the region's agricultural sector in order to detect early signals for the need for possible alternative activities. Special projects in collaboration with other institutions to develop varieties of sorghum and soybeans adapted to acid soils could be hosted, because they are complementary alternatives to upland rice, cassava and tropical pastures for frontier areas.

A brief description follows as to why CIAT's selection of crops provides a reasonable balance in meeting both production and nutritional goals in Latin America and how the research strategies in each case are consistent with the overall socioeconomic goals.

Tropical Pastures

Beef is a principal part of the Latin American diet and, even among the poor, forms a major portion of the food budget. Demand for beef in Latin America is increasing at a rate far ahead of growth in production. Moreover, beef is produced under extensive systems which do not require well-developed infrastructures for obtaining inputs or marketing outputs. In terms of fostering expansion at the frontier, beef production is a logical choice.

The research strategy of the Tropical Pastures Program has focused on overcoming the principal constraints on extensive beef production systems in the acid, infertile soils of Latin America. Constraints of the savanna regions have received most attention up to now. The principal constraint is the low nutrient production of the pasture system, especially in the dry season. The search for adapted and more productive grass and legume species was considered to be the key to developing a low-cost, minimal input technology for these areas.

Cassava

Cassava is a traditional caloric source of the rural population in Latin America but has limited importance in urban areas, except where consumed as a flour. The plant is extremely efficient in producing carbohydrates and is particularly well-adapted to more marginal agricultural conditions. Its low requirements for purchased inputs, relatively high labor requirement, adaptability to intercropping systems, and flexible harvest period result in production originating from small-farm systems. Given that demand is sufficiently elastic, the crop is ideally suited to intensifying small-farm production systems. The potential for developing alternative end uses for cassava – such as starch, as a carbohydrate source in animal feed, and as raw material for ethanol production – appear to guarantee this market elasticity. Competitiveness in these markets, however, appears to depend on lower production costs, and therefore the need for improved production technology.

The research strategy in the Cassava Program has three principal thrusts: (a) development of low-cost, minimum input technology, particularly directed at small farmers; (b) research on developing cassava as a crop for expansion into the frontier; and, (c) research on more efficient processing and utilization technologies. The Program combines research on both production and utilization technologies, since a primary constraint in cassava production systems is the crop's rapid perishability after harvest. As well, utilization research insures that processing technologies are of a sufficiently small scale to allow resource-poor farmers access to end markets. Cassava is thus one of the few crops through which improved technology can result in increased productivity of small-farm systems in more marginal production zones.

Beans

Beans are an important protein source, particularly in Brazil, Mexico and Central America where they constitute between 10 and 20% of the dietary proteins (Appendix 7). Bean production is stagnant in Latin America, and area expansion for the crop tends merely to compensate for yield declines in most countries, especially Brazil. Most bean production comes from the small-farm sector, where beans are typically produced in association with other crops—principally maize—and on the poorer lands. The maize-bean association is labor intensive and gives high returns per unit of land area.

Bean productivity is low because of a broad spectrum of insects and diseases that attack the crop. Due to the devastating nature of many bean diseases, farmers frequently prefer to plant beans under conditions of marginal rainfall. Moreover, governments seldom provide adequate price supports or other financial incentives to bean producers. As a consequence of these physical and economic factors discouraging bean production, few farmers are prepared to use expensive inputs such as fertilizers or fungicides; hence, yields are low. Yields and profitability have been so low that beans have been displaced from former production areas—such as parts of southern Brazil and the Cauca Valley of Colombia—by more profitable crops. Over the last decade bean yields in most Latin American countries have been declining due to these crop shifts and the inability to maintain yields at the extremely low levels of input use.

The research strategy of the Bean Program is to increase bean production by incorporating multiple disease resistance into commercial cultivars. Tolerances to drought and moderately low soil fertility are also sought. The search for cultivars able to fix atmospheric nitrogen is emphasized as well. The Program's strategy focuses on stabilizing and increasing bean yields without major increases in purchased inputs. Nevertheless, once new varieties are available, moderately increased input levels will be economically feasible due to higher potential yields and reduced yield variance. By emphasizing achievement of production increases without major increases in input costs, this strategy should help insure that the small-scale farmer will remain the principal producer of beans.

A significant portion of bean production comes from climbing beans, which are almost entirely produced in association or in relay with maize. The Bean Program is dedicating a considerable effort to the improvement of beans in association, while maintaining maize yields. Such technology is again most appropriate for the small farmers due to its very high labor requirements.

Rice

Rice is a major caloric staple in the Caribbean, Brazil and many countries of the Andean Zone. Rice consumption has been increasing in most of tropical Latin America because a rapidly urbanizing population has shifted from other staples to rice as a principal caloric source. This process has been accelerated by the stable (or even declining) price of rice, since production has kept up with demand growth in most Latin American countries. In many cases this rapid production growth has resulted from the introduction of improved varieties, combined with their rapid adoption by mechanized farmers in favored rice areas.

Rice is predominantly a large-farm crop but a great diversity in types of production systems does exist. Systems range from intensive irrigated ones to extensive upland systems on the frontier. Average yields in the different systems vary markedly. The principal factor determining the type of system is the rainfall pattern and possibilities of improved water management. The relevant issue for most rice-producing countries is the choice of system in which to invest research resources. The new technology has primarily benefited the irrigated sector and farm yields are rapidly reaching the feasible yield potential of current technology. Future yield increments in this sector will not be as dramatic. In order to maintain growth in rice production, Latin American countries must choose between expanding irrigated land or raising yields of upland production. The potential for meeting increased rice demand from irrigated areas and from upland areas varies among countries.

CIAT's Rice Program recognizes the need to focus on research for both irrigated and upland conditions. For irrigated rice, the largest yield gains have already been made in most countries. The focus will principally be on maintenance research and on basic research to develop resistance to rice blast and to the *Sogatodes* leafhopper. Upland research will concentrate on selecting for adaptation to stresses common under upland conditions. This research will focus on those upland areas with a more stable rainfall regime, where the chances of achieving a significant yield increase are the highest. The upland research strategy focuses on utilizing land at the crop frontier which will be farmed under relatively extensive, mechanized conditions.

2

The Roles of National Programs and CIAT

Effective agricultural research is a continuum encompassing activities from conducting basic research to monitoring farmers' adoption of improved varieties and cultural practices. This research continuum includes many interacting institutions conducting basic and applied research and extension activities. National agricultural research institutions and the international centers play important roles in this institutional complex.

NATIONAL PROGRAMS AND TECHNOLOGY DEVELOPMENT

Of the various institutions in the research continuum, none is more important than the national agencies involved in agricultural research and development. Only through strong national programs can the new technology be evaluated under varied local conditions, modified as necessary and transferred to farmers along with the essential support services required to make the technology useful. CIAT strives to maintain cordial and productive collaboration with its primary partners, the national institutions. Moreover, the Center works to strengthen the capacity of these institutions to carry out their functions as full and effective partners in the research continuum.

Because this long-range plan focuses on CIAT, the very vital role of national programs cannot be covered adequately. However, this plan is based on the supposition that an international center's activities must be complementary to, and closely coordinated with, those of national programs. Chapter 4 discusses the strategy and principles behind such complementarity and cooperation.

The urgency to develop improved food production technology in the tropics led to the establishment of the international centers to serve and complement the actions of local institutions. Thus, these relatively new research centers represent an added dimension in the agricultural development panorama. It is essential that national programs be strengthened and that international centers be involved in only those activities in which they have a clear comparative advantage and can most effectively provide a useful service to national programs. CIAT's unique role in helping overcome technological and institutional constraints must be examined in this context.

CIAT AND TECHNOLOGY DEVELOPMENT

Focus on Basic Food Commodities

Agricultural research in Latin America has focused on the more dynamic growth sectors of the agricultural economy, mainly the medium- and large-farm sectors. Before the development of a large domestic urban market, tropical export crops—such as sugar cane, cotton, coffee, cocoa and rubber—received the bulk of research resources. With rapid urbanization during the last three decades and the orientation to import-substitution development schemes, the principal growth sectors have shifted to highly income elastic food and feed crops, also associated principally with large-scale mechanized production patterns. Past efforts have paid relatively little attention to those crops that are the most important sources of calories and protein for the largest number of people and are a source of income to the largest number of farmers. By concentrating on these basic commodities, CIAT and other international centers can make a unique contribution towards overcoming the large agricultural technology gap that still exists, particularly when staple crops are grown by low-resource farmers.

Technology Development for Low-resource Farmers

Compounding the problem of scarcity of research is the fact that the relatively little research done on these crops often has been conducted under experiment station conditions similar to those of large, mechanized, irrigated farms. CIAT can play a special role in developing technology for farmers with limited resources and for less-favored environments. This can be accomplished by designing technology for the constraints faced by small farmers and through cooperation with national programs to strengthen and develop methods for on-farm evaluation of technology.

Technology Development for Expansion of the Frontier

Technology is also lacking that could guide the rational expansion into frontier areas of tropical America. These vast areas (approximately 50% of tropical America) remain underutilized because of low natural fertility of the soils and various local problems. As an international center, CIAT must look at future as well as immediate needs. Therefore, the Center has a comparative advantage in developing appropriate technology for logical and more intensive utilization of those frontier areas suitable for livestock production, which later will be combined with crop production.

CIAT AND INSTITUTIONAL IMPROVEMENT

In defining CIAT's role, it is clear that there are certain activities in which an international center has distinct comparative advantages over collaborating national research institutions, regardless of their stage of development. A permanent, complementary role for a center such as CIAT is to help overcome the limitations of national research systems. However, overcoming technical constraints to improved agricultural productivity is often inhibited by institutional barriers. An international center has the flexibility resulting from its apolitical, non-governmental nature to contribute to overcoming some of these institutional constraints.

Investment Level and Defining Priorities in Agricultural Research

There is much documented evidence that agricultural research plays an important role in agricultural development and that it is a highly profitable venture. Agricultural research expenditures in Latin America increased from U.S.$61 million in 1965 to $129 million in 1974. Nevertheless, Latin America ranked last among the world's regions in terms of research expenditures as a percentage of the value of agricultural products produced (Appendix 13). International funding for CIAT can contribute to increased total investment in agricultural research for the region, since most contributions to the Center come from sources not funding other Latin American agricultural research institutions.

Positive results from collaborative efforts between CIAT and national programs can also stimulate national planning and treasury officials to recognize the value of agricultural research and increase the funding for national research institutions. In addition, international assistance organizations, recognizing the importance of having strong national institutions to most profitably cooperate with the international centers, are increasing their loan and technical support to national agricultural research systems. CIAT's role thus becomes additive as well as stimulative and catalytic as it indirectly assists in increasing investment in agricultural research to more reasonable levels. Moreover, there are large economies of scale in research at a certain level of the research continuum. This level depends on the degree of development and self-sufficiency of national programs in each commodity. Avoiding unnecessary duplications in many small programs certainly will allow for a more cost-effective utilization of the total limited resources available.

While there are understandable pressures for national institutions to spread their research efforts over a broad range of export, plantation and food commodities, the international centers concentrate on basic foods and, because of the division of labor among individual centers, have the luxury of devoting their efforts to only a few commodities. Thus by working on only a few crops, CIAT can make more rapid progress in developing technology for these commodities. By demonstrating the usefulness of concentration of research efforts, it also can help national programs establish clearer priorities and thus avoid the dangers of overdiversification.

Building Human Capital

Insufficient qualified manpower is one of the most serious limiting factors in development of new technology. Data in Appendix 14 support the belief that Latin America has a low level of human resources available for research and extension, in relation to the value of agricultural products produced. Major responsibility for multiplying trained agricultural scientists continues to lie with universities in the region. Providing scholarships for advanced degree training should remain the responsibility of national programs, with the support of donor institutions. CIAT has a comparative advantage in providing postgraduate training in specialized commodity areas and helping increase the available human resources in these particular areas. By stimulating better support and prestige for agricultural research, CIAT can also be a catalyst in improving working conditions and remuneration to help check the migration of workers from the public agricultural research sector.

Stimulating Better Orientation of Research and Training

Some research institutions, particularly universities, emphasize academic, publication-oriented disciplinary research. This affects the orientation and quality of professionals trained in these institutions. As a center of excellence emphasizing problem-solving, production-oriented, interdisciplinary research, CIAT can demonstrate that practical research is also highly stimulating and intellectually rewarding. By collaborating closely with Latin American universities, especially in the area of thesis research for advanced degrees, CIAT helps encourage orientation towards applied research in these institutions and in the professionals they produce.

Strengthening the Links between Research and Extension

Agricultural research and extension are well integrated in some Latin American countries. In many countries, however, these activities developed separately and continue to operate independently. While CIAT is not actively engaged in agricultural extension, its emphasis on collaborative activities with national institutions for on-farm evaluation, its training of extension specialists in selected commodities, and its collaboration with national programs in developing in-country training, can help bridge the gap between these two important functions. Farm-level research to evaluate technology will continue to receive attention within CIAT commodity programs. Wherever possible CIAT will encourage this activity and assist in training national personnel for farm-level research. This will provide an excellent means of integrating the activities of research and extension.

3

CIAT in Perspective

The agreement between the Colombian government and The Rockefeller Foundation to found CIAT was dated May 12, 1967. The first meeting of the Board of Trustees was held on October 17, 1967. The official Colombian government decree established CIAT as an institution on November 4, 1967. CIAT's headquarters facilities were dedicated on October 12, 1973, when its Core senior staff numbered thirty-nine (about one-half of today's figures). A large portion of CIAT's current program activities began less than ten years ago.

The institutional accomplishments made since CIAT's inception have been fundamental to the Center's research and training achievements and were especially important in establishing the basis for this long-range plan for the 1980s. These institutional accomplishments relate to sharpening the program focus and developing policies, facilities and institutional relationships.

EVOLUTION OF CIAT'S MANDATE

The Original Broad Base

The success in the mid-1960s of the International Rice Research Institute (IRRI) in the Philippines and of the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico, together with the pending establishment of the International Institute for Tropical Agriculture (IITA) in Nigeria, prompted the Ford and Rockefeller Foundations to consider the problems of the tropics of Latin America. Dr. Lowell S. Hardin, of the Ford Foundation, and Dr. Lewis M. Roberts, of The Rockefeller Foundation, were commissioned by their foundations to study jointly the problems of agricultural productivity in that region and to recommend a course of action. Their study resulted in an October 1966 document, "A Proposal for Creating an International Institute for Agriculture Research and Training to Serve the Lowland Tropical Regions of the Americas." The document, hereinafter referred to as "the original proposal," commented on the variety of ecological zones of the Latin American tropics and divided the region into three classes:

(a) Favorable – these areas have unexploited potential and include the northern coastal plains of Colombia, the Caribbean and Pacific littorals of Mexico and Central America, the Pacific coast of Ecuador and eastern Andean slopes at altitudes between 500 and 1000 meters, from Venezuela to Bolivia;
(b) Unfavorable – the hot humid jungles of the Amazon and Orinoco basins and the Colombian Pacific coast; and,
(c) Unclassified – the central plateau of Brazil and the Llanos of Venezuela and Colombia.

The original proposal also identified high priority problems for the future institute's attention. The following section discusses this extensive list of commodity and production system responsibilities in relation to subsequent modifications. That report also stated that "the proposed institute would follow in many respects the successful International Rice Research Institute model," but then added, "the Latin American Institute would not be concerned with a single crop or enterprise. It would concentrate on the identification and solution of tropical crop and livestock production and distribution problems and on the training of people in a problem-solving research and educational environment."

Thus, the concept of the institute seemed to embrace both ecological and multi-commodity bases. However, it is also apparent that the authors recognized the complexity of an ecological mandate and opted for a set of commodities as the means of advancing agricultural productivity within the ecological zone.

Following the establishment of CIAT and appointment of its first Board of Trustees, the Center's program scope and operational philosophy were defined in greater detail by the management and the Board. Initially, this resulted in some expansion of the scope of activities set forth in the original proposal. Thus, CIAT's early development evolved from a broad foundation of development goals and commodity responsibilities set within geographical and ecological boundaries. This provided the base on which the Center could, with experience and further studies, build a solid, focused program.

Refinement of the Mandate

CIAT's development has been characterized by a progressive refinement of its objectives and scope of activities. As a result, CIAT has markedly reduced the number of commodities researched, clarified and sharpened program strategies and priorities and narrowed the geographical and ecological foci of its programs. Modifications of program responsibilities suggested in the original proposal are summarized in Table 4. Current objectives and strategies are outlined in Chapter 4.

Major redefinition of programs has not come about easily nor capriciously. Although the actual changes have been important, equally important has been the evolution of the interactive process among cooperating institutions, Center staff and management, and the Board of Trustees in making policy decisions.

Mechanisms for Program Review and Modification

Program Committee of Board of Trustees.

The Board of Trustees established a standing committee in 1974 to advise the Board on Center programs. Specifically, the Program Committee was charged with advising the Board on broad problems of research strategies and research requirements, particularly staffing as it affects the budget.

Participation by Lesser-Developed Countries.

The views of the scientists and policymakers in cooperating institutions of the countries CIAT serves are vital in the development of the Center's policies and operational procedures. Over the years various mechanisms have been developed to facilitate this essential input. Primary procedures include:

(a) Board membership. A majority of members of the CIAT Board of Trustees is from tropical, developing countries, especially Latin America.

(b) Senior staff selection. Nearly one-half of CIAT's senior staff are citizens of tropical, developing countries and have intimate knowledge of production problems and requirements of lesser developed countries.

(c) Consultation travel. CIAT staff travel extensively in the course of their work and consult frequently with colleagues on research priorities and government policies.

(d) Policy-level consultation. Leaders of cooperating institutions are invited to CIAT seminars in which they discuss ways that CIAT can improve the effectiveness of its technology generation and international cooperation activities. Two basic types of seminars are:

TABLE 4.
Major developments in the program mandate of CIAT.

Recommendations of the original proposal	Subsequent developments
1. Top priority to be given to one or more grain legume crops such as soybeans, beans, cowpeas and pigeon peas.	1. Decision made to direct all efforts to the common bean, *Phaseolus vulgaris*
2. "Corn and rice are of primary importance and should be investigated cooperatively with CIMMYT and IRRI, respectively, with the institute serving as a headquarters for collaborative work."	2. Original Maize Program dissolved in favor of collaborative work with CIMMYT whereby CIAT would host a CIMMYT team to assist national programs in developing and transferring maize technology in the Andean zone. IRRI stationed a liaison scientist at CIAT to work in the Rice Program and coordinate International Rice Testing Program activities in Latin America. IRRI and CIAT agreed that all their rice activities in the region would be conducted in close collaboration.
3. "Livestock work would concentrate on ruminants with emphasis on study and prevention of diseases; nutrition; forage production, and the economics of various systems of husbandry under tropical conditions."	3. Non-ruminants were added by the startup of a Swine Program in 1969. In 1975 the CIAT Board considered that the research component of this program had achieved its objectives, the staff was reduced to concentrate on technology transfer work. This was successful and the program phased out at the end of 1979. After input from several external reviews and position papers, the Board decided to restrict the geographic/ecosystem scope of the Beef Program to the acid, infertile soil regions of Latin America, with major emphasis on developing improved, legume-based pastures for this area. The program was renamed the Tropical Pastures Program
4. "The institute should look further to the development of proper cropping patterns or systems of rotation."	4. In 1973 the Agricultural Systems Program (later Small Farm Systems Program) was established to analyze farming systems in order to facilitate the rapid adoption of improved technology. After a special workshop in 1975, it was agreed that responsibilities for incorporating commodity technology into farming systems should rest with each commodity program. Accordingly, these recommendations were accepted: (a) that the Small Farms System Program be phased out, (b) that an economist and outreach agronomist be added to each of three programs (cassava, beans and beef); and, (c) an Agricultural Production System Coordination Group be created to oversee those inter-related studies outside the responsibility of any commodity program. The TAC Stripe Review of Farming Systems Research endorsed this decision in 1978, and stated that farming systems research was indeed active within the CIAT commodity programs which were essentially developing components for whole farm systems
5. "Additional crops or categories of crops that are important and may receive additional attention are root crops (cassava, yams and sweet potatoes); vegetables; tropical fruits (plantains and citrus fruits	5. From this range of possible commodities the decision was made that CIAT would concentrate all efforts on a single root crop, cassava

(1) Seminars on advances in research—in which the CIAT programs present their results and plans and seek suggestions for changes; and

(2) Special topic workshops—such as a 1977 meeting on rice. Rice research leaders from throughout tropical America were invited to advise the Center on its future Rice Program activities; the recommendation that CIAT begin work on upland rice came from that workshop.

(e) Program-level consultation. In order to give cooperators an important voice in designing and planning cooperative testing and CIAT program strategies, each commodity program organizes periodic workshops with cooperators in testing networks or with cooperators on specific research topics.

CIAT Staff and Management Involvement

Priority setting and program planning are daily activities of Center staff. These ideas are formalized in the biennial program and budget proposals. Two activities relating to the interaction of Center staff and the Board of Trustees merit special mention.

(a) Annual program review. This is basically an internal, peer review at which all senior staff discuss results and plans of all programs. CIAT encourages very frank, constructive and critical discussion at the reviews in which the Program Committee of the Board also participates.

(b) Position papers. The Board of Trustees has frequently requested the Center's management to present a position paper when faced with policy decisions involving CIAT's program activities. These are normally drafted by the program concerned and then submitted to peer review at an internal workshop. Sometimes an external review or a special workshop with outside consultants is used to help define positions. Finally, management presents the position paper to the Board, normally through the Program Committee.

INSTITUTIONAL DEVELOPMENTS

Program Organization

Initially the Center's research activities consisted of commodity programs staffed by personnel organized in disciplinary groups, with an individual scientist's time often budgeted in several programs. After several management and budgetary steps, the staff is now organized so that program scientists operate entirely in one commodity; management of each multidisciplinary commodity team is clearly the responsibility of the respective Program Coordinator. The Center's training activities have been integrated more fully into the various commodity programs. These changes are described in more detail in Chapter 6.

Administrative Organization

Several adjustments in the organizational structure have been made to accommodate various program changes and the growth of the Center. Research, training and support activities currently are organized within three directorates: Crops Research, Land Resources Research and International Cooperation. Administrative and financial functions are managed by the Executive Officer and Controller, respectively. These five principal officers are directly responsible to the Director General. More details of the current organizational structure are illustrated in Appendix 15.

Institutional Linkages

The development of strong collaborative institutional relationships was an important achievement in CIAT's formative years. Because it would be ineffective for CIAT to act alone, cordial and productive relationships—both formal (through various signed agreements) and informal—have been developed with national programs throughout Latin America, with regional and international organizations and with sister centers. The relationships and understandings developed through these agreements, together with mutual respect, form an essential foundation for the success of CIAT activities in the years ahead.

Infrastructure Development

Headquarters Facilities

CIAT's headquarters and its main research farm are located near Palmira (about 20 kilometers from Cali) on a 522-hectare parcel owned by the Instituto Colombiano Agropecuario (ICA), the national agricultural research and extension agency in Colombia. The land was leased initially to CIAT at no cost for ten years from July 1970 to July 1980. ICA and CIAT's management signed a new agreement in May 1980, extending the use of the facilities to the year 2000. CIAT began its activities on this station using the original dairy farm building as temporary facilities. On October 12, 1973, the new physical plant was dedicated. This consisted of the administration building, library/documentation/information building, training and conferences complex (including conference rooms, classrooms and seminar rooms, amphitheater, conference and reception area, offices, housing modules for trainees and conference participants, and kitchen, cafeteria and dining room facilities), two research laboratories, a field laboratory, motor pool, genetic resources building, and experiment station improvements (including fencing, drainage and irrigation ditches).

Even at that time it was recognized that these facilities were inadequate for the projected program levels. Since then, facilities originally omitted because of budgetary constraints and additional facilities required by program expansion have been built. These include an additional field laboratory, two office buildings, warehouse and purchasing offices, four greenhouses and associated headhouse facilities, farm equipment storage and maintenance facilities, seed processing and teaching facilities and a communications building.

Substations

From the beginning the Palmira farm was recognized as being an excellent site for CIAT headquarters and some limited field research activities. On the other hand, the area's soils, altitude and climate are not typical of most of Latin America's tropical agricultural area. It was also clearly understood that no one location could possibly represent the great diversity of environmental conditions in the region. It was anticipated initially that ICA's Turipana station in Monteria (northern Colombia) would serve as a major auxiliary site for work requiring more tropical conditions. However, subsequent experiences and program changes made it necessary to develop modest substation facilities in two specific ecosystems and to perform a major portion of other research activities on several ICA stations representing various ecosystems. The two substations developed to meet various specific needs are:

(a) *CIAT-Quilicaho.* This 189-hectare farm located 40 kilometers south of Cali has highly infertile, acid soils where much of the preliminary screening of germplasm (especially cassava and forage species) for these soil conditions is carried out. Various plant nutritional studies, which cannot be performed on the more fertile land at CIAT headquarters, are conducted here.

(b) *CIAT-Popayan.* This station, about 100 kilometers south of Cali, is at a higher altitude (1700 meters), receiving high rainfall. The site provides excellent conditions to screen beans, and to a lesser extent cassava, for diseases which cannot be adequately tested at the lower altitude of CIAT headquarters.

These two substations, fully operated by CIAT, are on land specifically purchased for research purposes and leased to CIAT at nominal rates by the Fundacion para la Educacion Superior (FES), a Colombian non-profit development foundation.

Cooperative Activities on ICA Stations

Colombia was a fortunate choice for CIAT's location because the country has a broad range of altitude and rainfall conditions. These make it possible to conduct research under the various ecological conditions found in Latin America without crossing national boundaries. It is also fortunate for CIAT that the host agricultural institute, ICA, is very cooperative. Through two specific cooperative agreements CIAT conducts much of its work under the varying ecological conditions of several ICA stations, particularly the following:

(a) ICA-Caribia, on Colombia's North Coast – cassava research for the tropical lowlands.

(b) ICA-La Selva, at 2200 meters, near Medellin – climbing beans for intermediate altitudes.

(c) ICA-Obonuco, at 2710 meters, near Pasto – bean research for high altitude conditions.

(d) ICA-Libertad, in the Colombian Llanos near Villavicencio – rice research particularly for favored upland conditions.

(e) CNIA, Carimagua, a 20,000-hectare station in the Colombian Llanos. This station is of vital importance to the Tropical Pastures Program and also is important to the Cassava Program, since both place strong emphasis on developing technology for highly acid, infertile savanna regions of the frontier. This work, of course, cannot be done at CIAT-Palmira. In Carimagua, CIAT and ICA have a unique arrangement in which most experiments are considered to be collaborative. The station is administered jointly by ICA and CIAT; the station director is an ICA appointee, and the station superintendent is a CIAT employee. Administrative policies for the station are made by a special joint committee consisting of three members from each institution.

Cooperative Research Activities in Brazil

The largest component of the Tropical Pastures Program's area of interest, i.e., the acid, infertile frontier regions, is the well-drained savanna ecosystem represented by the Campo Cerrado of Brazil. Through a cooperative arrangement with the Cerrado Agricultural Research

Center (CPAC) of the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), CIAT has stationed three of its Core senior staff of the Tropical Pastures Program at CPAC, in Brasilia. The work of these scientists is considered an integral part of the EMBRAPA research program but also has application beyond Brazil's borders.

TECHNICAL ACHIEVEMENTS

A long-range planning document is not the appropriate place to describe the many technical achievements accomplished in the Center over the years. Nevertheless, it is desirable to give a general overview of the progress of CIAT's programs, to better understand what these programs will be doing in the future and to estimate their accomplishments at the end of the decade.

While technology other than new crop varieties forms an important part of the output of the international agricultural research centers, the development of new varieties is the best understood. It also illustrates the sequence of activities related to generating and delivering technology.

The first phase of the sequence in which the international center is involved deals with accumulating germplasm accessions. Selections from the germplasm collection, a great amount of which comes from national crop improvement programs, often are distributed through international testing networks while the time-consuming process of hybridization is going on. The initial impact of an international center's crop improvement programs may well be through distribution of materials others have developed or selected. With time, however, the impact of the Center's breeding program should become evident. Since the intensity of the selection and testing activities is usually the highest that has ever been applied to that species, it is only to be expected that eventually the best varieties appearing in international testing should come from breeding programs of the international centers. However, as national programs develop their research capacities and establish strong cooperation with the international centers, these programs are in an increasingly better position to develop varieties that are superior under local conditions and that compete strongly in international testing networks.

The entire process from germplasm collection to releasing finished varieties by national programs is a long one, requiring at least six years for beans, and nine years for cassava and forage species. Rice and Tropical Pastures (formerly Beef) Programs began when CIAT was founded, with one and seven senior scientists, respectively. The Cassava Program began in 1972 with one senior scientist, and the Bean Program, in 1973 with three senior scientists. It is, therefore, somewhat early to expect the results to be affecting national production statistics. Dramatic production increases have been achieved in rice, where CIAT was able to build on the earlier program of IRRI and ICA's rice research. While the other commodities have not yet significantly increased national production levels, there have been substantial developments in problem assessment, germplasm accumulation, parental selection, progeny testing and methodology development. These developments are described in greater detail in Chapter 5. The remainder of this Chapter very briefly summarizes the accomplishments in the germplasm accumulation and technology transfer/adoption components, in order to illustrate the stage of each program and to give perspective to future plans and expectations.

Germplasm Collection and Preservation

The assembly of a large germplasm base is not only an essential first step in any plant improvement program but also an important responsibility in the preservation of valuable genetic resources. Within the CGIAR system CIAT has been given global responsibilities for the collection, evaluation, preservation and distribution of germplasm in cassava, beans and tropical forages. As of early 1981, the number of accessions in CIAT's genetic resources unit were: cassava, 2600; beans, 30,000; and tropical forages, 7250.

Technology Transfer and Adoption

Rice

- Average yields in twenty Latin American countries increased from 2.0 t/ha in 1967 to 3.2 t/ha in 1978, due mainly to new varieties developed at CIAT and IRRI, in collaboration with national programs.
- In Colombia the national average yield of irrigated rice has risen from 3.0 t/ha in 1968 to 5.2 t/ha in 1980.
- Eight countries have named twenty-nine new varieties using eight different finished lines received from CIAT, and six countries have named twelve varieties from selections derived from advanced CIAT breeding lines.

Cassava

- Improved agronomic practices developed at CIAT have been shown to double yields in farmers' fields in more than fifty regional trials conducted in six years in Colombia. These practices have now been adopted on state farms and by farmer associations throughout Cuba.

This dramatic increase in production caused cassava to be removed from the list of rationed foods in that country.

- Twelve countries are using CIAT materials in their own breeding programs.
- Eleven countries are increasing vegetative planting materials of varieties received from CIAT for distribution to farmers.
- Ten countries are using a technique developed at CIAT to rapidly multiply limited amounts of vegetative material for distribution to growers.
- Seven countries have established facilities to receive CIAT's hybrids as meristem tissue cultures to minimize disease hazards during the international movement of vegetative material.

Beans

- Since the international testing program began in 1976, some thirty countries have received a total of 150 individual bean nurseries for testing. These nurseries initially consisted entirely of varieties developed by others and selected for the CIAT germplasm collection. Now, over 90% of the materials in nurseries are CIAT-bred lines (the materials included in the nurseries are selected after being rated superior to all other materials in extensive tests).
- Seven countries have named a total of eleven varieties based on finished varieties or selections from advanced breeding lines received from CIAT. Six of these varieties already are being grown by farmers in four countries.
- The most popular local varieties from various countries have been crossed with parents that provide genes for resistance to major diseases and insects in the respective countries, as well as other desirable characters. After many generations of selections, advanced lines that combine disease and insect resistance and improved yield with seed color and size preferences of most bean-growing regions in Latin America are now available for use in national bean improvement programs.

Tropical Pastures

- *Andropogon gayanus*, a grass of African origin selected for use in Latin America by CIAT, has now been named as a new cultivar in Colombia and Brazil. It is highly tolerant to acid soils, low soil fertility, drought, insects and diseases. CIAT provided eight tons of basic seed for multiplication in those countries and also supplied seed to Venezuela and Panama for advanced testing.

- Several forage legume accessions collected and selected by CIAT have reached advanced stages of testing in Colombia and Brazil. Because of the growth habit of *A. gayanus* and the nitrogen fixation ability and higher protein content of legumes, a much greater impact is expected when *A. gayanus* is used with legumes. Several years of grazing trials of selected grass/legume associations over the best-managed native savanna have demonstrated a ten- to fifteenfold increase in liveweight animal gains per hectare and a two- to threefold increase in per animal productivity.

Part II

The Action Plan

4

Objectives and Strategies for the 1980s

STATEMENT OF OBJECTIVES

To generate and deliver, in collaboration with national and regional institutions, improved technology which will contribute to increased production, productivity and quality of specific basic food commodities in the tropics—principally countries of Latin America and the Caribbean—thereby enabling producers and consumers, especially those with limited resources, to increase their purchasing power and improve their nutrition.

This statement was developed to provide a condensed overview of CIAT's philosophy and operating objectives. While the Center expects to be flexible in responding to future needs for agricultural production technology, the statement's points should be applicable over future years. Features of the objectives statement are explained more fully in this chapter.

Technology Development Orientation

CIAT plans to continue concentrating on the generation and transfer of agricultural technology. This does not negate the importance of institutional, social and political changes, but does imply a confidence that modern science and technology can contribute significantly to solving food production problems.

Collaborative Nature of CIAT's Activities

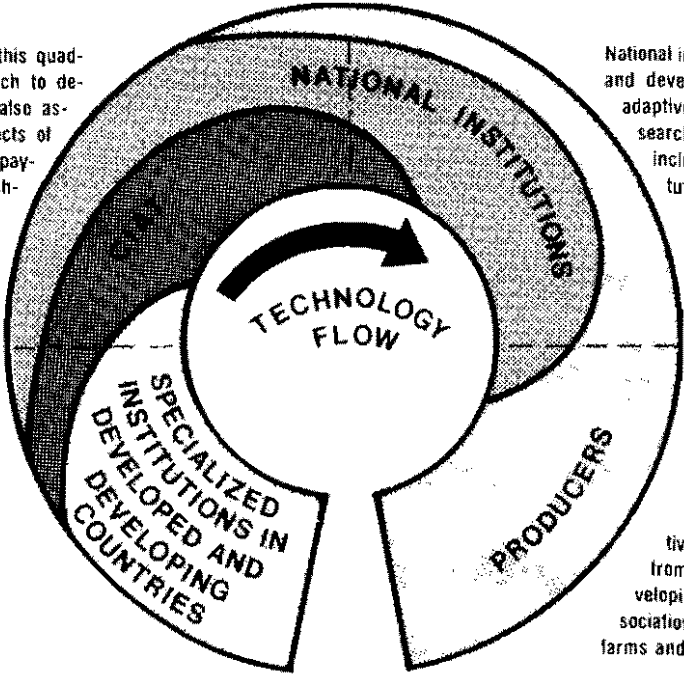
The objectives statement emphasizes the Center's strong conviction that accomplishing the desired results involves the collaboration of national, regional and international agencies, of which an international agri-

APPLIED RESEARCH

CIAT's activities are primarily found in this quadrant. While emphasizing applied research to develop basic elements of technology, it also assumes responsibilities for selected aspects of basic research having high potentials for payoff later in the development of new technology.

ADAPTIVE RESEARCH

National institutions involved in commodity research and development are seen as conducting mostly adaptive research based on their own applied research or the technology developed by others including international centers. National institutions, and especially those more developed ones, also engage in some basic research. At the same time, they are involved in selected production activities including on-farm trials, demonstration projects and certified seed production.



BASIC RESEARCH

PRODUCTION

While predominantly working in production *per se* to varying degrees producers also conduct applied and adaptive research. Their research activities range from the private seed producer who is developing new hybrid varieties to producer associations which maintain their own experimental farms and stations.

Figure 1 CIAT's location in the agricultural technology development process cultural research center is but one. Figure 1 displays the agricultural technology development process as four successive but interrelated stages–basic research, applied research, adaptive research and production. It also indicates the approximate extent to which CIAT and its principal counterparts, the national institutions, are involved within the process. Given CIAT's unique place between the more basic research institutions and collaborating national programs, the Center's activities must take two directions. First, CIAT must relate its technology generation efforts to developments in basic research conducted by other institutions. Second, all of CIAT's interlocking activities, whether in research or in international cooperation, must be designed to support and supplement collaborating regional and national research/development institutions.

Geographical Orientation

The Center directed most of its efforts towards the American tropics during its first ten years. All four CIAT commodities are basic staple foods in this region. The Tropical Pastures Program has a strong ecological focus on the underutilized, acid, infertile soils of the Americas, while the Rice Program, in close collaboration with IRRI, is directed exclusively to Latin America and the Caribbean.

However, during its evolution CIAT has been given world responsibility for cassava and beans within the CGIAR system. (IITA has responsibility for cassava in Africa.) With appropriate modifications, CIAT technology for these two crops can have considerable impact outside the Western Hemisphere. Active cassava technology transfer has already begun in Asia. Results are demonstrating that CIAT technology can be very effective in increasing the crop's productivity on that continent. Cassava is important in Asia but has not been studied very much there. CIAT intends to further develop mechanisms to disseminate cassava technology in Asia. Both IITA and CIAT consider it important that their respective cassava programs work together in Africa. A mechanism for such liaison is outlined in this plan.

Eastern Africa is the most important bean production region outside of the Americas. Except for maize, beans are the most important food in many countries of that region. New bean technology is critically needed. It has been demonstrated that CIAT technology could have a very important impact on bean production in eastern Africa.

While not retreating from its global responsibility for beans and cassava, CIAT does recognize the problems of increasing international travel costs and of diluting scarce manpower resources if they operate over the world. For reasons of proximity there are also obvious advantages to developing institutional relationships chiefly in the Western Hemisphere. The centralized activities of germplasm collection, breeding and documentation will be designed to respond to the global mandates in beans and cassava. However, decentralized activities for evaluation and transfer of technology will be developed to have maximum impact while minimizing diversion of resources from the American tropics. To accomplish this, CIAT will seek imaginative, new ways of cooperating with other international or regional organizations. For example, negotiations are underway now with the Food and Agriculture Organization (FAO) for collaborative bean projects in eastern Africa and with selected regional and national organizations in Asia for cassava projects in Southeast Asia. Further details regarding regional activities outside the Western Hemisphere are described in Chapter 6.

Orientation to the Poor

Based on the prevailing socioeconomic and nutritional conditions in Latin America (described in Chapter 1), CIAT has identified limited-resource producers and consumers, that is, the rural and urban poor, as the principal beneficiaries of its work. This decision clearly associates human welfare objectives with production goals and influences the design of technology.

In developing countries of the Western Hemisphere, the two communities of low-income producers and consumers overlap much less than they do in developing countries of Africa and Asia. Approximately 60% of the population in Latin America is urban and the percentage is expected to continue to increase through the 1980s. Consequently, total food production, regardless of the producer's resources, cannot be ignored since this affects the price of food for urban consumers.

Some countries, particularly those with large cooperatives and state farms, require technology for large-scale, mechanized production. Nevertheless, CIAT must concentrate its attention on production technology specifically adapted to the needs of small holders, because a large proportion of two of CIAT's food crops (beans and cassava) are produced by that group. Development of such technology requires a sustained, concerted effort best made by a publicly funded, international institution.

GENERAL STRATEGIES

Establishing Research Networks for Inter-institutional Transfer of Technology

The linking of individual researchers and research groups through the establishment of research networks is a major mechanism for creating and maintaining research and development momentum for any given commodity. Research networks not only facilitate the exchange of information and materials between national and international levels, but also serve to transfer technology between national programs. CIAT will continue to actively maintain and strengthen commodity-based research networks through information and documentation services, germplasm exchange activities, seminars and workshops, and consultation.

Development of Germplasm-based Technology

Analyses of production constraints of CIAT's commodities have indicated that of the possible research strategies, the largest impact on production would be generated by increasing the availability of improved germplasm adapted to environmental conditions and prevailing production systems. CIAT will continue to be involved in technology generation based on the collection, production and supply of new germplasm. Also, development of non-site-specific agronomic components will continue to be coordinated with germplasm development activities.

Strengthening National Programs through Training

A central strategy of the Center since its beginning has been the strengthening of commodity research groups within national agricultural research institutions. By providing training opportunities, CIAT can make an important contribution to strengthening its national counterparts. At the same time, training provides an efficient vehicle for the transfer of improved research and production technologies.

OPERATIONAL PRINCIPLES

Certain basic principles of operation that have evolved at CIAT will guide the Center in implementing its general strategy in the 1980s.

Relevance

CIAT's mission-oriented research is directed towards solving the most important production problems of the Center's four commodities. This includes sophisticated research whose relative magnitude will increase progressively throughout the 1980s as national programs are able to assume a greater share of the adaptive research responsibilities. The success of the Center's research will always be measured by its contribution to increased food production and productivity, rather than increases in the knowledge base or academic publications.

Complementarity

The basic premise of CIAT's strategy is that it represents only one small segment of the agricultural research and development matrix. All Center activities, therefore, are viewed as complementary to those of other organizations. Linkage to other closely related activities is essential. Such activities include the following three groups.

National Research and Extension Programs

The key role of national institutions has already been discussed. The division of labor between CIAT and such institutions depends on the state of development and resources of individual national programs (see Table 9 in Chapter 6). In general, however, CIAT concentrates on those activities in which there is a clear economy of scale and in which the results have international transferability. Such activities include the assembly of large germplasm banks, large-scale screening, crossing and selection, methodology development, and documentation services. Location-specific activities, such as agronomic research, breeding and selection for specific localized constraints, and extension can be performed better by national and regional programs.

Strong national programs also will be in a position to complement CIAT's activities by conducting collaborative research of great value to other countries with similar ecological conditions and/or consumer preferences. CIAT will continue to stimulate and support such horizontal technology transfer.

Advanced Scientific Institutions

Basic research institutions, in both developed and developing countries, can do much useful work that complements and supports CIAT's more problem-solving research approach. The Center will continue to encourage other institutions to engage in well-defined, basic research having much potential applicability to CIAT's work but requiring specialized facilities and skills not available at CIAT. Such research can be done entirely at the research institution or a portion of the project can be carried out at CIAT. Because the Center receives funds designated for financing only direct CIAT operations and because such collaboration is strictly an addition to the Center's Core operations, CIAT does not finance such research with Core resources. Whenever possible, CIAT helps interested scientists secure appropriate special project funds to make collaborative research possible.

Related International Activities

Another important part of CIAT's strategy is to host activities of sister centers of the CGIAR system and related institutions, when these activities clearly complement the Center's work and fall within its overall objectives. While maintaining good relations with other institutions by making its facilities available for such activities, CIAT can contribute to the broader purpose of increased food production without diverting financial resources from its programs. Institutions working at CIAT in this way are expected to pay the full costs of their operations, although there is always some cost involved in hosting such activities. Consequently, such collaboration is developed only when it clearly complements CIAT's programs.

This strategy has been implemented up to now through hosting the CIMMYT team for maize work in the Andean region, the IRRI liaison scientist responsible for the International Rice Testing Program (IRTP) in Latin America and an International Fertilizer Development Center (IFDC) team creating technology for the efficient utilization of rock phosphates in Latin America. Possible future associations of this type may include hosting scientists from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and International Sorghum and Millet Program (INTSORMIL) who will develop sorghum germplasm for acid, infertile soil conditions, International Soybean Program (INTSOY) scientists developing soybean technology for Latin American conditions (especially the acid, infertile soils), and an IITA cowpea scientist responsible for Latin American activities.

Principles of Technology Design

CIAT's orientation towards low-resource farmers greatly influences the nature of technology generated by the Center. This orientation dictates some basic principles that help govern technology design.

Minimal Input Orientation

The benefits of new technology often do not reach the resource-poor farmer if high levels of expensive inputs are required to utilize that technology successfully. So that improved technology will meet the needs of small holders, CIAT designs technology components minimizing the need for purchased inputs and irrigation. At the same time, however, the technology should maintain high production levels at higher levels of input use. These principles address both the need to assist small farmers and to increase overall food production.

CIAT's concern for minimal input technology is closely allied to a strong concern for energy conservation. As rising petroleum and natural gas prices increase the costs of irrigation, farm mechanization, fertilizers and chemicals, it is imperative that new technology minimize dependence on high-energy inputs. CIAT attacks the problem by developing: (a) germplasm resistant to such constraints as insects, diseases, adverse soil conditions, and drought; (b) germplasm that is more efficient in the uptake and/or utilization of soil nutrients and in utilizing applied fertilizers; and, (c) bean and pasture legume germplasm with improved nitrogen fixation capabilities.

Technology Component Orientation

As an international research organization working through national agencies, CIAT does not aim to produce finished technology for specific ecological and socioeconomic conditions and quality preferences. Rather, CIAT emphasizes the development of basic technology components such as an improved germplasm base, research methodologies for identifying optimal management practices and methodologies for developing single- and multiple-crop systems. National programs can use these components as needed to build relevant production systems that are viable and socially acceptable for local conditions. To this end program scientists become as familiar as possible with the whole-farm systems to which such technology components will contribute.

Due to environmental and socioeconomic constraints, production systems for each of CIAT's commodities vary throughout the region. CIAT attempts to develop technology components that are applicable to various climatic and socioeconomic conditions. When this is not possible, technology components are developed that are specific to a given ecosystem and/or a given set of broadly defined socioeconomic conditions. Whereas such research is an integral part of the Center's technology development efforts, research on production factors that are more site-specific is not a legitimate concern of CIAT but the responsibility of national programs.

Evaluation and Feedback Mechanisms

Technology designed and tested only on experiment stations is not finished technology. There is no assurance that any given technology package is useful until it has been validated under farm-level conditions and constraints. On-farm testing is, therefore, an integral component of the technology generation process. Because results of such work are usually very location-specific, CIAT depends on and encourages national agencies to evaluate new varieties and practices regionally, to modify them to meet local requirements, and to test the resulting technology systems under farming conditions representing the greatest number of producers and conditions. However, CIAT considers it vitally important to actively collaborate with selected national and/or local agencies in the regional testing and on-farm validation of improved technology packages involving CIAT commodities. In these collaborative projects CIAT's role normally is restricted to providing materials, information, and assistance for the design and evaluation of the farm-level research results. Such regional testing and on-farm validation serve as vital sources of feedback influencing CIAT's technology design.

Limits to CIAT Involvement

Because CIAT has neither the comparative advantage to evaluate and adapt new production technology in varied local socioeconomic and ecological conditions nor the resources to move effectively beyond the national level, it will continue to limit its direct technology transfer to national research programs. This implies that CIAT will not become directly involved in technology transfer at the farm level.

CIAT recognizes that improved agricultural productivity depends on the availability of viable production technology as well as the availability of inputs and favorable marketing conditions. National agricultural research policies and policies regarding incentives for technology development and adoption are strictly within the decision-making domain of individual countries. CIAT will continue to limit its role in these areas to providing appropriate forums so that national policymakers can fully explore the consequences of alternative policies. However, aside from advocating the need for strong national research organizations, CIAT will continue to abstain from advocating national policy options.

5

Commodity Program Strategies and Projections

CIAT's various commodities were analyzed in Chapter 1 in relation to the socioeconomic conditions in developing countries of the Western Hemisphere. It is clear from that analysis that rice, beans, cassava and pastures (i.e., beef) are important in the region. This importance is the basis for CIAT's involvement in these commodities.

A basic concept of CIAT's long-range plan is to increase productivity of its commodities through research in traditional areas of production while also helping develop stable, productive systems for the agricultural frontier. CIAT research in cassava and upland rice is directed towards this dual objective. Bean and irrigated rice research at CIAT is oriented more towards traditional areas and their margins, although limited irrigated rice areas are being developed in frontier situations by some countries. The development of improved tropical pastures with associated livestock management components for acid, infertile soil conditions is directed towards the agricultural frontier.

CASSAVA PROGRAM

Cassava, the fourth most important food energy crop in tropical developing countries, is a significant source of calories in the daily diets of over 500 million people in twenty-six tropical countries. In many countries dried cassava is by far the cheapest source of calories, making it especially important for the poor. Per capita consumption of fresh and dried cassava products tends to be high among the poor, climbing as incomes rise among the lower-income strata and then declining in the case of dry cassava products in the high-income groups. Since the crucial nutritional deficiencies in most low-income countries are calories, cassava is particularly important. Lower cassava prices will benefit principally the lower-income strata by helping to improve their nutrition.

Although cassava is relatively low in protein, it can help augment protein availability when used as an energy source in animal feed. Intensive livestock production systems in developing countries have created a strong demand for feed grains. In some cases, the concentrate industry and the human food sector compete for sources of calories and protein. Increases in demand for meat may tend to divert resources that could go to producing other basic foods. Animal feeds based on cassava could greatly reduce this competition because unused marginal land – which cannot support many other crops – can produce cassava.

Despite the rapid growth of sorghum production, domestic supply of feed grains often has been unable to meet demand. Many poorer countries have been forced to increase imports of feed grains or suffer upward pressures on the price of animal feeds. The resulting increase in the cost of meat tends to put it out of reach of the very poor. Production of cassava with underutilized domestic resources could promote employment, alleviate the burden of costly imports and contribute to maintaining a supply of cheap animal protein.

The development of alternative markets, such as animal feed, should help to stabilize the cassava market by creating a floor price. This should encourage farmers to adopt new production technology, without fear of saturating the market and causing disastrous price drops. Increased productivity should allow the farmers to maintain or increase their incomes while increasing the supply of cassava at low cost for human consumption.

The need to stabilize markets through alternative uses is of particular importance in Latin America. The demand situation in that region is described in detail below. In both Indonesia and southern India, cassava is second only to rice as a caloric source. In Thailand cassava is a major export crop, and in other areas of Southeast Asia it has the potential to become a major source of cheap calories. The production and demand situation in Asia is not as well quantified as that in Latin America. With the appointment of regional cooperation staff for Asia, a more complete analysis of the situation will be made. CIAT's activities in Asia and its cooperation with IITA in Africa will also ensure that the Program's main thrust is related to cassava as a staple food.

Production and Demand Situation in Latin America

Cassava has always been a traditional caloric source in tropical Latin America. Cassava has several key characteristics making it well suited for traditional agricultural systems: (a) high efficiency in the production of carbohydrates; (b) adaptation to soil and water stress; (c) an indeterminate harvest period; (d) high yields per unit of land and labor; and, (e) compatibility with a variety of crops in association. Because cassava fits well into small farm systems, it has been a major staple in rural areas of the lowland tropics of Latin America and in some Caribbean countries.

As Latin America urbanizes, the importance of cassava for direct human consumption will depend on its marketability and competitiveness with other caloric staples. Cassava's high perishability after harvest, its bulkiness and its low commercial value by weight result in high marketing margins and post-harvest losses. Whether low production costs can be converted into competitive urban prices depends on the efficiency of the marketing process. In most urban areas fresh cassava is more expensive than the principal grain staples, primarily because marketing margins are as much as 300% of farm-level prices. Where cassava goes through a processing stage before marketing, as in Brazil, the dried product is generally the cheapest caloric source available in urban areas. Thus in Latin America, cassava is a major caloric source in national diets only in Brazil, where most of the cassava is eaten in processed form, and in Paraguay, where most of the population is still rural. Cassava will continue to be a staple in rural areas throughout the lowland tropics.

A strategy to increase the incomes of small-scale farmers through the development of new cassava technology is constrained by limited demand for cassava as an urban food, except in Brazil. As a carbohydrate source with a low unit production cost, cassava has the potential to enter alternative markets, as a wheat flour substitute (suitably enriched), as a carbohydrate source in feed concentrates, as the raw material in ethanol production, and as an industrial starch. Major expansion in demand in either the fresh urban market or the industrial markets depends on the relative price of cassava. If cassava is to be competitive in industrial markets in most Latin American countries, its price must be reduced. Lower unit production costs, and thus cheaper prices for cassava, can be best achieved by applying new technology. Historically, there has been little research on the crop; a great potential exists to increase yields from their present average of 12 t/ha in Latin America. On the other hand, introducing improved cassava production technology without complementary processing technology could saturate traditional markets, resulting in decreased farmer incomes. Research on cassava production technology clearly must be linked to research on processing technology.

Production Systems and Constraints

Cassava, with its many mechanisms for stress tolerance, can be grown under a range of edaphic and climatic conditions. However, this very broad ecological range severely complicates germplasm improvement, especially because a very marked genotype x environment interaction exists. The ecological conditions under which cassava is grown can be divided into six major ecosystems (Table 5). The lowland tropical ecosystem with a pronounced dry season (ecosystem 1) is the most important in terms of production; about one-half of total world production occurs under these conditions. The acid soil savannas (ecosystem 2) and the hot humid lowland tropics (ecosystem 3) are not major production areas but have much potential. Expansion of cassava production in these areas is already occurring in Brazil, Mexico, Indonesia and Malaysia. The highland tropical areas (ecosystem 5) and the intermediate altitude tropical areas (ecosystem 4) of Latin America are presently least important. In Africa, potential for expansion in these ecosystems is great. High-yielding clones well-adapted to this ecosystem are not yet available in Africa but exist in the Americas. Approximately 30% of total cassava production in the Americas occurs in the subtropics (ecosystem 6); worldwide, 15-20% of the cassava is produced in this ecosystem.

Each ecosystem is defined by climatic and edaphic parameters and unique insect and disease complexes are associated with each one. These interactions between cassava pathogens and environmental factors are summarized in Table 6.

There are numerous cassava production systems. They range from the slash-and-burn system of the Amazon jungle, to planting cassava as an introductory crop when colonizing new lands, to the small-farm, multi-crop systems typical of most cassava production. The crop is labor intensive, requiring 80-120 man-days per hectare. Cassava is often grown in association with a legume or maize. It is frequently used as the last crop in a rotation, as the farmer maximizes its adaptation to infertile soil conditions. Purchased inputs are rarely used because generally it is very expensive to control pathogens in such a long-season crop, and soil fertility is usually managed through fallowing systems.

Evaluation and selection of cassava clones have been done for centuries by farmers across a wide range of agroclimatic conditions. Most traditional clones are relatively well-adapted to the stress factors found in the area in which they are grown. However, the narrow germplasm base in such a localized situation limits the varietal development process.

There are few systematic breeding and selection programs for cassava.

TABLE 5.
Cassava production ecosystems and their main characteristics.

Ecosystem	General description and representative areas	Mean temperature	Dry season duration	Annual rainfall
1	Lowland tropics with long dry season; low to moderate annual rainfall; high year-round temperature. Areas: North Coast of Colombia; southern India; northeastern Brazil; northern Venezuela; Thailand; sub-Sahelian Africa	above 25°C	3-5 mo	700-2000 mm (unimodal distribution)
2	Acid soil savannas; moderate to long dry season; low relative humidity during dry season. Areas: Llanos of Colombia and Venezuela; Cerrado of Brazil.	above 25°C	3-5 mo	above 1200 mm (unimodal distribution)
3	Lowland tropics with no pronounced dry seasons; high rainfall; constant high relative humidity. Areas: Amazon basins of Brazil, Colombia, Ecuador and Peru; rainforests of Africa and Asia	above 25°C	absent or very short	above 2000 mm
4	Medium altitude tropics; moderate dry season and temperature. Areas: Andean zone of Colombia; Costa Rica; Bolivia; Brazil; Africa; the Philippines; India; Indonesia; Viet Nam.	21-24°C	3-4 mo	1000-2000 mm (bimodal distribution)
5	Cool highland areas; moderate to high rainfall. Areas: Andean zone; highlands of tropical Africa.	17-20°C	–	above 2000 mm
6	Subtropical areas, cool winters; fluctuating daylengths Areas: Cuba; northern Mexico; southern Brazil; Paraguay; northern Argentina; southern China; Taiwan.	Minimum 0°C	–	above 1000 mm

TABLE 6.
Some major production constraints in different cassava growing ecosystems.

Ecosystem	Major constraints					
	Rainfall	Temperature	Diseases	Insects and Mites	Fertility/Soils	Others
1 Lowland tropics with long dry season (ICA-Caribia)[a]	3-5 month dry season	–	Anthracnose; pathogens of planting material	Mites (*Mononychellus*); thrips; hornworm, whiteflies	Usually low soil fertility	Sandy soils with limited water retention, low root starch content
2 Acid soil savannas (ICA-Carimagua)	3-5 month dry season, relative humidity near saturation during rainy season	Fluctuations enhance disease severity	Cassava bacterial blight, anthracnose, superelongation; Cercospora brown spots	Mites (*Mononychellus*) thrips, lacebugs; stemborers	Acid, infertile soils; aluminum toxicity	Drought stress
3 Humid lowland tropics (ICA-Florencia)	Soil water saturation	–	Cercospora brown spots, root rots	Mealybugs	Acid, infertile soils; aluminum toxicity	–
4 Medium altitude tropics (CIAT-Palmira)	3-4 month dry season	–	Root rots; Cercospora brown spots	Thrips, hornworm	–	–
5 Highland tropics (CIAT-Popayan)	Variable	Cool, 17°-20°C year-round	Phoma leaf spots, anthracnose; Cercospora white spots	Mites (*Oligonychus*)	–	–
6 Subtropics	Variable	Cold winter, with 3 months below 10°C	Anthracnose	Hornworm	–	Limited harvest period; drought

a Location in each ecosystem of CIAT's main research activities in Colombia

Very few improved varieties have reached farmers from existing programs. Yields of 80 t/ha under experimental conditions, in comparison with average farm yields of around 10 t/ha, suggest tremendous potential for raising farm productivity, through the development of higher-yielding varieties that give stable yields under stress conditions. The availability of such varieties is even more necessary as cassava moves from traditional to more intensive production systems.

Scientific breeding and selection methodologies for cassava are complicated by variations in production conditions, stress conditions under which the crop is usually grown, and limitations on purchased inputs due to the limited resources of traditional cassava farmers. Cassava's adaptation to relatively marginal agricultural areas, its long crop cycle and its low value suggest that it will not compete with higher value crops on prime lands. Its comparative advantage, therefore, is in areas where other crops cannot be grown unless very costly inputs are utilized. Moreover, given the labor intensity required, small farm systems should continue to have the comparative advantage in production. These factors imply that germplasm that yields well must be developed under stress conditions without recourse to major increments in purchased inputs.

Cassava is one of the most efficient sources of digestible carbohydrate, particularly when grown on marginal lands. Its high perishability, however, makes handling difficult after harvest when losses are estimated at 25% or more. Increased production is very frequently limited by lack of nearby markets or processing plants that can readily transform fresh cassava into a more stable product. Farmers are often reluctant to increase production because no ready outlet exists, and entrepreneurs are not willing to invest in processing plants because of uncertain supplies. When this cycle is broken, production can increase markedly, as occurred in Thailand recently with the establishment of many small drying plants and an effective marketing system.

Program Objectives

The Cassava Program seeks to satisfy a need for food and feed carbohydrates by converting cassava from a traditional rural staple to a major, multi-use carbohydrate source. To accomplish this, the plant's carbohydrate production efficiency under sub-optimal environmental conditions will be exploited. Recognizing the potential of cassava as a major food and feed source not only in Latin America but also in Asia and Africa, the Program will work to adapt its technologies to Asian conditions and work closely with IITA in Africa.

The overall goal is to be reached through these specific objectives:

(a) To develop germplasm and associated cultural practices that require low input levels and that respond to improved management, in order to increase per hectare cassava production in areas where it currently is grown.
(b) To develop germplasm and associated management practices that, under intermediate levels of inputs, will lead to profitable cassava production on the underutilized acid, infertile soils of the lowland tropics.
(c) To develop systems that can improve the utilization of cassava for direct or indirect human consumption.
(d) To strengthen national cassava research and development programs so that they can perform more effectively.

Research Strategy

New production technology for cassava must exploit the crop's productivity under marginal conditions with low inputs. This precludes using high levels of expensive, energy-consuming inputs like pesticides, soil amendments and irrigation. Rather, new technology must be based on improved germplasm that by itself overcomes many of the constraints on production. Not all problems can, or should, be resolved by improved germplasm. Some constraints should be minimized through management practices that include improved agronomic practices, biological control of insect pests, phytosanitary control of diseases and efficient techniques for fertilizer use. In fact, the quickest way to increase production in many areas may be with local materials combined with improved agronomic practices. Production then may be increased further by introducing new varieties as they become available.

The methodology used in the past will be modified somewhat. The CIAT Cassava Program has worked under conditions of low stress (at CIAT-Palmira), medium stress (ICA-Caribia) and severe stress (Carimagua). It has been difficult to obtain single new varieties well-adapted to all these conditions. It is probable that the same will apply to other cassava ecosystems. Accordingly, the Program will evaluate germplasm in each ecosystem (this has already been done in ecosystems 1, 2, 4 and 5) and use superior materials in crosses to produce clones specifically adapted to each area, rather than try to develop broadly adapted clones. The material produced will be evaluated in advanced yield trials for yield stability and quality.

Improved germplasm is not, however, a panacea. The rate of progress in a breeding program is roughly inversely proportional to the number of breeding objectives. Hence, if progress is to be made within a reasonable time, breeding must be used only to resolve major problems. Control of the many pathogens that attack planting material should not be resolved through varietal resistance, but rather by using inexpensive chemical protectants. In addition, other problems cannot be solved by breeding. For example, varietal resistance to the cassava hornworm has not been found, but effective biological control methods have been developed. Improved management practices of general applicability will be developed and then tested with the new improved lines for adaptability and stability over time within each ecosystem. From these regional trials, technology packages will be recommended for use in a limited number of on-farm validation trials in selected ecosystems.

To benefit from increased production, a sufficiently large market must exist. CIAT will concentrate on utilization research contributing to expanded demand for cassava products, as either direct or indirect human food. Several other institutes or private agencies are involved in processing research for starch or ethanol production, and CIAT will not duplicate their efforts. The fresh urban market will continue to remain the preferred (highest price) market; however, quality maintenance and high marketing margins limit consumption. The perishability of cassava is positively correlated to starch content. High starch content is important in determining quality, so high starch lines are being bred; however, they could be more perishable.

Cassava's high perishability and lack of alternative outlets lead to rapid saturation of markets and sharp farm price decreases as production increases. This often results in very low prices in one area of a country while prices are high and demand is not satisfied elsewhere. Farmers are thus often unwilling to increase productivity or area planted. Improved technology that allows arbitrage or the entry of cassava into more stable markets will produce a more stable floor price and thus break the vicious circle. The objective of the utilization section is to develop such technology.

Fresh Cassava

Initial work has shown it is highly probable that simple techniques for fresh storage can be developed. Efforts will concentrate on developing this technology for commercial use; this would allow expansion of the urban market, where prices currently are high but quality is low.

Cassava Flour

Cassava is used widely in a variety of flours made by traditional processes. The potential increased demand for this type of product is limited to the lowest-income sectors who will be the greatest beneficiaries of improved technology. On the other hand, demand for cassava flour as a partial substitute for wheat flour in bakery products is immense across all income groups. Flours of high quality can only be produced presently by using drying processes that consume large amounts of energy. The Program will develop solar and other natural drying systems that will ensure a higher quality product at lower cost.

Cassava as Animal Feed

Potential demand for cassava in animal feed concentrates is great. The main limitations on entering this market are: (a) the high price of fresh roots in certain regions; (b) lack of drying systems suitable for high humidity areas; (c) lack of information on the economics of drying cassava; and, (d) lack of information on animal performance at high levels of cassava intake. While the Program's production research continues to concentrate on reducing unit production costs, the utilization section will emphasize research to remove the remaining constraints.

Integrated Use of Whole Plant

Outside of Africa, except for isolated examples, the roots are the only part of the cassava plant currently utilized. As progress is made on the above aspects, research will be conducted on the use of the entire plant and particularly the leaves, as a protein source.

International Cooperation Strategy

The state of development of the cassava industry and the level of support by national programs and government agencies vary tremendously among developing countries. Consequently, assistance required by countries, or even different regions of the same country, will vary over time. CIAT has classified countries according to cassava program development to help identify the type of assistance required for each group. The overall objective is to help countries progress to the advanced category if they have both the potential and the need for increased cassava production.

Advanced Cassava Countries

These countries have a clearly demonstrated potential for increased production, they have declared increased cassava production as a definite goal in the national plan and/or local agencies or industries have shown real interest in increased cassava production. National programs or local agencies are strong and able to support the cassava industry. The national programs in these countries are relatively new and many need help in planning, particularly in defining priorities. In addition, many of the young professionals need further training and experience in research and management.

The Cassava Program will assist these national agencies in project planning and will provide advanced training opportunities. The base for improved production technology will be new agronomic practices and germplasm. The national programs in this group are strong enough to develop both aspects. However, in the case of improved germplasm, they will benefit greatly from CIAT materials for several years. CIAT estimates that nine to ten years are required from the inception of a new breeding program to the release of a new variety. By importing germplasm as sexual seed or selected clones, national programs can capitalize on CIAT's efforts and shorten the period to eight years with sexual seed, or to four years with clones.

The interchange of germplasm should not be haphazard. Selected crosses from CIAT, made for specific ecosystems, should be evaluated by national programs. CIAT and national program personnel will determine which varietal characters are required in each country. Feedback on their field performance will be essential so that second generation materials can be better adapted. Much of the useful information already being developed by national programs can be applied in other countries. CIAT will act as a relay agency to see that national agencies are aware of what is happening in other countries.

Achieving improved yields will depend greatly on the technical capability of the national programs to provide certain types of support to farmers. This support includes large stocks of disease-free seed of the new clones, insect hatcheries to support biological control and field diagnostic expertise. CIAT will assist in organizing in-country courses for training technicians in these activities.

Developing Cassava Countries with Strong National Programs

These countries have the potential for increased production but have no supporting national policy and only poorly developed channels for marketing or utilizing increased production. They are thus in the somewhat paradoxical position of having strong national programs but no overall strategy for increasing production and utilization of cassava.

CIAT will collaborate in establishing regional trials using local varieties and imported germplasm in order to assess the country's potential cassava productivity. The cassava economics section will help assess the economic gain the country could expect if cassava production were increased. This information will be made available to policymakers so they can decide if they wish to implement a full-scale national cassava project at the advanced-group level, in which case the operational strategy will be changed.

Developing Cassava Countries with Weak Programs

In these countries either government or private industry is interested in increasing cassava production and there is a known potential for increased production, but improved marketing and utilization possibilities have not been explored.

The main emphasis will be on training personnel to test CIAT-produced technology and germplasm and to assist in economic planning. CIAT will help establish trials to validate the new technology under local conditions and will collect data for economic planning. If the decision is made to strengthen the national program, assistance in training and project planning will be given.

Calorie-deficient Countries Uninterested in Cassava

These countries have no national cassava programs, and decision makers often are not aware of the new cassava technology and how it can help solve their caloric deficit. The main emphasis here will be to evaluate production potential through small-scale regional trials and to determine the status of cassava production and the economic viability of increasing production. CIAT will help establish regional trials and collect the necessary information on present cassava production methods.

Program Accomplishments

Collection of germplasm was initiated throughout Latin America in 1969, and by mid-1971, 2200 clones had been assembled. This germplasm bank has been the base for the varietal improvement program.

By 1973 the material was increased and evaluated for agronomic characters. Selected clones from the bank yielded as high as 60 t/ha of fresh roots and 22 t/ha root dry matter annually. The importance of the harvest index as a selection criterion was established. Sources of resistance to some of the major diseases and insects were identified and an agro-economic survey was done in Colombia to assess the production technology used by farmers and to determine the major constraints on yields and increased production.

One of the major problems in researching and distributing new varieties was found to be cassava's slow propagation rate. A rapid propagation technique was developed that increased the multiplication rate fortyfold. Meristem tissue culture techniques have since been developed and shared with national programs to facilitate international germplasm transfer with much less risk of pest and disease transfer. At the same time, work was started on perishability, one of the major utilization constraints. Basic physical data on drying of cassava roots were obtained, and curing of cassava roots was demonstrated to prevent rapid physiological deterioration after harvest.

During 1974 and 1975 the Program began to move its research outside of CIAT to test newly obtained results over a range of environmental conditions and to evaluate disease and pest resistance in the field. Two major sites were established on ICA stations – at Caribia, representative of lowland tropical areas with a pronounced dry season (ecosystem 1), and at Carimagua, a high-stress site representative of the acid infertile savanna (ecosystem 2). In addition, a series of regional trials was established in Colombia to test newly developed clones. This network provided basic data for the later establishment of international trials. Norms for these trials were established at a conference, sponsored by the International Development Research Centre (IDRC), in which national agencies expressed their needs.

As the international trials began, the first links were made with national programs. National programs, except for that of India, were universally weak or non-existent. Contacts were made with high-level government officials and a massive cooperative training program was started to provide the nascent national programs with trained personnel. As of 1980, 209 trainees from nineteen countries in the Americas and sixty-eight from seven Asian countries had received postgraduate training in various disciplines.

Between 1976 and 1980, thousands of hybrids were produced and tested; high-yielding, disease- and pest-resistant lines were selected for further testing. Improved agronomic practices were also developed; these were evaluated with the new clones in both regional trials and in on-farm evaluations. The net result of this work is best illustrated by the regional trials. With improved, low-input technology, average yields of local clones increased in Colombia to 20 t/ha (national average 8.0 t/ha). These data illustrate the potential for CIAT technology to double yields at selected locations without even changing varieties. On-farm validation trials have shown that small farmers can readily increase yields by 70% with this technology. In addition, selected clones and hybrids boosted yields as high as 30 t/ha in the regional trials. Although these clones have problems – such as slow multiplication rates and inferior eating quality

– they do demonstrate the tremendous yield potential to be realized at the farm level by further research and development in this decade. New clones being produced by the Program are rapidly overcoming some of the deficiencies of earlier evaluated materials.

Projected Program Developments

Although only minor changes and additions to the Core research staff are projected, emphasis within the overall program will change considerably. One major change will be to develop specific germplasm for each ecosystem. Less emphasis will be placed on ecosystems 4 and 5 and more given to ecosystems 1, 2 and 3. Outposted research work is projected for ecosystem 6. As national programs develop, providing sexual seed for selection in national agencies will receive more emphasis than the production of finished varieties. Figure 2 indicates how various activities will change in the Cassava Program throughout the 1980s.

Emphasis in crop protection will be on host-plant resistance as the basis for integrated pest management. More effort will be given to other methods, such as biological control and phytosanitary practices when they seem to be more appropriate control measures.

Until now much work has been done on realizing maximum yield potentials under moderate input levels by developing technology that is broadly adapted to a wide variety of conditions. This emphasis will be modified in order to develop technology providing high and stable yields in each ecosystem.

Since the research requirements in cassava utilization are quite diverse and often short-term, projected research in this area will be more opportunistic than in other areas. Fresh cassava storage and the future of cassava as an animal feed will be emphasized, as well as appropriate technologies for solar drying and for processing dried materials. The Program will continue to be alert to developments in industrial uses for cassava in order to develop farm-level processing to meet these new demands. This research will concentrate on techniques that have low energy requirements and that are appropriate for small-farm conditions.

Germplasm Improvement

The germplasm development section already is evaluating the germplasm bank in four ecosystems. The germplasm bank will be evaluated also in the hot, humid lowland tropics. As these evaluations are completed, attention will turn to producing elite lines containing combinations of desirable characters for each ecosystem. More attention will be given to selection for yield stability and root quality, for both the fresh

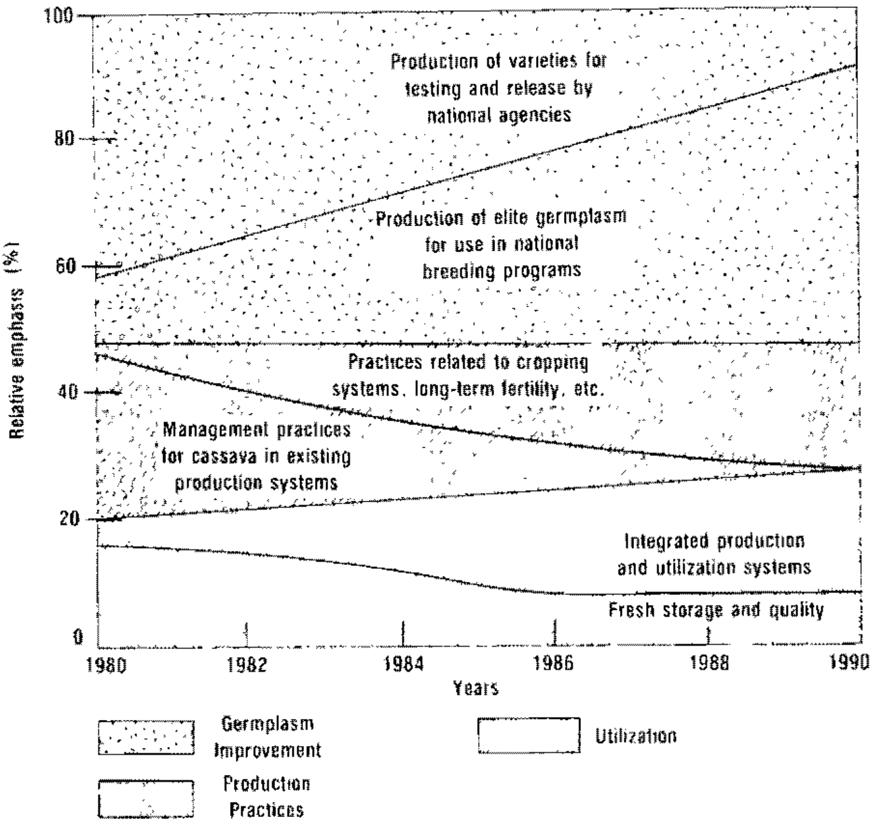


Figure 2. Relative emphases the Cassava Program will place on various aspects of technology development activities in the 1980s.

and processed markets. Large quantities of sexual seed from these lines will also be produced for use by advanced national programs. Breeding will be dynamic in order to incorporate new techniques.

The elite lines will form the basis for crosses in varietal improvement. The varietal improvement section will develop clones specifically adapted to each of the major ecosystems. In the coming years more attention will be given to selection for yield stability and root quality, both for the fresh and processed markets. Neither the varietal improvement section nor the germplasm development section can work directly in ecosystem 6 because this ecosystem is not represented in Colombia. The strategy to be pursued in support of ecosystem 6 is discussed later.

Tissue Culture

Major problems in a vegetatively propagated crop such as cassava are associated with germplasm storage and production of disease-free stocks. The tissue culture section of the Germplasm Resources Unit is developing methods for cheap storage of germplasm as plantlets in test tubes, and for production of planting stocks from meristems. Within three to five years these procedures will become routine. Then attention will be given to using tissue culture techniques for haploid production, protoplast fusion and eventually, genetic engineering in support of varietal improvement.

Plant Nutrition and Physiology

The plant nutrition section, in conjunction with physiology, will identify material performing well under extreme conditions of low soil pH and high aluminum levels and define characters associated with high yield potential under poor soil fertility conditions. In addition, particular attention will be given to the most efficient use of limited quantities of fertilizer. The possibilities of using cheap rock phosphates with mycorrhiza/cassava associations will be assessed. The physiology section will concentrate on stress factors causing yield and quality instability in order to develop varieties with high yield stability under climatic variation in each ecosystem.

Plant Protection

Economically important diseases and pests are studied in detail so that control measures can be developed when necessary. Much work has been done on finding resistance sources for superelongation disease, bacterial blight, thrips and spider mites. Many diseases and pests can be controlled by means other than breeding. Biological control and cultural practice measures have been developed; new emphasis is being placed on biological control of mealybugs and other insects. Treatments to control pathogens of planting materials have been developed by the pathology section, which now will work on pathogens of stored planting materials. Major diseases and pests and their control methods are shown in Table 7.

Agronomic Practices and Regional Trials

The agronomic practices section will concentrate on developing suitable cultural practices for ecosystems 1 through 5 and on modifying these practices to ensure their compatibility with the new germplasm. Later these practices will be tested in cropping systems with special attention to long-term effects on soil fertility. The regional trials section combines the best new clones with improved management practices and tests

TABLE 7.
Significance of the major diseases and insect pests of cassava, and present and projected control measures.

Disease or insect	Losses	Distribution	Control methods
Diseases			
Cassava bacterial blight	Up to 100%	Widespread	Disease-free seed; agronomic practices; (resistant varieties)
African mosaic disease	Up to 90%	Widespread in Africa and India	Disease-free seed; rogueing, resistant varieties
Superelongation	Up to 100%	Limited, only in Americas	Stake treatment; (varietal resistance)
Frogskin disease	Up to 100%	Very limited, only in Americas	(Disinfection of tools; disease-free planting material)
Phoma	Up to 100%	Limited to cool, humid areas	(Varietal resistance)
Cercospora leaf spots	Up to 30%	Very widespread	(Varietal resistance)
Pathogens of planting piece	Up to 100%	Very widespread	Stake treatment
Anthracnose	Unknown, but may be high	Limited areas of Africa and Americas	(Varietal resistance)
Preharvest root rots	Up to 100%	Mainly in poorly drained areas	Crop rotation; ridging
Insects			
Spider mites	Up to 50%	Widespread, in dry season	(Biological control; varietal resistance)
Hornworm	20% each attack	Widespread in Americas only	Biological control
Thrips	Up to 28%	Widespread	Varietal resistance
Scales	Reduces germination. Up to 20% from later attacks	Widespread	(Biological control; varietal resistance)
Mealybugs	Probably high	Limited	(Biological control; varietal resistance)
Shootflies	Up to 34%; generally very low	Widespread in Americas	Only necessary in early growth stages; (Varietal resistance)

SOURCES Bellotti, A., and van Schoonhoven, A. (1978). *Cassava Pests and Their Control.* CIAT Series 09EC-2. pp. 71; *and* Lozano, J. C., and Booth, R. (1974). "Diseases of Cassava (*Manihot esculenta* Crantz)." PANS 20(1)30-54.

NOTE: Control methods in parentheses are still being developed or are the most likely form of control to be found in the future.

them under a broad range of conditions. Special emphasis is placed on developing multiple cropping systems for small farmers.

Economics

The economics section analyzes the potential economic impact of improved cassava technology in Latin America. This analysis provides a framework for integrating demand potential and competitive prices in various end markets with necessary production costs at the farm level. On-farm research trials are being used to help evaluate potential productivity and technology design requirements. Production and demand studies developed at first for Colombia will be extended to other countries in the region.

Utilization

Research in the utilization section will concentrate on: (a) fresh cassava preservation methods, including pruning before harvest and using polyethylene bags and non-toxic chemical protectants; (b) solar drying and storage techniques to improve quality of cassava flour; and, (c) technology to prevent reduced animal performance when using cassava as feed, particularly for swine and poultry.

Although utilization is a complex research problem, only one senior staff member is present to give continuity to a program that will depend on several special projects. Research personnel with specialized skills will be engaged on a short-term basis to solve specific problems. The first such appointment will be in the area of cassava drying.

Future Headquarters-based Research Staffing Requirements

A virologist is projected for a new cassava senior staff position for 1983. Viral diseases of cassava are relatively unresearched. It is highly likely that viral pathogens are transmitted continuously through cassava planting material. Recent CIAT studies have indicated that yield losses from viruses could be significant in some production zones. One of the two new diseases tentatively identified as being of viral origin is capable of causing complete crop failure. In addition, Latin American material generally is not resistant to African cassava mosaic disease, which has not yet appeared in the Americas. Research on viruses at CIAT will be necessary for the detection, identification and isolation of pathogens in vegetative material. This research is particularly important for phytosanitary control in moving material across international boundaries and in producing disease-free seed within countries. The development of resistance to viral diseases through breeding also will be emphasized if other control methods are not satisfactory. At the present time continuing studies are conducted by postdoctoral fellows.

Recent work at CIAT and other institutions has demonstrated the importance of mycorrhizal associations in improving the phosphorus nutrition of cassava. A special project funded by the German Agency for Technical Cooperation (GTZ) was begun recently to determine the potential for economic exploitation of this association. If results suggest that the effect can be greatly enhanced through research, a microbiology position may be requested.

Production and storage of quality planting material are vital if high yields are to be obtained. More data are showing that plant production for seed may require different crop management practices than root production. A senior staff position is not required now but if new varieties with high yield potential do produce fewer good quality vegetative seed, it may become necessary to develop research in this area. New avenues of research described above may not require staff increases. The plant nutrition section may well move into the mycorrhizal field, and the plant physiology or agronomy section may conduct seed production research, without increased staff.

Outposted Research Staff

The following projected outposted staff are essential for achieving the objectives of the Cassava Program in the 1980s.

Research Position for the Subtropics

Ecosystem 6 (cool winter areas) is an important cassava producing ecosystem in the higher latitudes of the Americas and other regions. Due to its location, CIAT is not able to provide basic germplasm for this ecosystem which encompasses parts of Bolivia, southern Brazil, Paraguay, Mexico, the northern Caribbean islands and southern China. Beginning in 1983, one senior scientist with research support is proposed for posting at a research institute (probably Santa Catarina in southern Brazil), to evaluate CIAT and local germplasm for further breeding. This material will then be made available to other countries where an ecosystem 6 type of environment predominates.

Regional Cooperation

Asia

Asia produces about 40% of the world's cassava. Until quite recently India was the only country of that region with a major national cassava program. Indonesia, Malaysia, the Philippines, Thailand and Sri Lanka have developed national programs in the last five years. CIAT has supported these programs though training, consulting and providing improved germplasm. Special project funds have ended for the regional services scientist who facilitated this work, particularly the introduction of germplasm and organization of training.

Asian national agencies have requested that CIAT again station personnel in the region. It is becoming progressively more difficult and expensive to provide the Asian national agencies with technical assistance from headquarters in Colombia. Areas to be emphasized are coordinating training activities, maintaining awareness of changing national needs, and supplying germplasm specifically adapted for Asian conditions. The latter strategy is of great concern because the range of genetic variability in Asia is extremely limited. CIAT accordingly proposed to outpost one regional cooperation position in Asia, starting in 1982, to provide continuity and liaison for possible teams which would be non-Core funded.

Andean Zone

The countries of the Andean Zone are traditional cassava producers. They have recently become major importers of grains for animal feed, and several have expressed the desire to increase cassava production to replace imported grains. Cassava programs in this region are all weak or non-existent. No outposted regional position is projected for the Zone because services will be accomplished through interaction by headquarters-based staff with the neighboring countries in the Zone.

The Caribbean, Central America and Mexico

While the region is not an important cassava-producing area, many of the countries are classified as calorie deficient. Cassava programs are now being developed and require considerable assistance in planning and training during their formative years. For many years these areas will depend directly on CIAT-developed germplasm. In most cases they will require finished varieties rather than sexual seed or a large number of populations for selection. An outposted regional cooperation scientist is projected for 1985, to provide support to national agencies in the region. In the interim, a special effort will be made to obtain special project funding for this position.

Africa

About 40% of the world's cassava is produced in Africa. Many germplasm management practices developed at CIAT may be applicable to

Africa. There are two major differences in cassava production in Africa and the Americas: African mosaic disease does not occur in the Americas, and slash-and-burn culture is much more common in Africa.

The regional efforts of IITA in Africa could be greatly enhanced through more liaison with CIAT. This is especially true with respect to genetic resources. It is vitally important to evaluate American and Asian clones under conditions of African mosaic. If the disease should ever spread to these continents, resistant clones would be available. It is tentatively proposed to station one CIAT scientist at IITA, starting in 1986, to be more responsible for germplasm movement from the Americas to Africa and for more rapid interchange of research developments between the two institutes.

BEAN PROGRAM

The common dry or field bean (*Phaseolus vulgaris* L.) is the most important grain legume species for direct human consumption in the world. Production spans regions as diverse as Latin America, Africa, the Middle East, China and the United States. Beans are a traditional food in Latin America, particularly in Brazil, Central America, the Andean Zone, and some Caribbean countries.

The common bean, generally a crop of the small farmer, is grown in a wide range of cropping systems. Most production is in systems utilizing few purchased inputs where yields are generally low. While production in Latin America has increased approximately 1% per year over the last decade, yields have generally declined and currently average about 600 kg/ha. Area expansion has allowed a slight production growth, but this growth has not kept pace with population, much less demand growth. Latin America has become a net exporter of beans – due to Argentina's rapidly increasing exportation – mainly to Europe. Brazil, Cuba, and Venezuela have substantially increased their imports in recent years.

While bean prices have increased more rapidly than general inflation in many countries, the analysis in Chapter 1 indicates they are the cheapest source of protein and a relatively inexpensive caloric source. In Brazil, real prices of beans tripled between 1972 and 1976. Over the same period, per capita consumption decreased from 26 to 22 kilograms, thus further aggravating the nutritional problems of the poor.

Despite increased market prices, bean production is characterized by low profitability and high risk. Low and very unstable yields – associated with seasonal climatic variability – and consequent seasonal price fluctuations have led increasingly to the displacement of beans in traditional areas by higher value crops. In Brazil, soybeans have displaced beans on more fertile soils. Bean productivity continues to decline after moving to marginal soils with lower fertility. A similar situation has occurred in Mexico, but there increased sorghum production may have been the competitive influence.

Selected commercial bean varieties, grown under experimental conditions with appropriate plant protection and irrigation, are capable of far higher yields than those seen in national production statistics. Experimental bush bean monoculture yields of 3-4 t/ha in a crop season (90-120 days) are not uncommon. At CIAT experimental yields of climbing beans grown on artificial supports (monoculture) have exceeded 5 t/ha in 100 days. A large yield gap exists between farm and experimental situations and this could be reduced substantially by using improved varieties and production technology. Economic analyses have indicated that if production in Latin America was to increase 5% annually over the next five years, the additional production would be absorbed by increased consumption, with an average price decline of only 3%.

Production Systems and Constraints

In the developing countries of the Western Hemisphere beans are grown over a wide range of latitudes and altitudes and in a recurring series of cropping systems that have evolved as small farmers adjusted to various environmental and socioeconomic constraints. The four major cropping systems can be classified as:

(a) Bush beans in monoculture; common in low- to medium-altitude areas in Brazil, Chile, the Dominion Republic, Mexico and Peru.

(b) Bush and semi-climbing beans in relay systems with maize; found in low- to medium-altitudes of Brazil, Colombia, Central America and Mexico.

(c) Bush beans in direct association with maize (sown at same time); in medium-altitude areas in Colombia and Venezuela, and in many areas of Brazil.

(d) Climbing beans in direct association with maize; as found in higher areas of Colombia, Ecuador, Guatemala and Peru.

Maize predominates as a companion crop in these systems and its competition is a major constraint to increased bean production. Most studies show bean yield reductions of about 50% in associated systems with maize. It is obvious that for farmers the total return from the system is more important than the individual components. Data on bean production microregions in the Americas, now being collected by the agroecosystems analysis group, will provide an accurate assessment of the relative production importance of the various systems. Preliminary data suggest that rank order in terms of total production is roughly the order presented above.

Of the major world crops, beans are undoubtedly one of the most susceptible to diseases and insect attack. More than 200 identified pathogens can influence the productivity of the species. Diseases and insects in all production areas are the most important common constraints to increased production and productivity. The most common and widespread diseases in the Western Hemisphere are bean common mosaic virus (BCMV), bean rust (*Uromyces phaseoli*), anthracnose (*Collectotrichum lindemuthianum*), and angular leaf spot (*Isariopsis griseola*). Common bacterial blight (*Xanthomonas phaseoli*) and bean golden mosaic virus (BGMV) are also severe in certain locations, in particular years. Most commonly utilized cultivars are not resistant to the major diseases, showing, at best, a low level of tolerance. Each of these diseases can cause yield losses as high as 80-100%. The transmission of BCMV, anthracnose and bacterial blight through infected seed has spread these diseases not only in the Western Hemisphere, but also outside the centers of origin of the species. Disease problems in Africa are similar to those in Latin America, except that halo blight (*Pseudomonas phaseolicola*) is relatively more important.

Among the insect pests, leafhoppers (*Empoasca* spp.) and pod weevils (*Apion godmani*) are the most significant. Leafhoppers have reduced yields of highly susceptible varieties as much as 90%. Reductions of 20-50% are common on many farms, even when insecticides are used. Insects such as *Zabrotes* and *Acanthoscelides* inflict heavy losses in stored grain; farmers are forced to sell their harvest quickly, which contributes to post-harvest price declines. The bean fly (*Ophiomya phaseoli*), the most common insect constraint in Africa, causes severe yield losses in many countries of that continent.

Data on bean microregions have been used to classify growing season climates (Table 8). The seven zones are classified according to average growing season temperature and water balance conditions; each zone represents a group of diverse microregions with similar mean climatic conditions during the actual bean growing season. The data suggest that most beans (76%) in Latin America are produced at temperatures close to optimum for the species (20-23°C). On the other hand, 73% of total production occurs in microregions having moderate to severe mean water

TABLE 8.
Classification of bean production zones in Latin America.

Zone type	General description	Mean growing season temperature[a] (°C)	Range in mean daily growing season water balance[a] (± mm/day)	Latin American production ('000 tons)	(% of total)
A	Average temperatures and adequate mean seasonal water balance	22	−1.5 to +0.4	661	17
B	Average temperatures and slight excess in water balance	23	+0.4 to +4.0	118	3
C	Average temperatures and large deficits in water balance (irrigated areas)	23	−5.6 to −5.1	528	14
D	Average to moderately low temperatures with possible deficit in water balance towards the end of the growing season	20	−2.7 to −1.6	1672	42
E	High temperatures with possible deficit in water balance towards end of growing season	26	−4.1 to −0.3	262	6
F	Moderately low temperatures and moderate water balance deficits	16	−2.3 to −1.9	451	11
G	Low temperatures and adequate mean seasonal water balance	13	−0.9 to −0.5	45	1

a Mean of conditions in microregions constituting each production zone.

deficits at some time during the cropping season; very little of this production is irrigated. Serious water deficits are, therefore, a major constraint on production. The quite surprising tendency for production to take place within a narrow temperature range indicates the relatively high sensitivity of the species to temperature.

Physiological defects of currently utilized cultivars (mostly land races) contribute to low and unstable bean yields. Most cultivars are a poor plant type and have pods in contact with the soil at maturity. This produces a poor quality product when pods are attacked by soil-borne pathogens. Many cultivars are of determinate bush habit with early and intense flowering characteristics that contribute to yield instability. These cultivars show little ability to compensate for low sowing densities common on most small farms and have no mechanism for renewed flowering when stress is relieved.

As bean production moves to more marginal land, soil-related constraints become more important. Soil acidity and high phosphorus fixation characterize many of these soils. Associated aluminum toxicity reduces root development and increases sensitivity to water deficits. Nitrogen deficiency is also a limiting factor in many bean soils; this is complicated by a low capacity for nitrogen fixation in most currently used cultivars.

All of the major environmental and biological constraints to increased bean production can be researched. While national bean research programs have existed for many years, only limited progress has been made towards resolving the problems through new technology. Some countries with historically strong national research programs, such as Mexico and Colombia, have made considerable production progress, confirming the potential for improvement through research.

Program Objectives

The goal of the Bean Program is to increase – in collaboration with national research efforts – bean yields and to stabilize production by conducting research on the principal constraints. The Program has focused its research on the constraints found in the Western Hemisphere. In general, production constraints in Africa parallel those in Latin America. The problems at all levels are probably more serious in Africa and a concerted effort will be required to provide solutions through research. Much of the research carried out in Latin America is applicable to Africa but regional adaptive work is required.

Recognizing the magnitude of the task, the Program has always sought to delineate its range of activities and to concentrate on those areas where it has a comparative advantage. Thus, it has avoided the humid lowland tropics where disease pressure is excessive, and the highly acid, infertile soils of the agricultural frontier where bean production would be possible only with massive soil amendments. The Program has confined its activities to *P. vulgaris*, avoiding the temptation to work with other grain legumes, such as lima beans (*P. lunatus*), cowpeas (*Vigna ungiculata*), or soybeans (*Glycine max*). Research in other closely related *Phaseolus* species, such as *P. coccineus* and *P. acutifolius*, has been confined to some study of characteristics likely to lead to genetic improvement in *P. vulgaris*. The Program has narrowed its specific objectives to the following:

(a) To develop—in collaboration with national research institutions—improved technology for beans (*P. vulgaris*), particularly germplasm providing higher and more stable yields, which will lead to increased national production and productivity in those Western Hemisphere countries where the crop is an important food source.
(b) To assist in achieving the same objectives in other regions, particularly eastern Africa, through institutional arrangements in which CIAT can provide an input and allow advantages to be taken of work done in Latin America.
(c) To selectively strengthen existing national bean research programs through training and the establishment of a bean research network of collaborating professional scientists.

Research Strategy

The primary focus of the Program in terms of germplasm improvement has been on breeding for disease and insect resistance or tolerance in a range of selected commercial grain types. Initial emphasis has been placed on overcoming yield losses caused by BCMV, rust, anthracnose and *Empoasca*. By overcoming yield reductions from these principal diseases and insect pests, the Program not only seeks to increase yields but also to reduce yield variance over time. It became necessary more recently to put more emphasis on BGMV and common bacterial blight as the need for the materials with these resistances became more evident in particular regions. Continued breeding for host-plant resistance to the economically important diseases and pests will be necessary throughout the 1980s. The present emphasis on massive screening programs will diminish as national programs increase research in that area. Then it will be possible for CIAT to give increased attention to providing more stable resistance sources and studying the epidemiology of various diseases.

In addition to the primary focus on diseases and pests, the Program has increased its attention on improvements in a range of other germplasm characteristics. These include nitrogen fixation capacity and drought tolerance and some soil-related constraints, particularly low phosphorus availability. Improvement in basic plant types within the various growth habits has been approached gradually, and steady progress has been achieved. It is not likely that manipulation of physiological constraints will provide large yield increases in this species. The Program's heavy initial concentration on diseases and insects was planned in recognition of this situation.

The Program has made considerable progress in defining both bush and climbing bean plant types suitable for particular cropping systems. It is clear that no one type of plant can satisfy the rather diverse cropping patterns. In designing plant type objectives the Program has kept in mind the needs of the small farmer and the traditional cropping systems. Information provided by the agroecosystems analysis proved invaluable in orienting the research. Further progress is expected early in this decade and will allow the Program to continue to focus on principal constraints in each microregion and cropping system situation.

Program Accomplishments

Although CIAT did initial studies on beans and other grain legumes, formation of a coordinated program focused only on *P. vulgaris* dates from 1973. Initially, five man-years of senior staff activity were involved. As additional breeding and pathology work was undertaken, the team gradually increased to its present complement of twelve senior staff positions. The disciplines and staff now represented are: breeding (two in bush beans; one in climbing beans), agronomy (three), pathology (one each in mycology and virology), and entomology, physiology, soil microbiology and economics (one each). Assistance is received from the Genetic Resources Unit, which provides the sources of genetic variability, and from the Food and Nutrition Laboratory, which monitors nutritional and consumer preference characteristics of advanced materials.

Establishment at CIAT of the world *Phaseolus* germplasm collection, currently containing some 30,000 accessions, formed the base in the search for sources of resistance to major diseases and pests. These materials are utilized in a massive breeding program that currently carries out more than 1500 different crosses (parental combinations) per year.

Breeders conduct the first evaluation of breeding populations (F_2 and F_4) for disease and insect resistance, architecture and consumer requirements. In the second stage, involving all bean scientists, selections are tested in successive uniform nurseries for confirmations of disease and insect resistance and general adaptation at two altitudes (at CIAT-Palmira and CIAT-Popayan). At the third level of evaluation, the material is further selected for the above characters, and for nitrogen fixation, water stress tolerance, low phosphorus tolerance, resistance to minor diseases, protein content and cooking time. Yield performance is measured annually for 200-300 new advanced lines under stressed and non-stressed conditions at three locations in Colombia. The published results contain more than twenty character evaluations. CIAT makes these lines available as parental sources to national programs.

Approximately one hundred of the superior lines enter the International Bean Yield and Adaptation Nursery (IBYAN) each year. The IBYAN originally contained only germplasm bank selections but now is composed principally of CIAT-bred lines and entries submitted by national institutions. As national programs increase their capability to undertake breeding and selection activities, their entries will become a more significant part of this program. Currently, more than one hundred fifty IBYAN trials (or sets) are shipped each year, providing improved germplasm to all bean producing countries in Latin America, the Caribbean and other regions of the world.

In 1975 the Bean Program established a time frame which it hoped to follow in achieving bean yield increases in Latin America. To date results have been consistently better than predicted. Some selected highlights are given below:

(a) All lines leaving the second stage of evaluation are now resistant to BCMV.

(b) Improved germplasm having multiple disease resistance is now being distributed for international testing. Lines resistant to all known races of anthracnose have been identified.

(c) Germplasm has been identified with tolerance to drought, extreme temperatures, all major diseases and pests, high aluminum, and low phosphorus in the soil, and with maturity differences appropriate for different production systems.

(d) Yield levels of small, non-black-seeded experimental lines have been significantly improved. They now equal or surpass yields of the initally (1976-77) superior, black-seeded germplasm.

(e) Lines developed collaboratively in Guatemala for tolerance to BGMV out-yielded leading commercial varieties under heavy disease pressure, even when the susceptible local lines received heavy insecticide applications. Chemical protection further increased yields in the resistant lines.

(f) Over twenty lines originating from CIAT collaboration with national breeding programs are now undergoing varietal evaluation in farm-level testing or seed multiplication in national programs in Latin America and the Caribbean. Disease-resistant lines have already been released in several countries. In Cuba, an estimated 5000 hectares have been planted to multiply such improved germplasm; in Bolivia, 1000 hectares are devoted to this purpose.

(g) While emphasis has been placed on varietal improvement, the opportunity to improve agronomic practices has not been ignored. In farm-level testing in Colombia, improved agronomy has shown yield increases of 50-100% in a large number of experiments. An inexpensive, non-toxic, farm-level storage technology employing vegetable oils has also been adapted to beans. Diffusion of this technology has begun in Colombia.

Such progress has been possible only as a result of CIAT's intensive training programs and from the interest and collaboration by national program scientists. Through 1980, 360 national program scientists had received postgraduate training at CIAT, mainly in bean production short courses or intensive discipline-oriented training.

International Cooperation Strategy

National bean research programs reached varying stages of development during the 1970s. All countries where beans are important have given some attention to research. Most national agencies have a bean research staff and most members have received training at CIAT. An active network of collaborators has been established. Further selective strengthening of national programs through training, consultative visits, and other international cooperation activities will be continued in the 1980s. The ultimate aim is to help all country programs become full and equal partners in the network. CIAT then can gradually adopt a research backstopping role. The point at which this progress occurs will vary considerably among countries, and some attrition is to be expected.

Projected Research and Core Staffing

The 1980s will see progressive changes in priorities in the Program's breeding activities (Fig. 3). However, little change in overall staffing levels is anticipated. Currently, all breeding lines leaving CIAT are resistant to BCMV; various sources of resistance to anthracnose are available and can rapidly be incorporated into breeding lines. Therefore, greater attention can be given in the short term to other diseases, including rust, angular leaf spot and web blight. In each case various races of the pathogens have

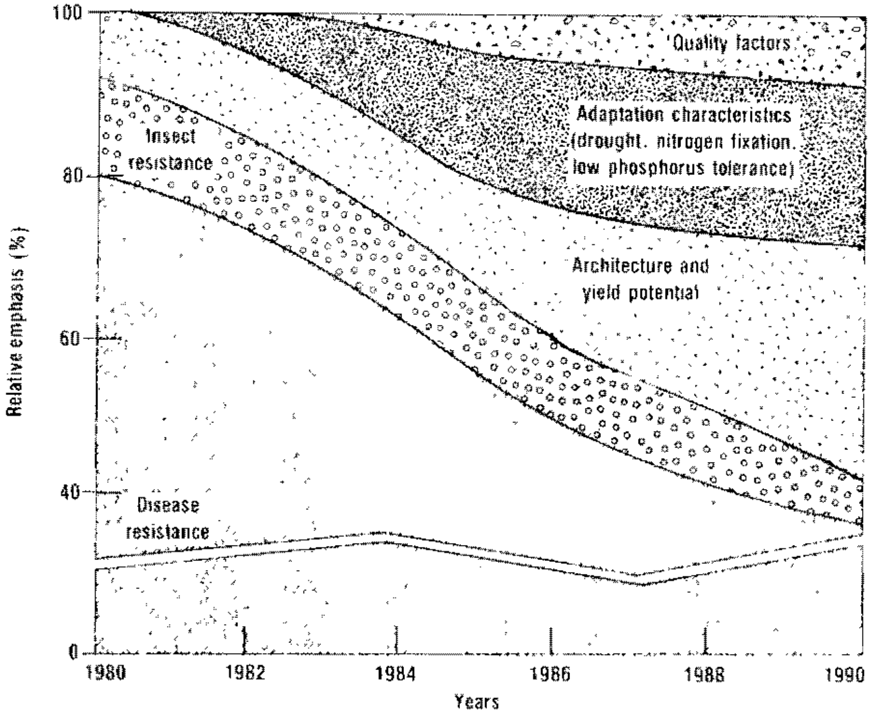


Figure 3. Relative emphases the Bean Program will place on various aspects of technology development in the 1980s. Changes in emphases will be reflected in the proportions of crosses in the breeding projects designed for general groups of constraints

been identified but no single line is likely to be resistant in all locations. This emphasis, plus the need for additional work on control strategies for common bacterial blight and halo blight disease, will require the addition of a second pathologist (bacteriologist) to the team in 1982. As the disease breeding goals are realized toward the end of the decade, the Program should be able to decrease its emphasis on disease breeding and put more emphasis on integrated disease control strategies.

Substantial variation in plant architecture and yield components has been obtained in the breeding and germplasm lines evaluated since 1976. Plant characteristics associated with higher yield are being sought and, once obtained, should permit development of lines possessing both improved yields and multiple disease resistance. Figure 3 reflects the increasing emphasis to be given to bean plant architecture and yield. Snap bean characters will be incorporated into particular elite lines during the decade.

With most fertilizer prices rising rapidly and the lack of credit for small farmers limiting their use of purchased inputs, future elite lines will need to be tolerant to several soil constraints. For regions such as Brazil and Venezuela, the Program will need to develop varieties tolerant to moderate soil acidity and low soil phosphorus and with increased capacity for nitrogen fixation. Incorporating these traits into agronomically acceptable cultivars will require not only innovative breeding methodologies but also closer collaboration between breeders, agronomists and soil microbiologists.

Obviously, the increasing capability of national bean programs will influence the scope and direction of CIAT's research. Training and network activities have helped to build several strong national bean programs that are capable of developing their own varieties. CIAT should increasingly assume a backstopping role for these programs, providing them with specific genetic variability for their improvement programs, postgraduate training opportunities and documentation support. This would permit more detailed assistance to smaller programs whose breeders, agronomists and pathologists could become more involved in evaluating collaborative local breeding nurseries to exploit specific adaptation. Problems of nutrition or consumer acceptance could also receive attention. However, the Bean Program expects to continue producing some finished varieties throughout the 1980s, because some national programs probably will not be self-sufficient in research.

As the Program evolves, the bean germplasm bank will be used constantly as a source for new variability. New collections will be made during the 1980s to add genetic variability from regions that currently are poorly represented or from areas where specific desired variability is most likely to be found. Collaboration with the International Board for Plant Genetic Resources (IBPGR) in these collection activities will ensure that sufficient resources will be devoted to this important task. The CIAT Seed Unit is expected to help in the formation of a strong seed industry in Latin America to promote and make available newly developed germplasm. The Seed Unit will pay particular attention to the problem of seed production for the small-farm sector.

Regional Cooperation

The Bean Program's policy of continuing in-depth evaluations of its germplasm, along with similarities in production conditions and constraints in the various bean-growing regions, has ensured that CIAT-derived materials are generally well-adapted to other production regions.

For this reason, it will not be necessary to deploy research staff away from CIAT headquarters. Specific regional problems, such as BCMV in Central America and Brazil, the *Apion* pod weevil in Central America, and the bean fly and halo blight in Africa, will be studied in collaboration with national programs and, it is hoped, with the support of the recently formed Title XII Bean/Cowpea Collaborative Research Support Program within United States universities.

Central America

This region, with numerous small national bean programs and high per capita bean consumption, will probably continue to rely on the CIAT program during this decade. Transfer of germplasm and technology from CIAT, and between national programs, can best be served by stationing one scientist in the region. One outposted regional cooperation position is projected for 1984 when the existing Swiss government-funded project is scheduled to end.

Brazil

Brazil, with 55% of the Latin American bean production, has a strong national program. Closer collaboration between the research programs of Brazil and CIAT will be developed to ensure two-way technology flow. Collaborative development of technology that overcomes soil aluminum toxicity and low phosphorus in important bean production zones in Brazil will be emphasized. Projected for 1984 is an outposted research scientist in Brazil who will work with Brazilian scientists as part of national bean activities and also act as a liaison with CIAT.

Southern Andean Zone

The Andean Zone is an important bean-consuming area. Production is concentrated on small farms, often in higher elevations. Although production systems vary, climbing beans are important. Little research has been done in the region. There is a great opportunity for the Bean Program to develop—in collaboration with these national programs—new technology in both bush and climbing beans. One outposted regional position is projected for 1986 for the Andean Zone. The staff member probably will be located in Peru, but will be responsible for developing collaboration in all of the subregion, including Argentina, Bolivia, Chile, and Ecuador.

Eastern Africa

Eastern Africa, the second largest tropical bean production region, has a much higher per capita legume consumption (over 50 kilograms per year in some countries) than Latin America. CIAT materials in the IBYAN program are well adapted to African conditions. It is likely that major gains can be made with CIAT assistance, despite the distance involved and germplasm quarantine restrictions. One outposted cooperation scientist is projected for this region. Special project funding will be sought to support this position, followed by Core-funded support starting in 1983. The scientist will be primarily responsible for the network collaboration, training, and regional coordination of germplasm activity. The scientist would lead a team located in the region under special project funding.

Middle East

Additional regional cooperation activities need to be developed for the Middle East; one position is projected for 1986.

Bilateral Arrangements

The Bean Program will continue to use special bilateral funding to cooperate more closely with individual national programs. At the present time one such scientist is working in Peru under Swiss funding.

RICE PROGRAM

Rice is one of the most widely cultivated cereal crops in Latin America and the Caribbean. The area planted to rice is increasing 2.4% annually and production is rising 3.3%. These rates have kept pace with population and income growth, which generates a 3.5% rise in demand each year. For the region as a whole, per capita consumption of rice has been relatively stable over the past fifteen years, although dramatic increases have taken place in Bolivia, Colombia, the Dominion Republic, Guatemala, Haiti, Paraguay and Uruguay. Per capita consumption (paddy rice basis) in the region was 44 kilograms annually during 1976-78.

Net regional imports remain about 150,000 tons per year. Trade within the region has increased to 320,000 tons per year, 36% more than 1963-65 levels.

If demand increases continue at the current 3.5% per year, rice production in Latin America will have to double by the year 2000 in order to satisfy internal demand at current relative price levels. In order to achieve a doubling of production over the next twenty years, rice research must be strengthened and directed to principal constraints.

The CIAT Rice Program, basically a regional program for the Western Hemisphere, collaborates closely with IRRI's efforts in global rice research. Research on major regional constraints is encouraged through an active network of rice researchers collaborating in the International

Rice Testing Program (IRTP). The IRTP is coordinated by an IRRI scientist located at CIAT.

Farming Systems and Constraints

About two-thirds of the regional rice production growth in 1978 came from an increase in area planted (mainly in the upland sector) and one-third from yield increases (mainly in the irrigated sector). However, these overall trends do not accurately reflect the situation in all countries or in all production systems. Some countries are experiencing accelerated growth in production and productivity, while others are making very little progress. The basic causes for this disparity are found in the predominant farming system in each country.

Several quite distinct rice farming systems exist in the region. Often rice production is divided—somewhat misleadingly—into two main systems, irrigated and upland. In 1978, irrigated rice comprised an estimated 2.1 million hectares, or about 28% of the total area; average yield was 3.5 t/ha. Upland rice (i.e., all non-irrigated rice) covered 5.3 million hectares, about 72% of the area; average productivity was 1.3 t/ha. To some extent this division obscures the actual productivity of each farming system and the potential productivity that can be achieved with research on specific constraints.

CIAT work with agroecosystem analysis has begun to identify and classify Latin American rice production areas. Five cropping systems have been identified. An evaluation of each system's contribution to total production will be made when more data are available. The most important distinction this classification makes is the three upland rice production systems. Vast areas of upland rice cover a spectrum of climatic and soil conditions. Progress in achieving substantial improvement in upland rice production through research depends entirely on understanding prevailing environmental conditions where each system is used.

Highly Favored Upland Rice

This system is generally confined to flat areas receiving over 2000 millimeters of rainfall in eight or nine months of the year. Normally, there are no marked dry periods during the rainy season. The alluvial soils are generally slightly to moderately acid and well drained. This system uses modern dwarf varieties, improved agronomic practices and mechanized farming methods. Yields average 2.5 t/ha, but better farms consistently produce 4-5 t/ha. The system is found in parts of Brazil, Central America and Colombia and could be used on the large amount of unexploited land in the region.

Major constraints are grassy weeds after two or three harvests, rice blast (*Pyricularia oryzae*), and lodging. CICA 8, developed in a collaborative program between ICA and CIAT, is the most productive variety available at present for this system in a number of countries.

Moderately Favored Upland Rice

Most of Central America and much of sub-Amazonian Brazil employ this system. It differs from the preceding one in having a shorter wet season with less overall rainfall, and with some dry periods during the growing season. Dwarf varieties used in Central America yield about 2 t/ha. Brazil grows tall varieties yielding an average 1.5 t/ha. Irregular rainfall causes high yield variances.

Constraints include mild to moderate droughts, mineral deficiencies (especially phosphorus), diseases (particularly blast), and weeds.

Unfavored Upland Rice

This system—found in areas having irregular, low total rainfall—is highly mechanized, has low planting densities and utilizes tall varieties producing an average yield of approximately 1 t/ha. Yield variance is extremely high. Much of Brazil's rice is produced with this system in highly acid soils having relatively high levels of aluminum toxicity.

The main system constraint is dry periods occurring during the wet season. This stress is compounded by poor root development associated with aluminum toxicity in the subsoil. The degree of drought seems to affect the severity of blast disease in this system. Phosphorus deficiency is a serious overall constraint, but, at least in the Brazilian case, fertilizer levels are generally adequate, given the limitations imposed by the other constraints.

Rainfed Lowland Rice

This system is a transition one between irrigated and upland and utilizes rainwater trapped and held by field levees. Nevertheless, water deficits and/or deep flooding are common. Dwarf varieties can be grown with adequate water control procedures, but tall varieties predominate. Average yields are 2.0-2.2 t/ha. The crop may be transplanted or directly seeded; few purchased inputs are used. Rainfed rice is important in coastal Ecuador, Colombia's northern coast and the Dominican Republic.

The main problem in this system is inadequate water control, which forces farmers to use tall varieties and, because of the risks involved, low levels of purchased inputs.

Irrigated Rice

Half of the total regional production comes from irrigated rice. This system is found in all countries and predominates in southern Brazil, Colombia, Cuba, Guyana, Nicaragua, Peru, Suriname, Venezuela, and Southern Cone countries. Average national yields range from 3 to over 5 t/ha. The system continues to have a comparative advantage in maintaining and further increasing national yields and stability of supply. Increasing production costs are starting to force farmers to adopt other systems in many countries.

Important constraints include rice blast, weak stems and lodging and, in some countries, suitable grain quality in the varieties available. Infrastructure problems in some countries limit the application of existing technology. The Southern Cone countries still grow tall varieties because dwarf materials with sufficient cold tolerance have not been developed. In addition, this area has very stringent grain quality requirements for the export market. In Chile, where the entire crop is of the Japonica type, the basic constraint is the lack of high-yielding varieties.

Program Objectives

Specific objectives for Rice Program work – in collaboration with national institutions in the Western Hemisphere – during the 1980s include:

(a) Continuing to develop germplasm-based technology designed to overcome the principal constraints to increased production of irrigated rice;

(b) Developing new germplasm-based technology to improve productivity and stability of supply, particularly in the region's more favored upland rice environments;

(c) Continuing active collaboration with IRRI in rice research, especially the IRTP activities; and,

(d) Continuing to help strengthen national rice research programs through training, consultative visits, and support to the active network of rice researchers which was established in the last ten years.

Research Strategy

Since its beginning in 1969, the Rice Program's basic strategy has been to improve yields and production of irrigated rice in the region. This strategy was adopted because: (a) irrigated rice offered the greatest opportunity for rapid gains, (b) irrigated rice technology was more easily generated and transferred than that for other production systems; and, (c) limited Core resources did not permit simultaneous work on all production systems.

Varietal improvement has been the key element in CIAT's irrigated rice research strategy. Tall varieties were used throughout the area before 1968, when IR 8 was introduced. An immediate increase in productivity of 2 t/ha confirmed the decision to work exclusively on dwarf materials for this system. The research has sought varieties combining dwarfing, strong stems, insensitivity to photoperiod, long grain with clear endosperm, resistance to the leafhopper (*Sogatodes*) and blast resistance. Earliness and improved adaptability to acid soils are more recent varietal objectives.

Once improved dwarf lines and varieties were produced, research was extended to developing appropriate cultural practices for the high-yielding varieties. Seeding rates and methods, fertilizer practices and timing of weed control were emphasized. Improvement of varieties and cultural practices has continued. Recent emphasis has been on reducing production costs by using combinations of puddling, reduced seed and fertilizer rates and varieties with enhanced disease and pest resistance. Collaborative research with the IFDC on improving nitrogen fertilizer efficiency has recently been initiated, since nitrogen prices are a chief component in higher production costs in the irrigated sector.

The unexpected adoption of the newer dwarf varieties in recent years in the highly and moderately favored upland systems allowed the Program to modify its original strategy. Entries for nurseries and regional yield trials, especially for the two favored upland systems, are selected from the advanced irrigated breeding lines and distributed to national programs for continued local selection and evaluation. The Program has concentrated on *Sogatodes* and rice blast, the two principal biological constraints in virtually all systems. Thus, CIAT has contributed directly to upland systems while focusing on irrigated varieties.

In 1981, CIAT began to expand its activities in upland rice.[12] Allocation of program resources and general research emphasis for the irrigated and upland sectors will differ during the decade because upland research is at a relatively early stage of development in the region. Also, the relative importance of the spectrum of constraints differs between the two sectors.

Figures 4 and 5 show the Program's projected breeding emphasis for each sector. In the irrigated sector the number of crosses will remain rela-

12. A full description of the proposal for CIAT involvement in the upland rice sector is contained in *Upland Rice Research for Latin America: A Report to the TAC Subcommittee on Upland Rice*. CIAT, December 1979.

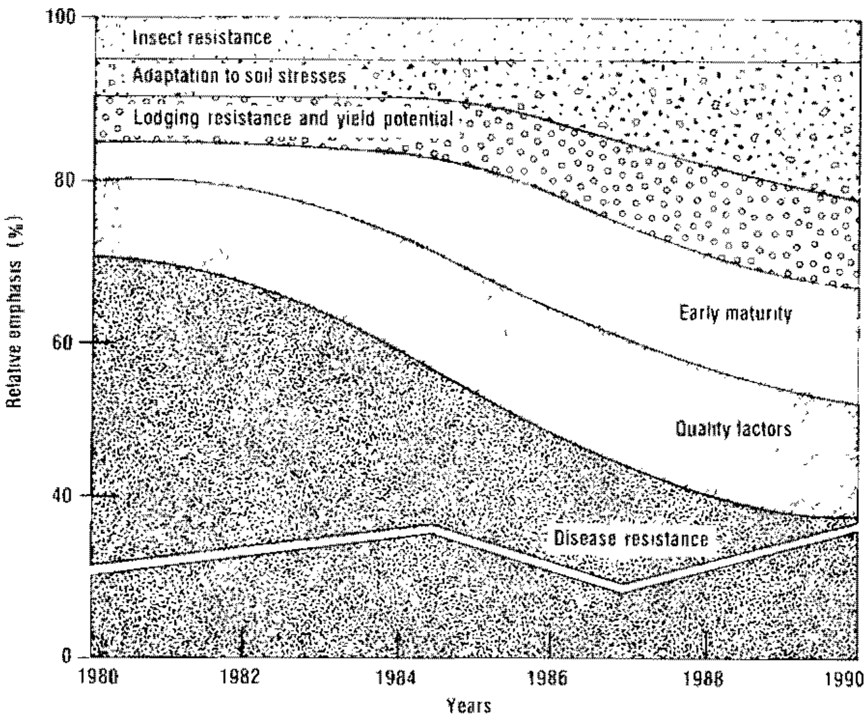


Figure 4. Relative emphases the Rice Program will place on technology development for irrigated rice in the 1980s. Changes in emphases will be reflected in the proportions of crosses in breeding projects designed for general groups of constraints.

tively constant; increased emphasis will be put on breeding for early maturity and adaptation to soil stresses. Relative emphasis on blast will decline since some progress has already been made and blast is not as serious as in the upland sector. Many more crosses will be made for the upland sector. Major work will include breeding for stable blast resistance and research on such general adaptation problems as drought, low soil phosphorus and aluminum toxicity.

The following specific strategies for the 1980s have been developed for the various production systems. Different approaches are evident, particularly with the systems in the upland sector.

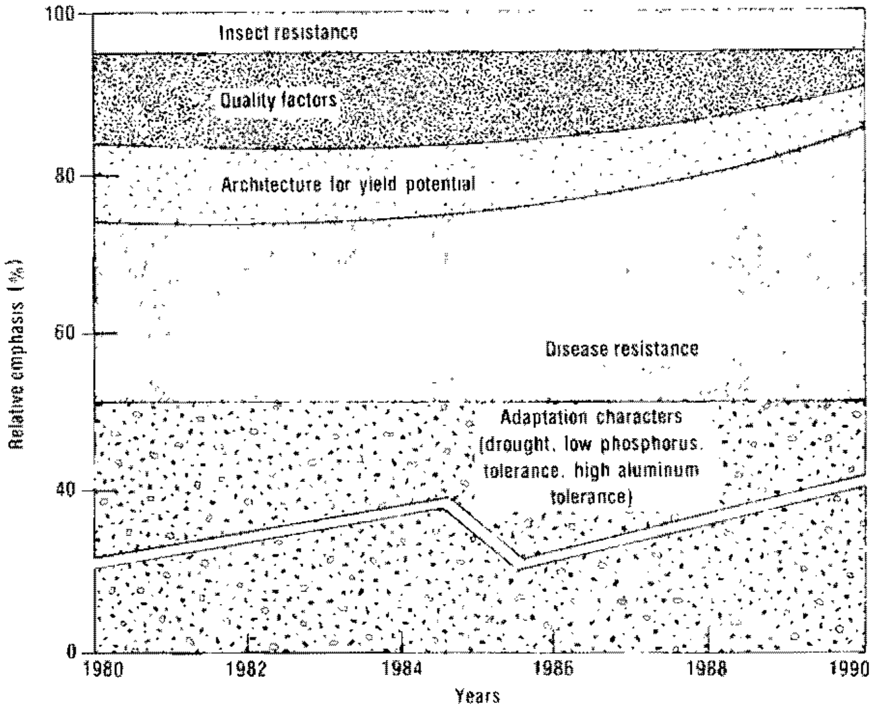


Figure 5. Relative emphases the Rice Program will place on technology development for upland rice in the 1980s. While total numbers of crosses are expected to remain about level for irrigated rice problems, the number of crosses for upland problems will increase markedly.

Highly Favored Upland Rice

As already mentioned, selected lines from the irrigated breeding program can serve as the varietal component for expanding this system in the region. Selections combining slow-blasting resistance to *Pyricularia* and clear grain endosperm will be evaluated, in collaboration with the respective national programs, in the Plochic Valley of Guatemala and in Uraba and La Libertad, Colombia. Evaluation of direct seeding combined with herbicide use will be undertaken with ICA and the Colombian Rice Federation (FEDEARROZ) in order to develop agronomic practices with wider applicability. CIAT will emphasize this sector because of its production potential and low production costs.

Moderately Favored Upland Rice

Because of the severity of constraints, a special research effort will be necessary to find the varietal component for the areas under this system. A collaborative program with Brazil and/or other countries is needed in order to provide for screening and selection under production conditions. Such a program would allow two generations of breeding material to be screened in one year (i.e., from April to September in Colombia, and from November to March in Brazil). An exchange of segregating and advanced lines by collaborating programs would halve the time required to breed new materials. CIAT research in mutational breeding has indicated that dwarf lines can be produced from tall materials in the M_1 generation, with some adaptation features for the soil and climatic constraints of this sector. Early generation selection also will continue in Costa Rica, Guatemala and Panama, in collaboration with national institutions.

Unfavored Upland Rice

Severe drought stress, combined with acid soil problems, is a condition not found in Colombia and CIAT has no comparative advantage for direct involvement in this system. The Brazilian national program will continue to give substantial resources to these difficult problems. CIAT will collaborate by providing materials with slow-blasting characteristics and shortened, mutant materials with tolerance to acid soil and drought. Obviously, any gains made for the more favored areas will have some application in the less favored system.

Rainfed Lowland Rice

Water control, the limiting production factor, must be improved at regional, community and farm levels. The potential contribution from civil engineering far exceeds that of research on other components. As water control is improved, this system can make more use of existing technology from the irrigated sector. CIAT will continue to provide improved germplasm.

Irrigated Rice

This system will continue to receive major attention. Stable resistance to blast is expected to increase regional yields by 0.5 t/ha; a similar gain is expected from better dwarf plant types with improved lodging resistance. Introduction and evaluation of Korean Japonica dwarfs in Chile could have a dramatic effect on that country's production.

New Production System Research

The vast savanna regions of Colombia, Venezuela and elsewhere receive high rainfall, but the soils are extremely acid and infertile. Although no rice is produced on these lands there is a clear need for a crop component in the pasture system being developed by the Tropical Pastures Program. Cropping would facilitate land preparation for pasture establishment. Upland rice could become a pioneer crop enabling the economically sound development of the Llanos, as has been the case in the Brazilian Cerrados.

A minimum-input, minimum-tillage upland rice system using cultivars having tolerance to acid soil and blast is a researchable possibility. Mutant dwarfs of upland land races and tall materials known to have tolerance to aluminum toxicity will be evaluated for yield potential, with a target yield of 2.0 to 2.5 t/ha. Agronomic evaluation of tillage techniques including sod seeding will be investigated at Carimagua. This research will be integrated with the Tropical Pastures Program.

Program Accomplishments

The excellent early collaboration between the CIAT Rice Program and ICA provided a very rapid impact, both in and outside of Colombia. In addition, the strength of the IRRI program is an extremely important component of the successes achieved. From its cooperative program with CIAT, ICA has released seven dwarf varieties with high yield potential. All of these varieties are now grown internationally. CIAT breeding lines have resulted in more than thirty other dwarf varieties released by national programs in the region. These varieties are now grown on about 1.5 million hectares annually in irrigated, highly favored and moderately favored upland systems. These new varieties, together with improved cultural practices, have made it possible to obtain 1 to 2 t/ha of additional rice. The surge in production in countries with these farming systems has equalled or exceeded population growth, and nearly all countries have reached effective self-sufficiency.

Rice consumption has continued to increase as rice has become cheaper in relation to alternative foods. A detailed analysis of the impact of new rice technology in Colombia showed that low-income consumers have received most of the economic benefits resulting from the large production gains.[13]

CIAT has provided professional training in production agronomy,

13. G. M. Scobie and R. Posada, *The Impact of High Yielding Rice Varieties in Latin America: With Special Emphasis on Colombia*. CIAT series JE-01 (Cali, Colombia: CIAT, April 1977.)

breeding and pathology to 211 rice researchers from twenty-three countries. Consequently, there is an effective regional network of cooperators for exchanging information and evaluating technology. The Program's regional activities include IRTP nurseries, monitoring tours, production courses within countries, and biennial conferences at CIAT for research workers.

Research over the next decade should lead to a marked increase in rice productivity in the region, particularly in those systems at the more favored end of the spectrum.

Research Staffing Projections

The Rice Program projects that a Core team of six scientists will be sufficient to study the production constraints in irrigated rice and alternative systems. These problems are not entirely mutually exclusive; concentrated attention on the more favored systems will produce results useful in the most difficult farming systems (subsistence upland rice, unfavored upland rice and rainfed lowland rice). It is difficult to predict whether significant research contributions will be made to these latter systems. The Rice Program will be alert to research findings directly applicable to those systems. The six-man research team would be responsible for these activities:

(a) An irrigated rice breeder, based at CIAT, will conduct more research on lodging resistance in dwarf varieties, development of early maturing varieties for drier areas, stable resistance to blast, and improved grain quality. Research will continue on maintenance testing for *Sogatodes* resistance to ensure that the pest does not again become economically important. Since CIAT-Palmira is not the ideal location for evaluations for these constraints, selection will be intensified at ICA experiment stations and other areas in Colombia.

(b) The upland rice breeder will work on stable resistance to blast and tolerance to acid soils (aluminum toxicity and phosphorus deficiency). Grain quality and *Sogatodes* resistance work will be similar to that of the irrigated program. It will include research on moderately tall to tall materials, as well as dwarfs. Selection and early generation yield evaluations will occur at ICA-La Libertad in Colombia and, possibly, in Brazil in collaboration with EMBRAPA.

(c) The agronomist will participate in both the irrigated and upland systems. Shifts in production emphasis in irrigated areas to more marginal soils make it necessary to study those general problems.

Research on general agronomic problems in upland rice will include evaluating the agronomic practices for the new germplasm, which could be of different plant type than the land races now being utilized.

(d) A physiologist/agronomist for upland research will be concerned with many production constraints not found in irrigated rice. A major research effort will be started on screening methodologies for evaluating drought and acid soil tolerances. This scientist may lead the development of a low-cost production system for upland rice on infertile savanna soils. This position is projected for 1983.

(e) Research by a pathologist will continue on rice blast, and specifically on methods to detect and evaluate slow blasting in distinct growth stages and methods to include required levels of disease pressure in populations and lines. Maintenance research and monitoring will continue on the minor diseases to avoid situations that could elevate them to the level of economic constraints.

(f) The economist will help other scientists in defining the best allocation of research resources among different rice cropping systems. Classificiation of the cropping systems and delineation of their environmental boundaries will be carried out in conjunction with the agroecosystem analysis group which is proposed in this plan. The economist will evaluate rice production potential at the country level and conduct surveys of the main rice production areas, area planted, and yield and production per cropping system. He will also evaluate how production increases will affect prices and potential benefits to be received by the various income strata in urban and rural areas. International trade possibilities associated with expanded rice production in selected countries will also be analyzed. The rice economics position is projected for 1982.

(g) Although not a CIAT-budgeted staff member, the IRRI liaison scientist fulfills a crucial role in the rice team. His duties involve the selection, distribution and evaluation of germplasm nurseries from IRRI. Nurseries created for distinct purposes are sent to all developing countries in the Western Hemisphere. Also, special nurseries of elite CIAT breeding lines are distributed and evaluated through his services. The position requires extensive international travel to promote national use of promising nursery materials. With the growing volume of nurseries and locations, and CIAT's expanded research in upland systems, it is doubtful that only one research scientist can continue to handle the responsibilities of this position. Since all IRTP activities in the region are funded by IRRI, consultations will be held with that organization on future expansion of the program.

Regional Cooperation

International rice activities have included activities of the IRRI liaison scientist, international traveling and consulting by all staff, training of national program researchers at CIAT and supporting in-country training courses for production and extension specialists. This strategy has been relatively satisfactory and will be strengthened by the additional Core staff projected for the Program in the 1980s. No Core-funded regional cooperation staff is projected for the Rice Program. Should the demand for more direct CIAT contact with national programs increase greatly, it may be necessary to seek bilateral and/or regional special projects for this purpose.

TROPICAL PASTURES PROGRAM

The abundance of underutilized land resources in tropical Latin America seems inconsistent with the existence of a large sector of small farmers. In most countries the coexistence of intensive farming–both large- and small-scale–and the abundance of underutilized land is explained by a combination of two factors: (a) the low or fragile fertility status of the soils in the agricultural frontier, and (b) the poor infrastructure development in these areas. Crop production with available technology is unprofitable in these areas without sizeable subsidies. Productivity is low under the poor fertility conditions, and soil amendments are not economical due to high input and transportation costs.

Tropical and subtropical areas of America have some 800 million hectares of significantly underutilized savannas and forests, two-thirds of which have acid, infertile soils (Oxisols and Ultisols). These areas have great agricultural potential since they have abundant sunshine, adequate rainfall and favorable temperature regimes for extended growing seasons. Topography and soil physical properties are also generally favorable.

In order to contribute to the development of ecologically sound, stable, and productive systems for these areas, the Center aims to help broaden the resource base of Latin American agriculture through a low-cost, low-input approach based on the selection of species most adapted to local edaphic and climatic conditions. Tropical pastures are CIAT's major effort for these areas and associated efforts in upland rice and cassava were described previously.

Potential for Pasture Improvement

Tropical Latin America has an estimated 190 million head of cattle, about 20% of the world total. Per capita beef consumption in the region of 16 kilograms per year is significantly higher than in Africa and Asia, and about two-thirds that of Europe.

During the last two decades consistent increases in beef production have been recorded in most countries of the region but with few exceptions, supplies have lagged behind demand growth.[14] As a result, beef prices increased in real terms in most countries during the period. These price increases have serious implications, since the proportion of family income spent on beef is extremely high among low-income urban consumers.

A study by CIAT[15] using data from the Family Budget Survey of twelve Latin American cities[16] showed that the lowest income group (quartile) in these urban centers spends 6-18% of their family income on beef. Beef purchases represent 10-25% of their total food expenditures. Similarly, low-income families spend 4-12% of their income (or between 7-19% of the food budget) on dairy products. These latter percentages are probably even higher in rural areas.

The extremely high income elasticities estimated for the low-income quartiles in the twelve cities (between 0.8 and 1.3 for beef, and 0.8 and 1.6 for milk) clearly indicate the strong preference for these commodities among the urban poor. Hence, beef and milk should be considered staple foods and wage goods in tropical Latin America. However, as incomes increase in the region, demand for beef and milk is expected to continue to rise faster than production. The resulting price increases will have a negative effect on both the diets and the incomes of the poor.

Such trends can be counteracted if appropriate livestock production technology is developed for the region's vast, underutilized land areas. These areas have an extremely high potential for cattle production with little or no opportunity costs. The current average stocking rate in the acid savannas of 0.12 animal/ha can potentially be increased more than tenfold. In addition, annual beef production per animal could be more than doubled. These areas could also contribute significantly to increased milk production. Most milk and dairy products consumed in the region come

14. CIAT. *Latin America: Trend Highlights of CIAT Commodities.* Internal Document Econ. 1.6 (Cali, Colombia: CIAT, April 1981).

15. E. Rubinstein and G. Nores. *Beef Expenditures by Income Strata in Twelve Cities of Latin America.* Internal Document (Cali, Colombia: CIAT, June 1979).

16. Survey conducted by ECIEL, Brookings Institute, and also by FIPE, University of Sao Paulo, during the period of 1968-72.

from small and medium beef herds, usually crosses of native ("criollo") and Zebu breeds. This type of dual-output production system is found not only in the densely populated areas with fertile soils, but is also in frontier areas with acid, infertile soils.

The Tropical Pastures Program seeks to develop – in collaboration with national programs – appropriate, pasture-based animal production technology for the acid, infertile soil regions of tropical Latin America. Overall objectives are:

(a) to increase beef and milk production and productivity;
(b) to promote economically and ecologically sound expansion of the agricultural frontier in tropical America; and,
(c) to release more fertile land for expanded crop production.

Rather than correcting soil deficiencies with large amounts of fertilizer, CIAT has adopted a low-cost, low-input approach of selecting grass and legume species adapted to acid, infertile soils. As a result of the Program's activities, pasture production systems will be developed that provide adequate forage throughout the year, complemented by cost-effective animal management and animal health practices. National research and extension institutions are both collaborators and clients; cattle producers are regarded as the users of the technology; and, both producers and consumers are regarded as the principal beneficiaries, since the final objective is to increase production and thereby lower relative prices of beef and milk in the region.

Program History

The Tropical Pastures Program evolved through three stages from its initial broad spectrum of disciplines related to animal production.

During the formative stage (1969-74), the Beef Production Systems Program dealt with the identification of problems and potential solutions in the areas of animal health, animal management and cattle production systems. A relatively small proportion of program resources was devoted to pastures and forages. Most field research was conducted in Colombia. Information collected during this initial period showed that low cattle productivity in tropical Latin America was due mainly to extreme malnutrition and nutrition-related diseases. Lack of good quality, year-round forage was identified as the most common critical constraint to increased production.

Between 1975 and 1977, the (new) Beef Production Program concentrated more on the acid, infertile savannas of Latin America. The program broadened the geographical scope of its activities to include other countries and sharply narrowed its research focus to pastures with the goal of removing the principal production constraints in the savanna ecosystem.

Grazing experiments in the Colombian Llanos documented the limited potential of the native savannas. It became evident that the most serious limitations were the low productivity and poor quality of most native species combined with the low fertility status of the soils and varying degrees of seasonal water stress. These limitations resulted in low animal production, malnutrition and high susceptibility to disease. Overall productivity, both per unit area and per animal unit, was extremely low.

Striking improvements in herd performance on native savanna were obtained by using appropriate mineral supplementation. The use of well-adapted exotic grasses such as *Brachiaria decumbens* provided dramatic increases in carrying capacity and production per unit area. However, production per animal continued to be disappointing, especially the breeding herd's reproductive performance. Protein supplementation was successful but too costly.

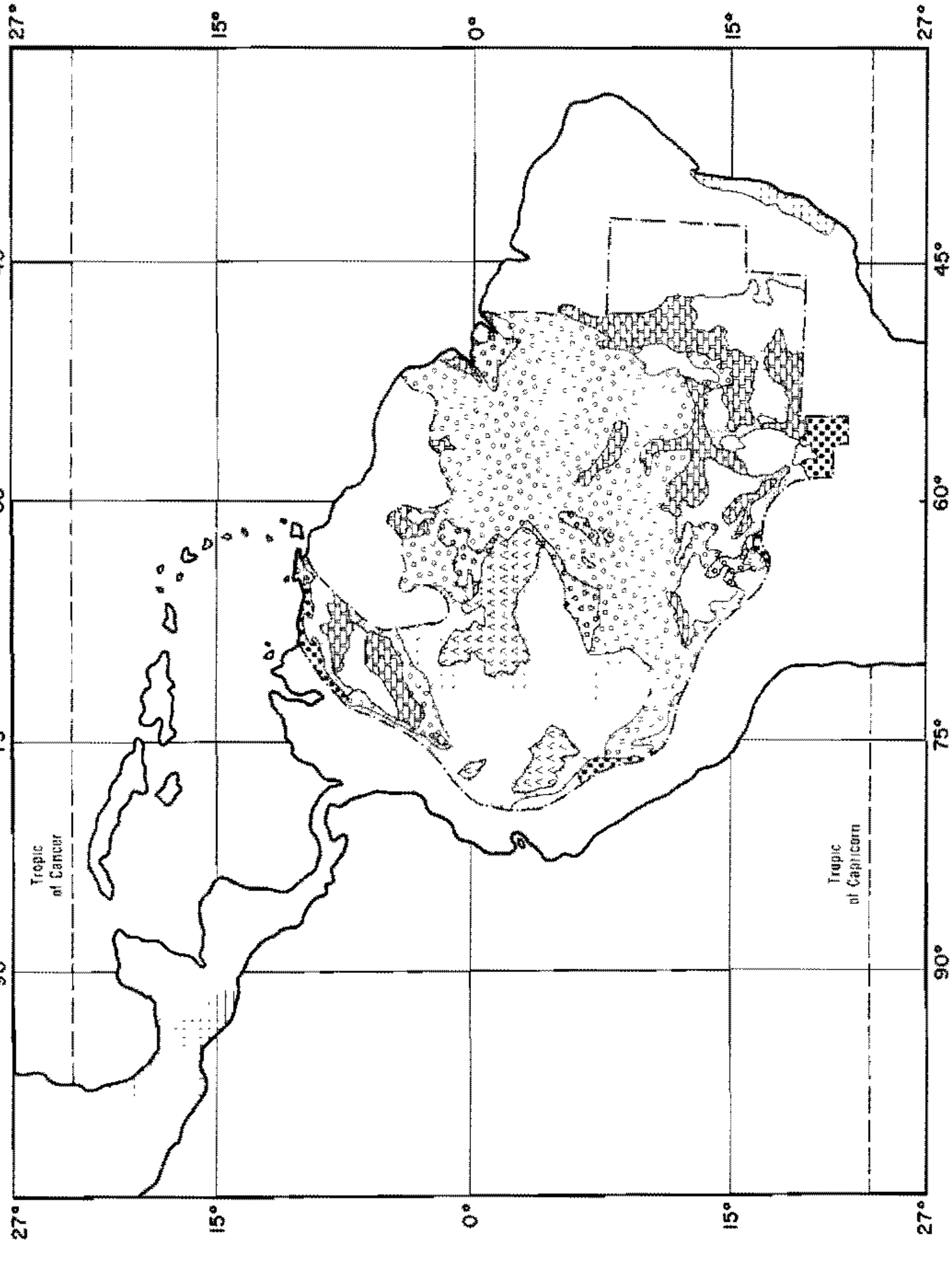
Preliminary experimental results obtained during this period with grass-legume pastures indicated clearly that persistent associations under low-input conditions could provide an economically attractive solution to the problem. During 1978 the Program consolidated its research along these lines, and its research was geared to obtaining inexpensive grass-legume associations for the acid soil savannas. To reflect this new focus, the Program was renamed the Tropical Pastures Program in mid-1979.

Area of Interest

A survey of tropical Latin American regions with acid, infertile soils was initiated in 1978. This classification of land resources in terms of climate, landscape, and soils provides a geographically oriented ecological perspective to the Program's area of interest and serves as the basis for its research strategy. Total wet season potential evapotranspiration (TWPE), a measure of energy available for plant growth during the wet season, was shown to provide a quantitative method to account for native vegetation distribution. The area has been divided into five major agroecological zones (Fig. 6):

Tropical well-drained savannas

"Llanos" type. This ecosystem is represented by the well-drained savannas of Colombia, Guyana, Suriname and Venezuela and the savannas of Roraima and Amapa in Brazil.



27°
15°
0°
15°
27°
45°
60°
75°
90°
Tropic of Cancer
Tropic of Capricorn

WELL-DRAINED ISOHYPERTHERMIC SAVANNAS (mostly Llanos). TWPE[a] 901-1060 mm, 6-8 months wet season, WSMT[b] > 23.5°C.

WELL-DRAINED ISOTHERMIC SAVANNAS (mostly Cerrados). TWPE 901-1060 mm, 6-8 months wet season, WSMT < 23.5°C.

POORLY DRAINED SAVANNAS. (Found in lowlands of tropical South America, in varying climatic circumstances.)

SEMI-EVERGREEN SEASONAL FOREST. TWPE 1061-1300 mm, 8-9 months wet season, WSMT > 23.5°C.

TROPICAL RAIN FOREST. TWPE > 1300 mm, > 9 months wet season, WSMT > 23.5°C.

POORLY DRAINED FOREST REGIONS.

DECIDUOUS FORESTS, CAATINGA[c] etc.

OTHERS[c]

AREA CURRENTLY BEING ANALYZED

AREA CURRENTLY BEING STUDIED

[a]TWPE: Total Wet Season Potential Evapotranspiration.

[b]WSMT: Wet Season Mean Temperature.

[c]Not included in the activity area of the Tropical Pasture Program.

Figure 6. General extensions of the ecosystems in which the Tropical Pastures Program is or will be working during the 1980s

"Cerrados" type. The primary area is the Brazilian Cerrado, which extends into Paraguay and Bolivia.

Tropical poorly drained savannas

Regions. Representative areas include the Beni in Bolivia, the Pantanal in Brazil, the Casanare region in Colombia and the Apure region in Venezuela.

Islands. Flooded savanna "islands" are found throughout the well-drained savannas and forest areas.

Tropical forest

Seasonal forests. These are found in vast areas in the Amazon and Orinoco basins in Bolivia, Brazil, Colombia, Guyana, Peru, Suriname and Venezuela, and along the Atlantic coast of Central America.

Rainforests. Areas include the upper Amazon basin of northwestern Brazil, Colombia, Ecuador, northeastern Peru and Venezuela.

The classification makes it easier to understand the differential response of germplasm observed across ecosystems. While preliminary results of regional trials generally indicate wide adaptability of the most promising grass and legume germplasm, a distinct response to the different ecosystems is shown in many cases. Edaphic conditions have some effect on germplasm response, but these differences are due mainly to climatic variations. Differences in legume performance are due largely to strong environmental interactions with diseases and pests. Thus, germplasm should be tested in all ecosystems. To date, major emphasis has been in the two well-drained savanna ecosystems through collaborative research with ICA at Carimagua in the Colombian Llanos, and with EMBRAPA at the Cerrado Center near Brasilia, where three research staff were outposted in 1978. During 1979-80, regional trials were established in the other ecosystems, to obtain preliminary data on the degree of adaptation of many species to these distinct environments. However, major research thrusts are yet to start in these three ecosystems.

Research Accomplishments

The Program has achieved many research advances. Major accomplishments for tropical well-drained savannas, especially the Llanos type, include:

(a) The identification through farm surveys of major farm constraints to cattle production in savanna ecosystems and in-depth characterization of cattle production systems in Brazil, Colombia and Venezuela (a project partially funded by GTZ).

(b) The identification of several genera and species that are well adapted to the conditions of one or more ecosystems: *Andropogon gayanus, Brachiaria* spp., *Stylosanthes* spp., *Desmodium ovalifolium, Pueraria phaseoloides, Zornia* spp., and *Centrosema* spp.

(c) The determination of nutrient requirements of the more promising accessions for the well-drained savannas.

(d) The development of simple, low-cost pasture establishment methods adapted to savanna conditions.

(e) The definition of the potential productivity of a large number of pasture grazing alternatives in the Llanos ecosystem, including native pastures, planted grass pastures and numerous grass-legume associations. Various grass-legume associations in low-input, controlled grazing experiments have produced annual liveweight gains of 200 kilograms or more per animal, while yielding more than 300 kg/ha.

(f) The identification and epidemiological assessment of major cattle diseases in the area and their relative importance.

(g) The *ex-ante* determination of expected profitability of various pasture systems.

(h) Postgraduate training of 305 professionals from collaborating institutions in twenty-two countries in the region.

(i) The evaluation and subsequent release by Colombia and Brazil of a new grass cultivar derived from *A. gayanus* CIAT 621, and the delivery of large amounts of basic seed to each country.

Other accomplishments of more general applicability across ecosystems are:

(a) The computerized inventory of land resources in the area of interest, with edaphic, topographic, and climatic characterization of the region organized in a systematic and easily retrievable manner.

(b) The development of a germplasm bank of 7200 accessions, with a high proportion of material specifically collected from acid soil areas of many regions in the world. This germplasm pool is complemented by a collection of Rhizobia from the same areas.

(c) The development of rapid screening techniques to determine tolerance of plants and Rhizobia to soil acidity.

(d) The inventory of pasture insects and diseases, by forage species and ecosystem, with an assessment of current relative importance.

(e) The initial development of a collaborative Regional Trial Network to evaluate germplasm for adaptation, productivity and persistence throughout the area of interest.

Technical Constraints

Despite these significant advances, many general and specific constraints must be overcome.

The savanna ecosystems are characterized by native vegetation of very low nutritive value – the major limitation to increased animal production. The low feeding value of forages results from species with low primary productivity and quality in combination with the extreme acidity and low fertility of the soils. Soil pH varies between 3.6 and 5.0 in the area. Aluminum saturation is high, often reaching 70-90%. Available phosphorus levels are very low, usually below 3 parts per million. Rather than using heavy applications of lime and fertilizer to overcome this constraint, the Program has adopted the approach of selecting adapted species.

Lack of infrastructure is common and varies in severity, depending upon topography and distance to market. Economic conditions (on-farm input and output prices, and access to credit and extension mechanisms) vary between countries and with distance to market. Machinery requirements, high costs of pasture establishment and maintenance, and erosion hazards during pasture establishment are other serious constraints to the adoption of new pasture systems.

Since all of these constraints are common to the five major ecosystems, the technical solutions to the overall nutritional constraints must be inexpensive, of a low-input nature and suitable for a wide range of management levels. Variability observed in existing production systems within and across ecosystems and the need to develop alternatives for colonization programs suggest that various pasture systems are needed. This will allow farmers to adopt those pasture solutions that best suit their particular situation.

Other critical constraints vary between regions. Water stress is critical in the Cerrado type savannas but is less important in the Llanos type; excess water is the problem in the poorly drained savannas. Therefore, lack of good quality forage is the major constraint in the well-drained savannas during the dry season; in the poorly drained savannas, forage availability is the major constraint during the wet season.

In terms of persistence and productivity, the success or failure of a species adapted to the physical environment often depends on its reaction to diseases and insects. Most promising forage legume genera (*Stylosanthes, Zornia, Centrosema* and *Aeschynomene*) are native to the Latin American tropics and are widely distributed. Hence, disease and insect pests affecting these forage legumes are also widely distributed. Disease and insect surveys and regional trials provide clear evidence that several important diseases and insects are found in different geographical areas and that tolerance to them differs within species. This suggests the need for using many locations to screen a broad range of germplasm of promising species and genera for which critical disease or insect problems have been identified. Also, exotic materials should be introduced. Rigorous selection by ecosystem is essential to overcome this major constraint.

Program Objectives, Organization and Research Strategy

The strategy to achieve the Tropical Pastures Program's goal of developing low-cost, low-input pasture technology for tropical America's acid, infertile soils is based on:

(a) selecting pasture germplasm adapted to environmental constraints (climate and soils) as well as to pests and diseases;
(b) developing persistent and productive pastures and basic practices for pasture utilization and management; and,
(c) studying the role of improved pastures in the production systems and development of complementary animal management and animal health systems components.

The tropical pastures research team is comprised of twenty senior scientists; fifteen are based at headquarters, two are based at Carimagua, and three are outposted at CPAC near Brasilia. The scientists work in three functional groupings:

- *Germplasm development* (collection, selection and breeding) *and evaluation* includes the agronomists and breeders working in collection and agronomic evaluation in major screening sites and regional trials, and support specialists in the areas of soil microbiology, pathology, and entomology (nine senior scientists).
- *Pasture evaluation and development* includes pasture agronomists and plant and animal nutritionists who work in regional trials, soil fertility, pasture establishment and maintenance, seed production, pasture evaluation under grazing, and pasture management (six senior scientists).
- *Pasture evaluation in production systems* includes animal scientists, a veterinarian and an economist who evaluate pastures in alternative

cattle production systems and related animal management and animal health practices (four senior scientists).

The activities of these three groups are based on a dynamic flow of germplasm and the development of appropriate production technology for the most promising materials (Fig. 7). The basic strategy is to exploit natural variability and adaptation of species to the various ecosystems. The research strategy consists of a sequence of germplasm screening and evaluation steps geared toward achieving the stated objectives. These steps, applied up to now only in the well-drained savanna ecosystems, are:

(a) The collection and assembly of pasture germplasm and *Rhizobium* banks based on geographically broad but ecosystem-specific criteria. Legumes receive emphasis because of their inherent nitrogen fixing capacity and nutritional quality, especially during the dry season.
(b) An extensive characterization and performance evaluation of accessions, which often include agronomically unknown species. Characteristics sought include: tolerance to extreme soil acidity, high aluminum saturation and low base status; adaptation to low phosphorus soils; nitrogen fixation potential (in legumes); resistance to diseases and insects; tolerance to burning and drought; vigor, productivity and good distribution of yield; seed production; ease of establishment and spreading; freedom from toxins and estrogens; and high forage quality and palatability.
(c) The determination of minimum nutrient requirements for each species and the development of low-cost methods of establishment and maintenance, as well as grazing management strategies required for best pasture persistence and animal productivity.
(d) The estimation, for each type of pasture (usually grass-legume associations), of animal productivity potential per unit area and per animal unit, with associated economic input/output values.
(e) The selection and formation of cultivars, candidates for release by national programs, and the production of basic seed by developing production technologies to assure seed availability. This includes defining seed production systems and determining environmental requirements for satisfactory commercial seed yields.

In summary, initial emphasis is upon collection of accessions, evaluation of growth patterns, and assessment of reaction to acid, infertile soil conditions. Then reaction to diseases and insects within each ecosystem is determined. Finally, accessions are evaluated after exposure to competi-

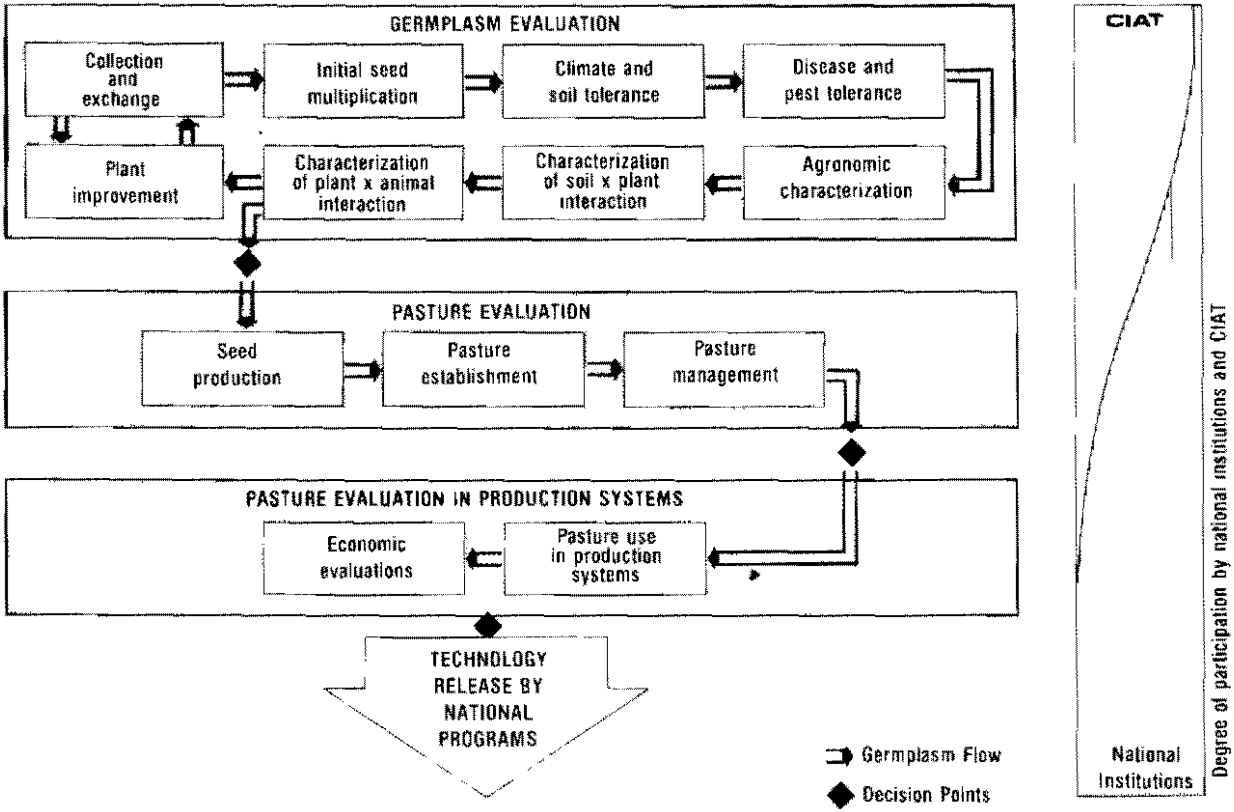


Figure 7. Germplasm flow and research steps of the Tropical Pastures Program

tion and grazing. As this evaluation process progresses, there is a continuing reduction in the number of accessions utilized.

Germplasm accessions are progressively classified in five categories reflecting the degree of promise of accessions in the systematic screening and evaluation process. After testing, those accessions that meet desired requirements are promoted to a higher category where they form the basis for planning the next phase of the evaluation. The relative ranking of accessions within species is done separately for each ecosystem. Requirements for progression to a higher category vary with the species, depending upon the principal limitations of the species. The limiting constraint of each species is used as the promotion criterion.

The germplasm bank (Category 1 accessions) is maintained at CIAT-Palmira as seed and/or single potted plants, and at CIAT-Quilichao as spaced plants in the field. Activities at these locations include identification, maintenance, multiplication and initial characterization of materials. All accessions (Category I) are evaluated for adaptation to edaphic conditions in introduction gardens at both Carimagua and Brasilia. Accessions advanced to Category II undergo agronomic evaluation at both Carimagua and Brasilia. Selected accessions are also evaluated in preliminary Regional Trials (Type A) in the various ecosystems. Some of them are retested at additional selected locations in Type B Regional Trials, under subecosystem conditions.

Selected accessions advanced to Category III are associated with grasses, and placed under heavy intermittent grazing to assess their resistance to trampling, competitive ability, dry matter productivity, quality and relative grazing preference. These evaluations are conducted at Carimagua, Brasilia and CIAT-Quilichao, as well as in Type C Regional Trial locations. In addition, specific grass-legume mixtures are grazed under different intensities and maturities to determine relative palatability of associated species.

In Category IV the pasture is evaluated for potential animal productivity, and its appropriate grazing management is determined. Measurements are made of sward botanical composition trends over time, presentation yields, animal grazing preferences, and nutritive value of the species, in order to explain the recorded animal productivity. Also, Regional Trials (Type D) are assembled to measure the performance of selected improved pastures against the traditional pasture in given animal production systems in specific areas.

Finally, in Category V, the objective is to complete a profile of species and varietal evaluation, to obtain simple technology prior to release of the cultivar by national programs, and to define the best pasture utilization under different production systems.

Program Projections

Projections for the 1980s are based on two factors. First, progress on the stated objectives will shift relatively more emphasis towards the advanced stages of pasture evaluation and outreach. Second, better knowledge of the area of interest and of germplasm performance will result in systematic organization of the Program's germplasm evaluation strategy within each major ecosystem.

While these developments will force considerable changes in emphasis within the Program, they will result in only minor changes and additions to the Core research staff. Major changes are projected in the allocation of staff time to principal activities and ecosystems. Research activities will continue to be emphasized during the first half of the decade. Outreach activities will be increased gradually and require almost one-third of the staff time toward the end of the period. Research on the well-drained savanna ecosystems will continue, but new research activities will begin early in the decade for the poorly drained savannas and the humid tropics (Fig. 8A).

Evolution of Research Emphasis

Staff time allocated to germplasm development and evaluation will be maintained during the first half of the decade, but is expected to decline during the second half as promising germplasm is upgraded in status (Fig. 8B). Also, more staff time will be devoted to pasture development and evaluation in both controlled experiments and actual production systems.

Germplasm Development and Evaluation. The Program will continue to exploit natural variability; therefore, germplasm collection will play a critical role throughout the period. In order to increase the cost effectiveness of the overall program, collection will increase during the first half of the decade but should decline later as key species are identified and the Program's collection needs become more specific (Fig. 9A). Future collections will focus on promising key species identified for each major ecosystem and on specific goals such as tolerance to anthracnose in *Stylosanthes* spp. and tolerance to *Sphaceloma* in *Zornia* spp.

Although most collections will be in tropical Latin American areas with acid, infertile soils, some specific collections will be done in areas with similar soils in Southeast Asia. These collections will focus on such genera as *Desmodium* and *Pueraria* that are adapted to acid soils in general, and to

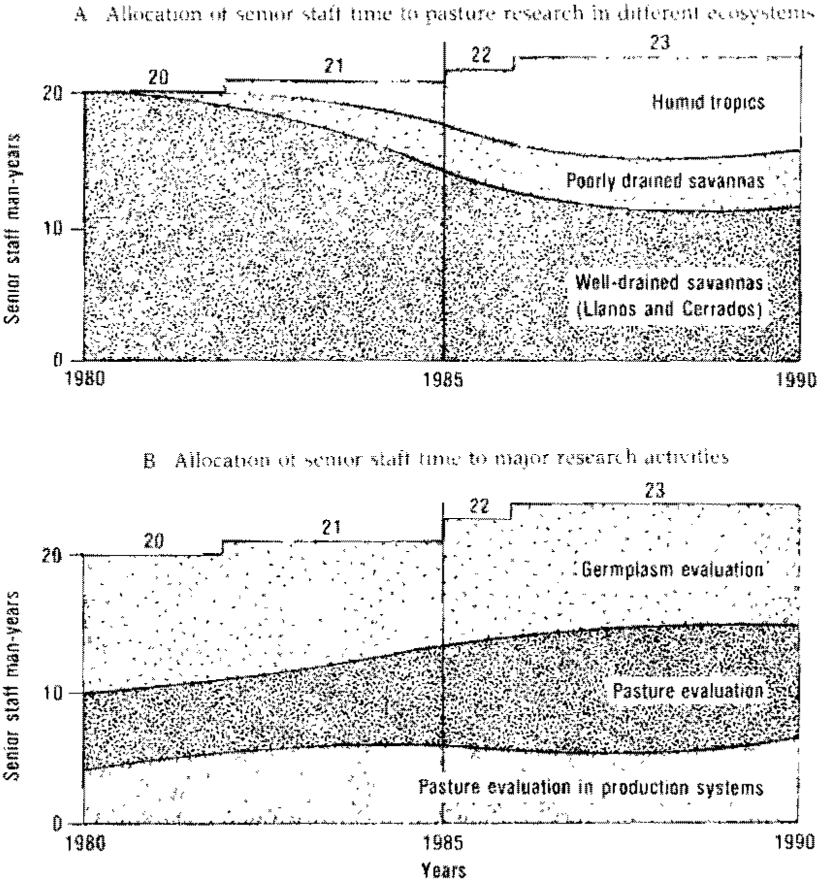


Figure 8 Estimated allocation of senior staff time in the Tropical Pastures Program during the 1980s

the humid tropics in particular. For grasses, emphasis will be placed on germplasm exchange to obtain as much variability as possible in such genera as *Brachiaria, Panicum,* and *Andropogon,* which have all shown general adaptation to these edaphic conditions.

Agronomists will continue screening for promising species in both well-drained savanna ecosystems. When well-adapted species are identified, emphasis will be shifted to identifying lines with superior overall performance. The pathologist and entomologist will assist in identifying

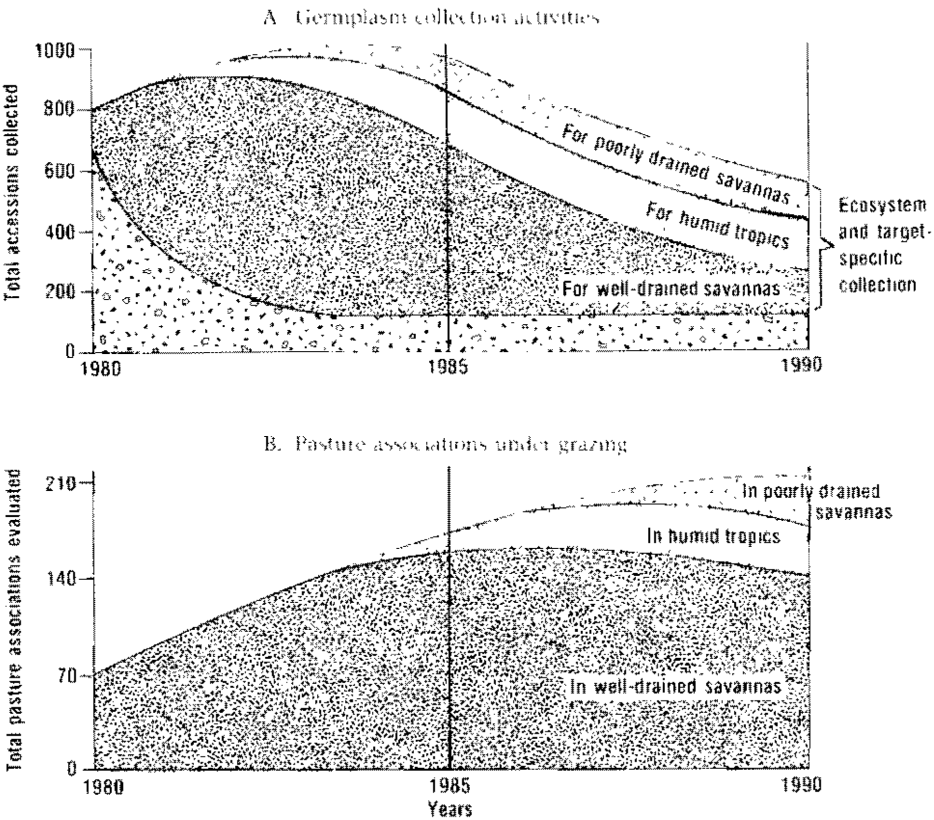


Figure 9. Estimated relative emphases to be given to different ecosystems by the Tropical Pastures Program in the 1980s

accessions that have tolerance or resistance to diseases and pests that are economic constraints.

Genetic advances in some key species will be made not only by introduction and selection, but also by plant breeding, when appropriate. Relative emphasis on breeding material is expected to increase during the second half of the decade. As a natural evolution of the selection process within some key species, plant breeding will be used when it is probable that missing desirable characteristics can be incorporated. Among species subject to genetic improvement by plant breeding (i.e., *Stylosanthes* spp., *Centrosema* spp., and *Leucaena leucocephala*), individual lines may be nominated to different categories in the evaluation, while the final breeding products are incorporated into the germplasm bank.

As promising lines are identified and cultivars are about to be released, the following needs become evident: (a) the need to provide documented summaries of experimental performance and potential productivity of these new cultivars, since the species may be totally unknown; (b) the need to collaborate with national institutions in providing practical recommendations on pasture establishment methods, stocking and management practices; and, (c) the need for seed production and processing technology to assist in rapid successful commercialization of seed production, implemented in cooperation with national agencies that control cultivar release.

Pasture Evaluation and Development. Agronomic evaluation of a large number of accessions (Categories I, II and III at both Carimagua and Brasilia) will identify an increasing number of accessions for evaluation under grazing conditions (Fig. 9B). It is expected that the need to expand these activities will be met partially by reassigning responsibilities within the present team, and partially by establishing more grazing experiments in cooperation with national institutions.

Once an adapted, productive pasture is defined for a region, either as a mixed or a pure stand, inexpensive, efficient establishment methods will be needed that provide adequate stands for persistence and productivity. Seedbed preparation, minimum fertilizer requirements, methods of applying alternative nutrient sources, seeding densities and methods, and pasture management systems are among the practical issues facing the Program when a cultivar is released. Soil fertility status will be monitored under grazing in order to determine minimum fertilizer maintenance requirements for persistence and stability of the association.

Pasture Evaluation in Production Systems. The present monitoring of animal production systems in selected areas of Brazil, Colombia, and Venezuela will be expanded to include other representative areas in Venezuela, a poorly drained savanna area in Colombia, a dual-purpose production area in Panama, and representative areas in the Amazon region. The resulting diagnosis of on-farm production constraints, along with the farm production and economic parameters, will provide a data base that—combined with the Program's experimental data—should simulate alternative pasture uses in the various production systems. Modeling will be used in anticipation of the expected outcome of alternative uses of various pastures in the region's different production systems.

On-farm validation of improved pasture technology – planting new cultivars into pasture on a small portion of a farm and using these pastures for animals with the highest response capacity – has already been initiated on four farms in the Colombian Llanos. As cultivars are released, this activity is expected to increase throughout the decade in a few selected locations and in close collaboration with national programs. It should provide a means of validating pasture persistence and productivity under farm conditions and also of validating and improving modeling activities.

Evolution of Outreach and Feedback Activities

Research and outreach activities are linked because national research institutions are both collaborators and clients of the Program. Collaboration exists in the early stages of germplasm collection and evaluation, but it increases rapidly as germplasm accessions advance through the research process. The main limitation on expanded collaboration is the absence, in most countries, of strong national pasture research programs working in areas with acid, infertile soils. Existing programs concentrate on more fertile soils, where beef and milk production have expanded in the past and where most of the cattle are still located.

The proportion of acid, infertile soils and the degree of policy commitment towards developing such areas vary considerably among tropical Latin American countries. Therefore, collaboration possibilities, assistance required and feedback will differ among countries. Using these criteria, countries can be categorized into the following five groups (see also the International Cooperation Activities section of Chapter 6):

(a) Countries with large areas of acid, infertile soils and strong development programs for those areas;
(b) Countries with large areas of acid, infertile soils but with less defined development programs;
(c) Countries with moderate areas of acid, infertile soils and well-defined development programs;
(d) Countries with moderate areas of acid, infertile soils and with less defined development programs; and
(e) Countries with only small areas of acid, infertile soils.

To date, the Program has developed strong research cooperation with countries in the first group; collaboration with the other countries has been limited to exploratory regional trials and training. Because collaboration starts at the beginning of the research process and increases as it advances, international cooperation will expand naturally as the germplasm evaluation process advances. Thus, cooperation in research, mainly through advanced regional trials, will increase significantly with countries in "b" and "c" groups.

The Program's training activities are directed towards increasing the human resource base working in tropical pastures, especially in acid, infertile soil areas. In the past, training efforts included all animal production disciplines. Since 1978, the emphasis has gradually shifted towards tropical pastures in acid, infertile soils. However, the Program will continue providing postgraduate training opportunities in pasture evaluation research methodology, as required by various countries. The objective of all training efforts is to achieve during the decade a critical mass of research workers in key locations in cooperating countries.

Germplasm exchange and testing through the regional trials network are another important outreach/feedback activity. This will be expanded substantially throughout the decade. Germplasm requested for research purposes will continue to be distributed. Exploratory regional trials (Type A) will be conducted in all network countries regardless of the extent of their acid soils. This type of trial will be conducted in all five major ecosystems.

The full series of regional trials (Type B, C, and D) for the two types of well-drained savannas will be extended to cover all countries having moderate to large areas of these ecosystems. As research in the poorly drained savannas and humid tropics starts early in the decade, and as promising material for each ecosystem is identified, the full series of regional trials will begin at selected sites in countries with moderate to large areas of these ecosystems.

Relative Ecosystem Emphasis

Well-drained Savannas. Until now, the Program has concentrated on the Llanos type of well-drained savannas. Research in the Cerrados type savanna started in 1978 with the outposting of senior scientists to work in germplasm utilization. Regional trials (Type A) in the humid tropics and the poorly drained savannas began in 1980, but so far these are exploratory; new research activities will begin soon in these ecosystems. By the middle of the decade the Program will be active in all ecosystems. The primary emphasis, however, will remain on the well-drained savannas, which will receive more than two-thirds of the staff time at mid-decade and more than one-half by 1990 (Fig. 8A).

Poorly drained savannas. This ecosystem is found throughout the lowlands of tropical Latin America as small to relatively large "islands" within other ecosystems. Small areas of poorly drained pastures are found on almost every farm. New thrusts in germplasm evaluation and soil fertility/plant nutrition for this ecosystem will begin in 1982. Germplasm evaluation will concentrate on screening for adaptability and persistence on the major soils subjected to flooding. Simultaneous, in-depth studies on farms will provide information on the role of improved pastures in different land forms. Core staff additions will not be required because the research will be conducted by agronomists at CIAT-Palmira, Carimagua and Brasilia, in close collaboration with national programs. These activities will require the equivalent of three senior staff man-years by 1985 and a maximum of four man-years by 1990.

The Humid Tropics. An expanded germplasm evaluation effort for the humid tropics will give the Program a much-needed germplasm screening site characterized by acid, infertile soils and more extreme environmental conditions than in savanna areas. This site will provide an excellent location for screening for tolerance/resistance to diseases and pests, resulting in better understanding of resistance mechanisms.

Increasing numbers of settlers are moving into the humid tropics, as a result of demographic, socioeconomic and geopolitical pressures. Most existing patterns of land use cause rapid degradation of soil resources. The most prevalent exploitation system replaces the original vegetation with pastures and crops. However, the productivity of the pastures diminishes rapidly because settlers do not use adapted forage species and do not understand the dynamics of soil fertility after clearing. The useful life of these pastures is often only four to seven years. However, well-managed, adapted legume-based pastures maintained at minimum fertility levels are efficient at recycling nutrients and provide excellent erosion protection.

A broader range of adapted forage species and appropriate pasture development/management technology are urgently needed for these regions. It is estimated that more than one-half of the 6-8 million hectares of cleared Amazonian forest is in a state of degradation. Recovery of areas already cleared is one of the main objectives of this new thrust of the Tropical Pastures Program.

Two outposted research scientists will be assigned to work with a research team of a collaborating institution, probably located in a seasonal forest ecosystem. The two positions are:

- A research agronomist whose duties will commence in mid-1982 and will include major germplasm screening plus coordination of a series of regional trials within the two humid tropic ecosystems.
- A research pasture development agronomist, who will develop, starting in early 1983, strategies for renovation of degraded pastures and alternative strategies for pasture establishment and maintenance. This agronomist will also conduct related soil fertility/plant nutrition studies.

These two staff members will receive operational support from present staff, especially in the areas of germplasm collection and evaluation, pathology, entomology, soil microbiology, plant nutrition and seed production. In many ways, activities within the humid tropics will complement savanna-based programs, by broadening the ecological base for testing germplasm and technology.

Staffing Patterns in the 1980s

Although five additional staff positions are proposed for the decade – three in regional cooperation and two in research – the program staff will be increased by only three because two existing positions are to be terminated. A total of twenty-three staff, to be reached in 1986, will remain constant throughout the 1980s.

Research staff. As described above, two senior staff will be located in the humid tropics. Two research staff positions currently located in Brazil will end in 1985 and 1986, respectively, as more intensive regional cooperation activities are initiated. The number of staff at Carimagua will remain constant although their activities will shift from soils and agronomy research to pasture evaluation and utilization.

Although headquarters-based research staff will become increasingly involved in work on the poorly drained savannas and the humid tropics, the total number of staff will not change. Total research staff will increase from twenty to twenty-one during 1982-84, and decrease to twenty thereafter.

Regional Cooperation Staff. From zero in 1980, this staff category will grow to a maximum of three positions by 1986 and remain constant until 1990. The first two appointments are proposed for 1983 (1985 at the latest), followed by a third appointment in 1986. These proposed positions will be located in the following regions:

(a) Central America and the Caribbean: This staff member will respond to the needs of a region having at least nine countries with nationally significant areas of acid, infertile soils utilized essentially for beef production. Activities will include regional trial coordination, on-farm validation trials and technology transfer. The position, located in Panama or Costa Rica, is required by 1985.

(b) Cerrado: This scientist will assist in coordinating regional trials throughout the very extensive Cerrado ecosystem and adjacent, poorly drained savannas. The position should be filled in 1985, coinciding with a reduction of one Core research position. Only two staff members will be located in Brazil by 1986: one in research activities, predominantly in pasture evaluation, and the other in outreach and regional trials.

(c) Subtropical South America: This staff member will work in both Paraguay and Bolivia and could be located in either country. While the primary function will be to coordinate regional trials, a secondary function will be to provide liaison to national research teams working in the Chaco regions of Bolivia, Paraguay and northern Argentina where there is interest in testing CIAT's germplasm in distinctly different ecosystems. The position will start in 1986.

6

International Cooperation Strategies and Projections

The principal goal of CIAT's international cooperation activities is to provide for collaboration in research and inter-institutional technology transfer. Because the research programs in collaborating countries are continually encouraged to define their needs and aspirations as related to the Center, they determine much of the direction and emphasis of CIAT's research programs. CIAT is most interested in strengthening the research capacity of its national counterparts so that they can assume more responsibility in the research process.

Cooperative activities such as the exchange of germplasm, operation of international/regional testing networks and collaborative research are included in discussions of the individual research programs in the previous chapter. This chapter explores chiefly those aspects of international cooperation that are part of the direct management responsibility of the Center.

SELECTIVE INSTITUTION BUILDING THROUGH TRAINING

In the 1980s training will continue to be the principal means by which CIAT collaborates with national programs to build their capabilities to cooperatively and independently conduct agricultural research. Virtually all of the training opportunities offered by CIAT are commodity-based and are on the postgraduate level.

Types of Organizations Relevant for Training Assistance

CIAT gives first priority for training to commodity research programs in government research institutions, followed by universities with active research projects on CIAT's commodities. To help link research with extension and private industry, third priority is given to selected leadership staff in extension and development organizations. It is expected that increasing emphasis will be given to universities during the 1980s, as they become more active in research and as international centers and national research institutions play a larger role in the university teaching curriculum. The Center will train university staff who teach production courses that relate to CIAT's commodities and will help develop teaching materials for such courses. Such efforts will have a significant multiplication effect on the utilization of CIAT's technology and will contribute to increased productivity and production in the respective commodities.

Selecting Training Candidates

The primary purpose of training is to strengthen the ability of national organizations to carry out research on CIAT's commodities. Accordingly, training participants must be actively working in a national research and/or development organization. The organization must also certify the continued employment of CIAT-trained professionals and outline the type of work the candidate will perform after training. National institutions have the prerogative for preliminary selection of training candidates. Final selection is made after mutual consultation and agreement. CIAT training is always determined by the national commodity program's stage of development and its particular needs and priorities. In all cases, the training candidates are selected in order to form research teams for each CIAT commodity, or to train professionals who will bridge the gap between research and extension on the national level.

Countries of Origin

Reflecting CIAT's primary concern with tropical Latin America, approximately 80% of the past training participants (1700 professionals between 1969 and 1980) have been selected from this area. In the next five years, participants from Asia and Africa are expected to increase to approximately 10% of the total trained each year, as regional cooperation expands to those areas. Nevertheless, the great majority of CIAT training participants will continue to come from tropical Latin American countries in the 1980s.

Funding of Training Scholarships

Approximately one-third of the scholarships for CIAT training participants are Core-funded. The rest come from special project funds or are financed by national institutions. This ratio is expected to continue throughout the 1980s and will allow CIAT to provide scholarships for representatives of national institutions that cannot support their training candidates at CIAT. This arrangement stimulates active financial participation in CIAT-based training by collaborating national institutions that can support trainees and by donor agencies interested in providing resources for manpower development.

Thesis Versus In-service Research Training

Many of CIAT's current training opportunities are non-degree programs. Because such training often does not result in commensurate professional and leadership opportunities for the trained worker, the Center must strive to provide increased opportunities for thesis research in conjunction with cooperating universities. However, there are few candidates for graduate thesis work. Also, some Latin American countries require relatively short but intensive practical training to allow young graduates to perform efficiently in practical agronomic research, validation of technology and technology transfer. With restricted budgetary and manpower resources, these countries cannot assign their personnel for long training periods. Therefore, non-degree, in-service training is expected to be in great demand for some time.

Assistance to In-country Training

Certain types of training, especially for research personnel with major extension responsibilities, can best be conducted in the countries. To date CIAT has collaborated with some fifteen countries in planning and conducting more than thirty in-country courses on research and production of CIAT's commodities. Throughout the 1980s CIAT expects to continue to provide requested training in methodology and new technology to assist national programs in conducting courses that will strengthen their technology validation and transfer capabilities.

Relative Magnitudes of Training Activities

Each year some 280 professionals participate in training at CIAT for one of twelve months (selected thesis students stay for longer periods). The average length of stay is four months. The number of training participants in the first half of the 1980s is expected to remain at approximately this level. In the latter half of the decade the number of professionals trained is expected to decrease somewhat, but their research-oriented training will be on a higher level for longer periods. At the same time, more production-oriented training will be given through in-country courses. It is projected that during the 1980s, about 15% of the Center's budget and an average of two man-years of training per senior staff member will be invested in training personnel from collaborating national research institutions.

CIAT's highly decentralized training is done within the commodity programs under the supervision of senior staff personnel who devote 10-15% of their time to training. Training is coordinated by the Training Office comprised of a senior staff coordinator and professional support personnel who serve as liaisons between that office and the commodity programs. This centralized coordination and decentralized execution assure effective integration of training with research and Center-wide application of uniform training standards.

CONFERENCES

CIAT has long recognized the value of international and regional conferences and workshops as a means of: (a) focusing attention on a given research issue, establishing priorities and defining inter-institutional collaboration; (b) consulting with national counterparts on selected CIAT program strategies and mutual coordination of research; and, (c) consulting regularly on the nature and operation of commodity-based research networks.

All three types of conferences will be continued throughout the 1980s. The first two types of events will be scheduled as needs arise. One network workshop in each of CIAT's commodities is expected to be held every other year.

Because organizing and conducting conferences require considerable financial and time investments, conferences will be held only when they contribute to achieving the Center's objectives. In general, Core-financed conferences will never exceed 0.75% of the total Core budget in any one year. In addition, co-sponsorship with other international organizations will be sought whenever the conference subject lies within their interests or mandates.

CONSULTATION

CIAT senior scientists and administrative staff provide technical consultation with national programs as needed. Staff spend an average of 15-20% of their time visiting research projects of cooperating members in the various research networks. Upon request staff may also provide advice on organizing and developing national research programs in CIAT's four commodities. Demand for such visits is expected to remain high in the 1980s. Time allocated for consultations will remain the same because increased consulting would conflict with research activities.

CIAT encourages professional program staff and leaders of national programs to visit the Center periodically to gain information on CIAT program developments.

COMMUNICATION AND INFORMATION SUPPORT

An international agricultural research center produces a massive amount of technical information on agricultural research, new production technology and research methodology. This information must be organized and made available to the regional and international research and development communities. CIAT develops and produces technical message packages that include the following publications series:

- Annual Reports. CIAT's technical annual report is published as separate reports for each of the four research programs. Also, a yearly *CIAT Report* is published.
- Newsletters. Periodic commodity-specific newsletters contain information on: (a) developments in the CIAT commodity program; (b) new technology (generated by CIAT and others); and, (c) commodity-related work being done by cooperating national programs.
- Technical Publications. This series includes conference proceedings, monographs, production manuals, field problem guides, and others.
- Audiotutorial Units. Audiovisual instructional materials provide technical information on CIAT's commodities and are used at CIAT and at universities and national research institutions in various countries.
- Public Information Materials. Selected materials are produced to inform the general public of the purpose and work of CIAT.

Throughout the decade the volume of CIAT's communication products is expected to increase. CIAT will continue to explore innovative alternatives for using message channels to improve the effectiveness of messages addressed to various audiences. Because the most important audience is the collaborating national research scientists, CIAT will assure that its messages are always usable by these people.

In the technical information field (documentation and library services), CIAT has acquired international recognition for its timely delivery of agricultural information services to national research scientists. These services include abstracts, tables of contents, photocopying of research documents, specialized literature searches, annual cumulative bibliographies, and the publication of monographs containing syntheses of technical information in selected fields.

CIAT recognizes that providing timely technical information services both to CIAT and national research scientists is vital to the development of improved agricultural production technologies. In the 1980s the Center will systematically strengthen its documentation services of research work in cassava, tropical pastures, beans grown under tropical conditions, and rice. These documentation efforts will be integrated with comprehensive agricultural information systems (such as AGRINTER). The more general information services that are not linked directly to research and development on CIAT's commodities will gradually be phased out during the mid-1980s. The responsibility for providing information services in commodities outside the Center's mandate must be assumed by other regional and national organizations.

CIAT has four senior staff positions in the area of communication and information. (A considerable portion of the work in this area is devoted to direct support of general CIAT programs and is related only indirectly to international cooperation activities.) Neither the number of senior staff positions nor the relative proportion of resource allocation to communication/information activities is expected to change significantly in this decade.

INTERNATIONAL COOPERATION SERVICES IN RELATION TO NEEDS OF NATIONAL PROGRAMS

The mix of international cooperation services provided to a national counterpart organization generally depends on the level of development of its research program in the CIAT commodities. Levels of program development can be defined as follows:

- Group I: Advanced national commodity programs that have clearly defined their research and development strategies and are equipped to carry them out;
- Group II: Developing national commodity programs in a dynamic state of growth and development;
- Group III: Developing national commodity programs at a beginning stage of development, staffed by personnel with baccalaureate level degrees and low levels of training;
- Group IV: Organizations without a formal program on the CIAT commodity involved but whose country has good potential for producing that commodity; and,

TABLE 9.
A generalized scheme for CIAT international cooperation services to national programs.

	Training					Germplasm			Technical consultation		Information services			Consultation on national program planning	
						Exchange level[b]									
Program classification[a]	PhD or MS thesis	In service	Methodology and special techniques	Short research courses at CIAT	Short production courses in countries	I	II	III	Research staff visits	Workshops and conferences	Network news letters	Program publications	Documentation services	Research	Economic analyses
Group I	****[c]	*	***	***	****	****	***	*	***	****	Yes	****	****	**	*
Group II	*	**	**	***	***	*	**	***	****	***	Yes	***	****	****	***
Group III	*	***	0	0	0	0	*	****	**	**	Yes	***	****	**	****
Group IV	0	0	0	0	0	0	0	*	0	*	Yes	**	**	0	**
Group V	**	***	*	***	**	**	**	**	**	***	Yes	***	****	**	***

NOTE: All CIAT international cooperation services are available upon request by any collaborating national program. This scheme indicates the expected demands from national commodity programs at the different levels of development.

a. For definitions, see text at International Cooperation Services in Relation to Needs of National Programs.
b. Levels: I = Germplasm Bank Accessions; II = Segregating Populations; III = Finished Varieties.
c. Relative emphases: High = ****; Medium = ***; Low = **; Very Low = *; None = 0.

Group V: National commodity programs that because of economic and/or other circumstances are in a state of decline and need revitalizing.

Clearly, CIAT's efforts to strengthen national commodity research must meet the different needs of these national programs as they develop. Table 9 provides a general overview of international cooperation services provided to collaborating national programs at various levels of development.

OUTPOSTED PERSONNEL

Outposted personnel – any CIAT staff stationed outside of Colombia – are a very important part of international cooperation services. Their number is expected to grow considerably in the 1980s. The Center has three categories of outposted personnel: outposted staff for research, regional cooperation staff and bilateral contract staff.

Outposted Research Staff

Research staff will be posted away from CIAT only when three conditions are met: (a) the research problems to be solved are of significant importance to a given region (normally CIAT will not outpost permanent Core-funded research staff to conduct research relevant to only one country); (b) the research problems must occur under conditions not adequately represented in Colombia and therefore require the outposting of research staff; and, (c) there is a strong regional or national research organization in the area that assigns high priority to solving the research problems and can provide effective research support to the outposted staff. Since the research conducted by this type of scientist is an extension of CIAT's commodity research programs, it is preferable that these positions be funded through the Core budget. CIAT's plan for the 1980s calls for one outposted research position in cassava (beginning in 1983) and a maximum of five outposted positions in tropical pastures.

Regional Cooperation Staff

Regional cooperation staff are outposted to strategic locations in order to serve regions in which a particular commodity is important. In recent years a modest effort has been made to serve selected regions through a few regional cooperation staff positions funded by special projects. The 1980s will bring maximum expansion in regional cooperation staff, because stronger regional cooperation is becoming imperative as more technology becomes available. Until CIAT has added the full contingent of regional cooperation staff outlined below, the Center cannot be considered fully developed.

All regional cooperation positions should be Core-funded and are so projected. Nevertheless, the funding situation at any one time may necessitate that given positions be funded under special projects.

Within the Western Hemisphere

These staff members are assigned to a specific national or regional program to assist in transferring technology in a given commodity and to provide feedback for the research process. Thus, they are essential in the technology generation/technology transfer continuum. In close collaboration with national programs in their respective regions, they conduct or encourage research on problems of special importance to that area. They specifically help organize international nurseries and other collaborative trials in the region, assist in selecting participants for CIAT training and help develop in-country training courses. This long-term plan calls for seven regional cooperation staff positions within the Western Hemisphere in the 1980s: three in beans, one in cassava, and three in tropical pastures.

Outside the Western Hemisphere

These staff are posted to major regions outside the Western Hemisphere where a CIAT commodity is of great importance. These regions can benefit from new CIAT production technologies with only minor research to adapt the technologies to regional conditions. Posted scientists will be located at strong international, regional or local research institutions that assign high priority to the commodity research/development effort under consideration. These institutions can provide sufficient infrastructure for training, germplasm quarantine, varietal selection and seed multiplication. The principal role of scientists posted outside the Western Hemisphere is to provide an organizational framework allowing for regional adaptation and validation of new production technology, and to stimulate active collaboration in this process by national programs in the region. Generally, these CIAT scientists will cover a larger geographic area than their counterparts within the Western Hemisphere. They will organize much more regional training. They will select candidates for research training at CIAT only in those disciplines in which adequate regional training is not available.

For the 1980s, CIAT projects a total of four Core-funded regional cooperation staff positions outside the Western Hemisphere: two in beans and two in cassava.

Bilateral Contract Staff

These staff are appointed temporarily (usually three to five years) as local components of national or subregional research teams at the request of individual countries or small groups of countries. Their purpose is to strengthen an institution in their field of expertise while national staff complete training to fill such positions. Bilateral contract staff normally will work with one of CIAT's commodities and will maintain very close ties with the respective program in CIAT.

Because these appointments are temporary and depend on the availability of special project funds, it is not possible or desirable to project precisely the countries for which funds will become available and which meet the criteria established by CIAT for considering bilateral contract staff. (Criteria are discussed fully in the CIAT publication *CIAT's Strategy for Outreach Services,* Series 12E-1, 1979.) It is anticipated, however, that an individual commodity program will not be involved with more than three countries or engage more than five such bilateral contract staff at any one time.

7

New Core Initiatives and a Future Challenge

Two initiatives to be incorporated into CIAT Core funding during the 1980s are the Seed Unit and agroecosystems analysis by the Data Services Unit. Both complement the Center's existing activities and are oriented towards the Western Hemisphere.

SEED TECHNOLOGY AND TRAINING

A special project funded by the Swiss Development Cooperation (SDC) was initiated at CIAT in 1979 to help strengthen national seed-related activities in the region and to provide CIAT with the capacity to produce and process seed of its commodities. This seed production will decrease the time required for new germplasm to reach the farm level.

Initial plans called for Seed Unit activities to be decreased after five years of SDC funding to a level that could be maintained with existing Core resources. However, the extremely positive response from national programs in the first two years of the project led to a reconsideration of earlier plans. Because a continuing need has been demonstrated for additional seed-related activities at CIAT, the Seed Unit will be incorporated into the Core budget during the decade. The exact nature of the Unit's activities and staffing pattern will be determined later by the Board of Trustees. This policy decision may somewhat alter the objectives, strategies and projections tentatively described below.

Objectives of the Seed Unit

The principal factors limiting progress in national seed programs and the industry are lack of trained personnel, often unclear and inconsistent government policies, limited supplies of breeder and basic seed for transfer to the seed industry, problems in producing, processing and storing of good quality seed, weak marketing systems and lack of effective mechanisms for the transfer of improved seed to small farmers. The role of seed-related activities at an international center must be defined clearly since these problems cannot be solved only at that level. The Unit has thus defined four objectives:

(a) To strengthen seed programs and local enterprises through training of, and technical collaboration with, seed technologists in the region;
(b) To provide assistance to national programs, including the production of breeder and basic seed by CIAT on request, to stimulate more rapid use of good seed of the most promising materials available;
(c) To encourage research on seed-related problems limiting seed production and distribution, and to improve technical communication among seed technologists in the region; and,
(d) To foster discussion on the development of policies and strategies that will permit greater use of improved varieties released by national research institutions.

Seed Strategies for the 1980s

During the first phase of the program considerable attention has been given to introductory training of seed technologists since only a limited number of personnel have been trained specifically in seed technology. Most persons in these programs received general agricultural training that did not emphasize seed-related activities. To fill this knowledge gap, CIAT developed a number of basic courses covering all aspects of seed production, processing, marketing and quality control. Through the end of 1980, 123 seed technologists had received this broad training.

In the second phase of the training program increased emphasis will be placed on more advanced specialized courses and workshops on such topics as producing breeder and basic seed, organizing and operating seed program activities at the national level, seed quality control, seed drying and processing, and seed marketing and national seed policies. Leaders of public and private seed programs will participate in these courses.

The Seed Unit will provide increased assistance to national seed programs to accelerate the use of improved hybrids and varieties. Also national programs will receive help in forming seed associations and new local seed enterprises. Much of this activity will be channeled through professionals who have had previous training at CIAT. The Unit will support local short courses offered by subregional groups and national programs.

The Unit will continue its support to the CIAT commodity programs by multiplying breeder and basic seed of the most promising materials and making it available to national programs and other interested organizations. CIAT does not propose to distribute commercial seed directly to farmers since this is a national activity. Multiplication of materials of interest to national programs will be encouraged wherever possible.

CIAT has already established links with other international centers, especially CIMMYT and ICRISAT, in order to assist them in their collaboration with national programs, through production and dissemination of promising materials.

CIAT is helping to identify priority areas for research in seed technology in its commodities. Many problems of production, harvesting, storing, and quality evaluation must be solved in the course of introducing new pasture species. Because these species are entirely new to the seed industry, basic seed technology has not been developed. For beans, cassava and rice, the Unit expects to participate in research to facilitate improved seed production and distribution.

In order to encourage professionalism and good communication among the region's seed programs, the Unit will provide information services on seed activities, including documentation and audiotutorial teaching materials.

Projections for the 1980s

The Seed Unit presently has two senior scientists and other supporting personnel, provided entirely by the special project funding. Funding for the first phase of the project will terminate in 1984. CIAT proposes to continue seed-related activities as a separate unit throughout the decade. It is hoped that the present donor can provide some continuing assistance.

Two Core-funded senior positions are projected for the Unit beginning in 1985 and 1986. In addition, the senior seed scientist in the Tropical Pastures Program will be associated with the Unit. One of the projected positions will be in the area of seed technology (processing, quality control and enterprise management), and the other in seed production and allied research. The Tropical Pastures position will continue to be dedicated to the problems associated with all aspects of seed technology in pasture species.

To maintain current levels of training, workshops, conferences, and technical collaboration activities, special project funding will be required.

EXPANSION OF THE DATA SERVICES UNIT: AGROECOSYSTEMS ANALYSIS

The Data Services Unit was originally established to provide an essential service to the Center through support in all statistical, mathematical and computational aspects of research and administration. The Unit currently consists of two major sections, Biometrics and Computing. CIAT proposes to add Agroecosystems Analysis as another section.

Background

The report of the TAC Quinquennial Review of CIAT (1977) recommended support for CIAT proposals for a program designed to collect ecological, land use and farming systems information. It especially recommended that the Center undertake an effort to integrate and classify regional information, particularly in areas where CIAT commodities are important. The Report of the TAC Stripe Review of Farming Systems Research in 1978 pointed out the lack of adequate characterization of the environmental and socioeconomic conditions in the areas where CIAT commodities are, or could be, potentially important. These two reports were followed by the recommendation of the TAC Subcommittee on Upland Rice (1980) which highlighted the pressing need for a more adequate description and classification of upland rice production zones in Latin America.

CIAT management and staff have always concurred with these recommendations by the various review teams. Since resources have been limited it has not been possible to mount a concerted effort, through Core funding, to adequately cover the needs of all programs at CIAT. Given its strong ecosystem emphasis, the Tropical Pastures Program was considered to be the highest priority. Accordingly, a modest effort was begun in 1978 by utilizing visiting scientist provisions in the Core budget to provide for agroecological characterization and analysis of areas of interest to that Program. More recently, limited work has been carried out for the Bean, Cassava and Rice Programs.

One of the most important underlying reasons for doing agroecological analyses is that crop and pasture improvement for less-favored areas and their wider diversity of production constraints imposes severe problems on new technology design, development and transfer. Less-favored production zones—i.e., most nonirrigated areas in the tropics with a wide range of soil constraints and insect and disease pressures—are the main targets of CIAT research. The rate of progress in genetic improvement of any species is generally inversely proportional to the number of constraints to be overcome through new genetic variability. It is clear that accurate information on the relative constraint spectrum, from zone to zone, is essential at all stages of increasing production and productivity of basic food commodities in the tropics. This need is even more critical in the small farm situation since the environmental conditions on farms in this sector—particularly those in Latin America—are generally more severe, and constraints are more varied than in the case of the large farm sector. Given the very great diversity of prevailing climates, soils, cropping systems and socioeconomic conditions, the need for an inventory of production conditions in the small farm sector is pressing.

Objectives for Agroecosystems Analysis

Some general areas have been identified that represent common needs across CIAT programs with respect to agroecosystem information for the areas of interest in each commodity. These needs are reflected in the following objectives:

1. To develop a system for environmental and economic assessment of conditions in the production areas of present or future importance in each CIAT commodity. Such assessment will allow for a more *accurate definition of research priorities,* and thus the allocation of research resources among the wide range of alternatives available for action.
2. To develop an agroecological information system which can be integrated with the germplasm development process. This improved process would provide for a more *cost effective and efficient operation of the cooperative germplasm transfer and evaluation programs* with collaborating national institutions. The objective is essentially to reduce the burden on national institutions imposed by testing all germplasm in all locations.
3. To develop a data system which would permit the *evaluation of responses* of new genetic variability when exposed to a wide range of selected conditions in terms of meteorological, edaphic and agronomic factors. One example would be crop/weather relations in international nurseries and in other experiments.
4. To develop a data system which will provide a firm base for *comparative socioeconomic studies* on the wide diversity of production zones. This system will enable both *ex-ante* and *ex-post* assessments of the *impact of new technology, in particular within the small farm sector,* so that the research process can be further focused on real needs. In addition, the data system would provide a medium in which to assess economically the development priorities for underutilized frontier lands, and to analyze marketing and associated economic constraints to increased production and productivity.

Research Strategy

A computer-based information system designed for the needs of four quite ecologically divergent commodity programs must be flexible in order that the degree of detail and scale provided is appropriate in each case. In addition, the collection of data, and its storage, retrieval and analysis, must be at a level of definition appropriate to the resources available. In other words, CIAT could not implement a massive new survey involving a great deal of field work. Accordingly, a methodology has been developed which relies on prior surveys, census information, and local knowledge of the situation in each zone. Information is gained on an opportunistic basis by CIAT personnel during duty travel and from the large number of visiting scientists and trainees from the region who visit CIAT. In this way, a cost effective collection system has been developed which appears sufficiently accurate. Any attempt at a more detailed approach would probably be frustrated by lack of accurate local data.

The following components of the data system have been developed to provide the necessary flexibility and coverage.

Land System Data

The concept of the land system[17] has been redefined as an "area or groups of areas throughout which there is a recurring pattern of climate, landscape and soils." This analysis relies on satellite and radar imagery—and occasionally, on aerial photography—to provide a geographical base. Each land system is a regionally based reference unit with a strict geographic boundary to the basic data element. Existing information on soils is compiled and restructured to a common base for storage of descriptors of the land system.

The land system concept has its main role in the definition of conditions at the agricultural frontier in the underutilized lands of the region. The scale (1:1 million) is appropriate for use in the areas of interest of the Tropical Pastures Program and in defining potential areas for upland rice and cassava in the tropical lowlands.

Crop Microregion Data

The concept of the crop microregion has been defined in analogy to the land system as "an area or groups of areas with a relatively uniform pattern of climate, edaphic factors and cropping system for a particular crop commodity." Early studies have begun to define these microregions for the present production areas of rice, cassava and beans. Each microregion

17. C. S. Christian and S. A. Stewart, *Survey of the Katherine-Darwin Region, 1946* (CSIRO, Australia, 1953).

will eventually be described by a series of edaphic, climatic, meteorological and cropping system descriptors. Initial emphasis has been placed on the Western Hemisphere but could be extended later to bean areas in Africa and cassava areas in Asia.

Climatic and Meteorological Data

Long-term climatic normals have been collected and processed for 3800 meteorological stations in the Western Hemisphere. Historic daily and weekly observations are being collected at selected stations. These data will provide a flexible system for climatic definition of microregions and will be useful in studies to define appropriate locations for regional trials and in the evaluation of crop/weather responses. While long-term averages are relevant for defining microregions, short-term meteorological data are needed for studies on climatic risk involved with new technology, as well as for interpreting crop performance and regional trial results.

Socioeconomic Data

Data on input/output prices, transportation costs, distance to markets, distribution of farm size, etc., will be managed on a microregion basis as are the cropping systems data. The data will provide the means to evaluate socioeconomic constraints faced in each zone as an important input in the research design. Commodity program economists work with the Agroecosystems Analysis Section in this portion of the study.

Progress of Agroecosystem Analysis in Commodity Programs

The following examples illustrate some of the work completed and planned in the various programs.

Tropical Pastures

The study on the South American lowlands[18] has enabled a classification of the major ecosystems making up the Program's area of interest. Aggregation of the land system units within each major ecosystem has permitted a quantitative assessment of the natural resources available in each ecosystem. The basic philosophy of the Program outlined in this plan revolves around this classification.

In technology evaluation and transfer, the study has provided direction for defining sites for regional experiments within the germplasm evalua-

18. T. T. Cochrane *et al.*, *An Explanatory Manual for CIAT's Computerized Land Resources Study of Tropical America*, (Cali, Colombia: CIAT, May 1981).

tion scheme of the Program. In the future, an accurate definition of the environmental constraints in each land system will provide a means for defining new technology specifications, particularly with respect to germplasm characteristics, for each zone. Economic studies on the relative comparative advantages of different zones with respect to future development will facilitate national policymaking. The studies are already in use at CIAT and in Brazil and are in the form of computer files in EMBRAPA.

Beans

The Program has been considerably aided by early studies in defining research priorities and strategies and in the location of its primary sites for the first two stages of the germplasm evaluation program. A climatic analysis of the 110 bean microregions permitted an assessment of crop/temperature conditions. It also verified that growing season temperature conditions at CIAT-Palmira and CIAT-Popayan are clearly representative of, and bracket, the major proportion of production zones (with respect to temperature) in Latin America.

In the future the Program will link its detailed and computerized data file on breeding activities (SIFRI) with the agroecosystem files in order to better predict the potential for particular experimental lines. This will greatly facilitate the Program's desire to reduce the quantity of international material needed to be evaluated by already overworked and understaffed national bean programs.

Rice

Initial studies have begun to define, locate and classify the microregions of production of upland rice in South and Central America. Census data have defined municipal level information on which to aggregate data into definable and relatively homogenous microregions. This information is vitally needed to help define more closely the research strategy for the upland sector. As in the other crops, this will be followed by applying the system to all stages of the research and technology transfer process.

Cassava

The cassava production zone or ecosystem classification provided in this plan is a preliminary one. A quantitative assessment of the accuracy of these definitions and of the location and relative production importance of the various zones is now in progress. One early result of the study would suggest that the location of markets plays an extremely important role in determining the location of cassava production zones.

Projections for Agroecosystems Research

The planned expansion of the functions of the Data Services Unit to encompass a formal Core-funded activity in agroecosystems analysis has been based on a thorough trial of the potential value of this work. The planned activity will constitute a centralized service function to the four commodity programs since the basic natural resources inventory and methodologies are common to all. The research will contine to be done in collaboration with program scientists. The new positions required to carry out the central research within the Data Services Unit are an agrometeorologist (starting in 1982) and a land systems specialist (starting in 1983). Until the positions can be Core-funded, CIAT will attempt to continue existing activities at a level consistent with presently available Core resources.

A FUTURE CHALLENGE

Within the wide spectrum of on-going basic research in the biological and physical sciences perhaps no one area is more important to CIAT's future than the dynamic field ranging from tissue and cell propagation to research in molecular genetic engineering. Results of research in areas such as anther culture and the production of new variation in somaclones cultured from protoplasts suggest that traditional plant breeding methods may be overtaken to varying degrees by these and other methodologies. These new genetic manipulation techniques could lead to important changes in present plant breeding systems, particularly with respect to the time needed to produce new variability. As a center largely dedicated to producing such new variability, CIAT is keenly aware of the advances now being made and will constantly monitor future developments.

Other more basic research institutions are better able to conduct this type of work. CIAT has not projected any direct Core involvement in this area beyond the existing physiologist position in the Genetic Resources Unit. Applied research in the meristem propagation of cassava, and in anther culture in rice, is already well advanced and is designed to be directly complementary to the needs of the research programs. Scientists in basic research institutions will be encouraged to carry out research on the commodities in the Center's mandate. In the future CIAT may need to assist in encouraging special projects for such research in those institutions. At the same time, CIAT facilities could be made available for short terms to enable scientists from those institutions to validate their methodologies under tropical conditions. CIAT could thus play an important bridging role to speed up the application of these new techniques, particularly in the more intractable research areas where ready genetic solutions are not presently available.

The future application of the new methodologies in the germplasm development programs of the Center will depend on the practicability of the methodologies and their advantages when compared to traditional breeding approaches.

This plan does not make any major special provision for this type of research. Any changes required to facilitate the use of such new methodologies will be possible through rearranging projected program resources.

8

Expected Costs and Benefits of CIAT Activities

The first section of this chapter presents the budgetary implications of CIAT's long-range plan for the years 1982-90. The second section juxtaposes estimated comparable values for benefits and costs to arrive at benefit/cost ratios for each of the Center's research programs. Due to the precarious nature of any *ex-ante* estimates of the impact of new technology, and the concomitant importance of the precepts underlying such estimates, this latter section also makes explicit the methodology used, and assumptions made, to arrive at the benefit/cost ratios reported.

BUDGET PROJECTIONS FOR THE PERIOD 1982-90

The budgetary implications of the long-range plan presented in this document are principally a function of the projected man-years of senior scientists. Table 10 presents a breakdown of actual senior staff positions for the period 1978-81 and projections of Core-financed positions for the period 1982-90. Figure 10 summarizes actual and projected senior staff positions in the areas of research, research support and administration, and regional cooperation.

Table 11 lists the projected CIAT Core budgets for the year 1982 through 1990 in constant (1981) U.S. dollar terms. The estimates are based on the projections in this plan with respect to staffing and associated requirements in operations, working capital, and capital.

ESTIMATED BENEFIT/COST RATIOS

In order to relate the above investments to expected economic social benefits, it is necessary to arrive at monetary values for costs and benefits that allow for a direct comparison of the two values. While costs of re-

TABLE 10.
CIAT actual Core-financed senior staff positions for 1978-81 and projected Core-financed positions for 1982-90.

	1978	'79	'80	'81	'82	83	'84	'85	'86	'87	88	89	1990
Research. Headquarters-based													
Beans	11	11	12	12	13[a]	13	13	14[p]	14	14	14	14	14
Cassava	9	9	10	10	10	11[g]	11	12[q]	12	12	12	12	12
Rice	3	3	3	4	5[b]	6[h]	6	6	6	6	6	6	6
Tropical Pastures	17	17	17	17	17	16[i]	16	16	17[w]	17	17	17	17
Swine	2	2	–	–	–	–	–	–	–	–	–	–	–
Research Outposted													
Beans	–	–	–	–	–	–	–		–	–		–	–
Cassava	–	–	–	–	–	1[j]	1	1	1	1	1	1	1
Rice	–	–	–	–			–	–					–
Tropical Pastures	2	2	3	3	4[c]	5[k]	5	4[r]	3[x]	3	3	3	3
Regional Cooperation													
Beans			–	–	–	1[f]	3[n,o]	3	5[y,z]	5	5	5	5
Cassava			–	–	1[d]	1	1	2[s]	3[aa]	3	3	3	3
Rice	–	–	–	–	–	–	–	–		–	–	–	–
Tropical Pastures	–	–	–	–	–	–		2[t,u]	3[bb]	3	3	3	3
Administration and Support													
Administration	6	6	7	7	7	7	7	7	7	7	7	7	7
Communication/ Information	4	4	4	4	4	4	4	4	4	4	4	4	4
Data Services	1	1	1	1	2[e]	3[m]	3	3	3	3	3	3	3
Genetic Resources	3	3	2	2	2	2	2	2	2	2	2	2	2
Laboratory Services	–	–	1	1	–[l]				–	1[dd]	1	1	1
Seed Unit	–	–	–	–		–		1[v]	2[cc]	2	2	2	2
Station Operations	1	1	1	1	1	1	1	1	1	1	1	1	1
Training Office	2	2	1	1	1	1	1	1	1	1	1	1	1
Total	61	61	62	63	67	72	74	79	84	85	85	85	85

TABLE 10—*Continued*

1982 a. Addition of one bean pathology position

b. Addition of one rice economics position

c. Addition for one forage agronomy position for the humid tropics

d. Addition of one regional cooperation position for Asia

e. Addition of position for agrometeorology

f. Deletion of position for biochemistry

1983 g. Addition of position for virology

h. Addition of position for upland rice physiology/agronomy

i. Temporary deletion of one headquarters-based research position

j. Addition of one breeding position for the subtropics

k. Addition of one pasture renovation/establishment position for the humid tropics

l. Addition of one regional cooperation position for eastern Africa

m. Addition of one position for land systems analysis

1984: n. Addition of regional cooperation position for Central America and the Caribbean

o. Addition of regional cooperation position for Brazil

1985: p. Addition of position for program coordinator

q. Addition of position for program coordinator

r. Deletion of one research position in the Cerrado

s. Addition of regional cooperation position for Central America and the Caribbean

t. Addition of regional cooperation position for the Cerrado

u. Addition of regional cooperation position for Central America and the Caribbean

v. Addition of position for seed production specialist

1986: w. Reinstatement of headquarters-based research position temporarily deleted in 1983

x. Deletion of one research position in the Cerrado

y. Addition of one regional cooperation position for the Middle East

z. Addition of one regional cooperation position for South Andean zone

aa. Addition of regional cooperation position for Africa

bb. Addition of regional cooperation position for subtropics of Latin America

cc. Addition of position for seed technologist

1987: dd. Addition of position for the coordination of laboratory services

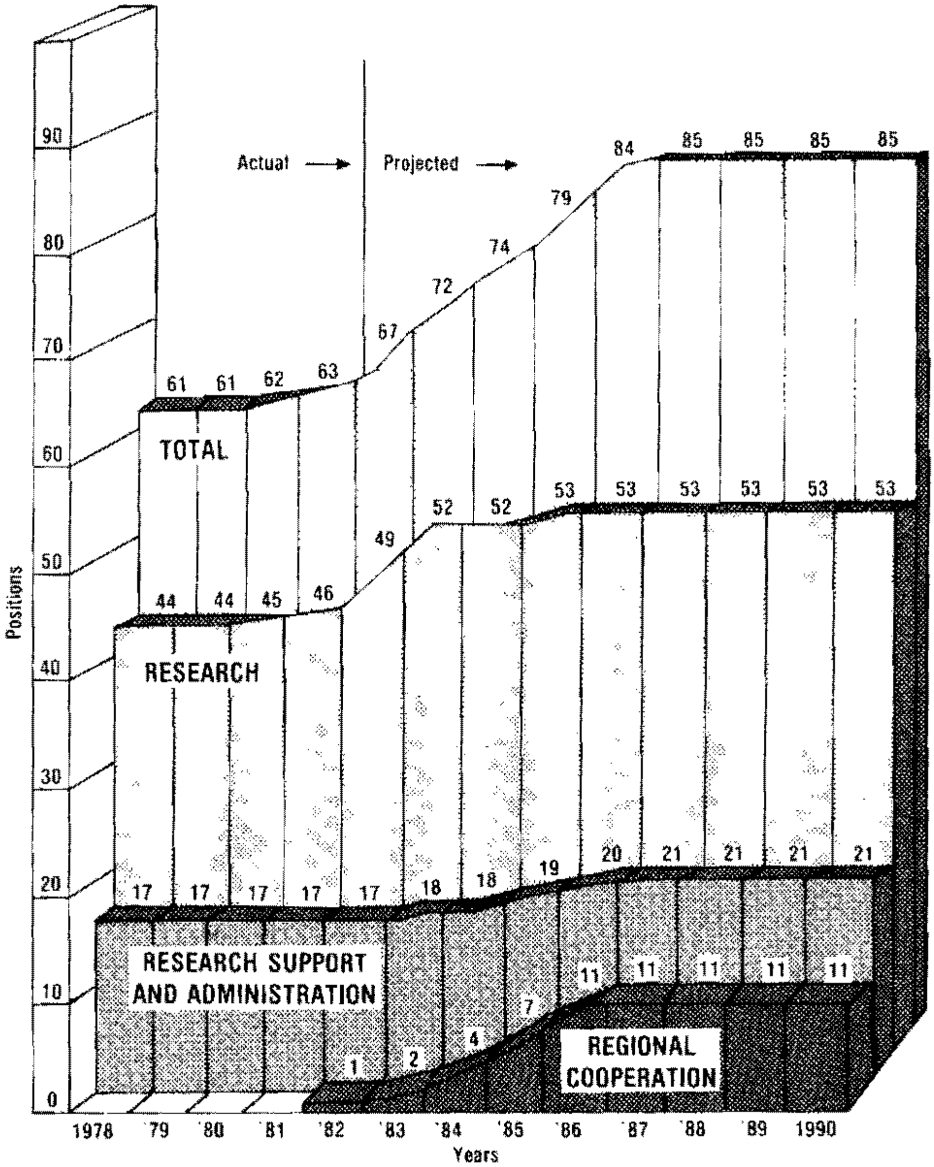


Figure 10 CIAT actual (1978-81) and projected (1982-90) Core-financed senior staff positions

TABLE 11.
CIAT Core budget projections to 1990.

Year	Millions of constant 1981 U.S. dollars
1981 (actual budget)	17.8
1982	18.4
1983	19.4
1984	20.7
1985	21.7
1986	22.9
1987	23.7
1988	24.0
1989	24.0
1990	24.0

NOTE: See Appendix 16 for methodology used in calculating budget estimates.

search can be projected with a certain degree of accuracy, it is difficult to predict the results of research, and even more difficult to estimate how, where and when such results will be applied by national agencies in a world that is experiencing rapid social, political and economic changes. The predicted results presented here should be viewed in light of the fact that CIAT is but one link in the research/production continuum. Hence, the overall outcome will greatly depend on the actions of other links on this continuum, as well as on the agricultural and economic policies adopted by each country. Accordingly, the real outcome could be significantly different from that projected here.

The estimates of benefit/cost ratios presented in this chapter are single nonprobalistic values and are only meant to convey the order of magnitude of the economic benefits resulting from CIAT's work. The estimates will, of course, be subject to continuous refinement by CIAT as additional information becomes available in coming years.

Estimated Social Benefits of CIAT Activities

Monetary social benefits of new technology were assessed by estimating the effect of increased supplies made possible by new technology on the economic welfare of both consumers and producers. (For consumers the increase in welfare is derived from the commodity price decline, while for producers, the increase in welfare is derived from the increase in return to production factors brought about by a decline in unitary costs beyond the market equilibrium price.) Due to the *ex-ante* nature of this analysis, a series of assumptions pertaining to supply and demand had to be made. Whenever possible, these assumptions were made on the conservative side to guard against overestimating potential benefits. Explanations in Appendix 17 summarize the general and program-specific assumptions underlying this exercise.

The methodology used to arrive at social benefits included the following procedures.

- Calculations of economic benefits to be derived from CIAT production technology were made for the case of tropical America only – i.e., the effects of new technology on other geographic areas were not included in the calculations of estimated social benefits.
- Prices used are at the wholesale rather than the retail level, implying that consumer benefits are underestimated.
- The resulting estimates of annual real benefits were converted into a present value estimate using two alternative real discount rates (5 and 10%), assuming that the opportunity cost of capital from the donor agencies lies within that range.
- Since part of the total value of the estimated benefits is attributable to national program efforts, it was assumed that only one-fifth of the benefits was due to CIAT's work.

Estimated Cost of CIAT Contribution

The projected costs of CIAT operations for the years 1981-90 (Table 11) served as the basis for estimating costs to the year 2020, the time frame used for calculating expected social benefits. Procedures for arriving at appropriate cost estimates involved the following steps:

- Total projected CIAT costs were allocated to the four research programs according to the relative proportion of the projected senior staff positions in each program.
- The resulting costs for each program were divided into three components: (a) new research cost (e.g., cost of developing higher yielding varieties); (b) maintenance research costs (e.g., cost of sustaining achieved average yield levels over time); and, (c) regional cooperation (e.g., cost of providing assistance in the diffusion process). All three cost components were included for the period 1981-90. Thereafter, the first component was deleted at the point where the adoption process is assumed to start in most countries; the third component was deleted at the point where adoption is predicted to approach its ceiling.

TABLE 12.
Anticipated benefit/cost ratios of CIAT research programs at two discount rates.

	Benefit/Cost ratio	
Research Program	with a 5% discount rate	with a 10% discount rate
Beans	13:1	8:1
Cassava	13:1	9:1
Rice	15:1	10:1
Tropical Pastures	31:1	15:1

- As in the case of estimated social benefits, the estimates of annual real costs were converted into a present value using the two alternative real discount rates of 5 and 10%, respectively.

Comparison of Benefits and Costs

The comparison between benefits derived by the developing countries in the Western Hemisphere and the cost of CIAT's research programs result in the expected benefit-to-cost ratios presented in Table 12.

The interpretation of the ratios reported here is explained by taking the case of the Bean Program as an example. Assuming that the opportunity cost for financial resources invested in the CIAT Bean Program is a real annual return of 5%, and using this percentage as a discount factor to obtain the benefit/cost ratio in present value terms, it is estimated that the economic benefits accruing from the efforts of the Bean Program will outweigh investments in this program by a ratio of 13:1.

Of course, the monetary expression of benefits relative to costs is but one criterion to be applied to the evaluation of research resource allocation. Other important criteria—such as the implications of new technology on income distribution, employment generation and nutrition improvement, or the contribution to the catalyzation of agricultural research and development efforts—may be equally or even more important than benefit/cost analyses. In this regard the reader is referred to the discussion of the role of CIAT technology in the socioeconomic environment presented in Chapter 1, and the role of CIAT in relation to national research and development agencies discussed in Chapter 2.

Appendices

APPENDIX 1

Percentage Growth Rates of Demand and Supply of Food in Latin America, 1966-77

	Population[a]	Per capita income[a]	Food demand: Income elasticity[b]	Food demand: Growth[c]	Total food production[d]	Food production by small farmers[d,e]
Mexico	3.5	2.8	0.51	4.8	4.0	1.8
Caribbean	2.1	1.8	0.21	2.5	1.4	2.5
Costa Rica	3.0	2.9	0.51	4.5	4.6	3.6
El Salvador	3.3	1.8	0.62	4.4	3.9	4.3
Guatemala	2.5	2.8	0.53	4.0	5.0	3.2
Honduras	2.3	1.8	0.62	3.4	2.3	1.9
Nicaragua	2.7	3.5	0.76	4.4	3.9	3.8
Panama	3.1	3.8	0.52	4.1	3.4	2.1
Central America	2.8	2.8	0.46	4.1	3.9	3.1
Venezuela	2.9	2.2	0.40	3.8	4.6	2.2
Bolivia	2.8	2.7	0.47	4.1	2.4	2.0
Chile	1.9	0.6	0.44	2.2	2.8	2.2
Colombia	2.6	2.7	0.51	4.0	3.4	4.2
Ecuador	2.9	3.8	0.47	4.7	1.7	2.9
Peru	2.9	2.5	0.62	4.5	1.1	1.7
Andean Countries	2.6	2.1	0.49	3.5	2.6	2.8
Brazil	2.7	4.2	0.50	4.8	4.7	2.6
Argentina	1.3	2.5	0.27	2.0	2.3	0.8
Paraguay	2.8	2.1	0.47	3.8	3.7	2.2
Uruguay	0.6	0.4	0.37	0.7	0.1	3.3
River Plate Countries	1.3	1.9	0.30	1.9	2.2	1.6
Latin America	2.6	3.0	0.34	3.6	3.6	2.5

SOURCES: Data for 1966-70 based on Economic Research Service, "Agriculture in the Americas: Statistical Data," FDCD Working Paper, U.S. Department of Agriculture, (Washington, D.C., 1976), pp. 1-8. Data for 1971-77 based on Economics, Statistics and Cooperative Service, *Indices of Agricultural Production for the Western Hemisphere, 1968-1977*, U.S. Department of Agriculture, (Washington, D.C., 1978). The income elasticities of demand were estimated from Food and Agriculture Organization of the United Nations (FAO), *Agricultural Commodity Projections, 1970-78*, (Rome, 1971).

a. Over 1960-75.

b. Estimated from the proportional weights of average consumption of vegetable and animal products and the FAO income elasticities of demand.

c. Calculated as $d = p + Ey \cdot y$; where, d is the rate of demand growth for food, p is the rate of population growth, Ey is the income elasticity of demand for food, and y is the rate of income growth.

d. Over 1966-67

e. The small farmer crops were defined by the USDA as maize (except in Argentina and Uruguay), rice (except in Colombia), potatoes, sweet potatoes, cassava and pulses.

APPENDIX 2

Estimates of Potential for Expanding Cultivated Area, by World Regions, 1974

Region	Actual arable area[a]	Calculated potential arable land (millions of hectares) Estimates[b] (1)	(2)	(3)	(4)	(5)	Arable land as a proportion of potential arable land (%) Estimates[b] (1)	(2)	(3)	(4)	(5)
Latin America	127	570	429	586	680	692	22	30	22	19	19
Africa, Sub-Sahara	186	304	423	470	733	658	61	44	39	25	28
Northern Africa, Near East	80	80	86	80	n.a.	122	100	93	100	n a	66
Asia, Market Economy	274	296	278	330	627	360	93	99	83	65	76
Asia, Centrally Planned	132	n.a	122	201		388	n.a	100	66		34
Developing Countries	799	1250	1338	1667	2040	2220	53	60	48	39	36
North America	235		392	347	466	533	–	60	68	50	44
Oceania	46		150	70	154	275		31	66	30	17
Europe, Market Economy	116	–	163	137	174	164	–	71	85	67	71
Europe, Centrally Planned	278	–	382	280	356	491	–	73	99	78	57
Industrialized Countries	673	n.a	1087	834	1150	1463	n.a	62	81	58	46
World	1472	n.a.	2425	2501	3190	3683	n a	61	59	46	40

SOURCE International Food Policy Research Institute, *Criteria and Approaches to the Analysis of Priorities for International Agricultural Research* (Washington D C , February 1978)

a Arable area data from Food and Agriculture Organization of the United Nations (FAO), *Production Yearbook 1974* Vol 28-1, Table 1, (Rome, 1975) Includes permanent crops.

b. Sources of estimates. (1) – Food and Agriculture Organization of the United Nations (FAO), *Provisional Indicative World Plan for Agricultural Development* Vol. 1, Ch 2, Tables 6-8 (Rome, 1970), 327 p (2) – Calculations by M. D Mesarovic and E Pestel, *Mankind at the Turning Point the second report to the Club of Rome* Table III A 2 (New York, 1974), 210 p (3) Calculations by A Strout "Resources for the Future," Annex Table III, unpublished study (4) – U.S President's Science Advisory Committee, *The World Food Problem* Vol 2 adapted from Tables 7 6 to 7 9 (The White House, Washington, D.C May 1967) (5) – Wageningen Agricultural University, "Computation of the Absolute Maximum Food Production " Table 15, (Wageningen, the Netherlands, 1975) As these five sources have different base years and also vary in their estimates of 'actual' arable area in the base year, they are all compared here to the same base year taken from the FAO 1974 *Production Yearbook*

APPENDIX 3
Percentage Distribution of Present Land Use in Latin America by Countries, 1978

Region and country	Total area	Arable and permanent crops: Total	Arable	Permanent	Permanent pasture	Forest and woodland	Other land[a]
United States	98	20	20	—	26	31	20
Tropical Latin America	98	6	5	1	22	55	15
Brazil	99	5	4	1	20	60	15
Mexico	97	12	11	1	38	36	12
Colombia	91	5	4	1	15	68	16
Venezuela	97	6	5	1	18	53	20
Peru	100	3	2	1	21	57	18
Ecuador	98	9	6	3	9	52	27
Paraguay	98	3	2	1	37	50	8
Bolivia	99	3	3	—	25	51	20
Cuba	100	28	22	6	19	18	35
Dominican Republic	99	25	18	7	31	23	21
Central America	97	14	11	3	19	52	12
Nicaragua	91	12	10	2	26	48	5
Costa Rica	100	10	6	4	31	49	10
Guatemala	99	17	14	3	8	53	21
El Salvador	98	32	24	8	29	13	25
Honduras	100	16	14	2	18	63	3
Panama	99	7	6	1	15	54	22
Caribbean	93	7	5	2	7	74	6
Guyana	92	2	2	—	5	85	1
Haiti	99	32	20	12	19	7	42
Jamaica	99	24	19	5	19	45	11
Trinidad and Tobago	100	31	14	17	2	44	23
Temperate Latin America	99	12	9	3	46	22	20
Argentina	99	13	9	4	52	22	13
Uruguay	99	11	10	1	79	3	5
Chile	99	8	7	1	16	27	48
Latin America	98	7	6	1	26	49	16

SOURCE: Food and Agriculture Organization of the United Nations, *Production Yearbook, 1979*, (Rome, 1980).

a. Land area under rivers and lakes.

APPENDIX 4

Daily Per Capita Nutrient Availability and Requirements, in Mean National Consumption, Latin America, 1972-74 Average

	Calories			Protein (grams)		
Region and country	Availability	Requirements	Supply as a percentage of requirements	Availability	Requirements	Supply as a percentage of requirements
Mexico	2687	2330	115	65.6	38.1	172
Central America	2103	2280	92	55.0	35.6	154
Caribbean	2453	2280	108	55.9	35.6	157
Venezuela	2388	2430	98	62.6	36.7	171
Tropical South America[a]	2193	2420	91	52.4	38.0	138
Brazil	2537	2390	106	63.2	38.7	163
Temperate South America[b]	3113	2630	118	93.8	38.8	242

SOURCE: Food and Agriculture Organization of the United Nations (FAO), *Provisional Food Balance Sheets, 1972-74 Average*, (Rome, 1977).

a. Bolivia, Colombia, Ecuador, Paraguay and Peru.
b. Argentina, Chile and Uruguay

APPENDIX 5

Estimated Percentages of the Population Consuming Inadequate Amounts of Calories in Various Latin American Countries, 1973

Country	Below minimum caloric levels	Below 90% of recommended caloric levels
Brazil	45	31
Chile	33	10
Colombia	61	46
Costa Rica	34	20
Dominican Republic	58	44
Ecuador	70	61
El Salvador	72	61
Guatemala	69	48
Honduras	60	50
Jamaica	30	21
Mexico	34	22
Panama	51	38
Peru	53	41
Uruguay	33	20
Venezuela	56	47

SOURCES: S. Reutlinger and H. Alderman, "The Prevalence of Calorie Deficient Diets in Developing Countries," World Bank Working Paper No. 374. (Washington, D.C., March 1980), pp. 27, 28; for further details see. S. Reutlinger and M. Selowsky, "Malnutrition and Poverty: Magnitude and Policy Options," World Bank Occasional Paper No. 23, (Johns Hopkins, Baltimore, 1976).

NOTE: Data are available from the Food Balance Sheets of the Food and Agriculture Organization (FAO) on mean caloric consumption and FAO/WHO have made estimates of caloric requirements. The distribution of the population by caloric consumption utilizes income distribution data and the functional relationship between caloric consumption and income.

APPENDIX 6

Percentage Contribution of Various Foods to Total Caloric Consumption in Latin America, 1972-74

Region and country	Sugar	Maize	Wheat	Rice	Cassava	Potatoes	Oils	Beans	Beef	Meat
Mexico	14.7	37.3	11.4	1.9	0	0.4	8.2	5.1	2.2	5.4
Central America	16.1	36.0	7.0	5.6	0.8	0.3	8.6	4.6	2.2	5.4
Caribbean	16.9	6.7	16.1	13.3	2.6	0.4	8.3	2.1	3.1	5.7
Venezuela	18.3	16.2	15.1	5.0	1.9	0.8	8.0	1.3	5.8	9.3
Tropical South America	18.3	12.5	11.0	9.9	4.0	5.3	8.4	1.1	3.6	5.6
Bolivia	12.7	16.8	19.2	4.9	4.3	10.3	6.9	0.7	3.7	6.9
Colombia	24.6	12.9	5.7	12.5	3.7	3.6	7.1	0.8	4.3	5.4
Ecuador	18.3	11.9	8.8	9.2	2.8	5.5	10.4	2.2	2.5	4.4
Peru	14.8	9.3	18.1	8.6	2.8	9.3	9.9	1.5	1.9	4.7
Paraguay	8.3	18.1	10.2	3.6	14.4	2.6	8.7	5.1	8.8	12.6
Brazil	17.1	9.2	10.7	15.5	9.4	0.8	7.9	7.6	4.3	6.7
Temperate South America	13.1	1.3	30.9	2.0	0.3	3.6	12.2	0.6	11.1	16.0
Argentina	12.9	1.1	27.2	1.7	0.4	4.6	12.2	0.3	13.4	17.9
Chile	13.4	1.7	42.9	2.4		3.7	9.2	1.8	3.9	6.2
Uruguay	12.3	2.2	27.2	3.5		3.9	8.7	0.2	14.3	20.4

SOURCE: Food and Agriculture Organization of the United Nations (FAO), *Provisional Food Balance Sheets, 1972-74* (Rome, 1977).

NOTE: Since not all food commodities are included, rows will not sum to 100%.

APPENDIX 7

Percentage Contribution of Various Foods to Total Protein Consumption in Latin America, 1972-74

Region and country	Maize	Wheat	Rice	Beans	Beef
Mexico	39.0	12 7	1 5	11.4	7 8
Central America	35 7	7 5	4.7	12 1	9 1
Caribbean	7.3	18.5	10.9	2.9	5 9
Venezuela	13 4	19.0	3.8	3 2	16 8
Tropical South America	10.3	13.2	8 4	2.8	11 5
Bolivia	16 6	21.7	3 7	1.7	10.6
Colombia	14.4	7 0	11.3	2 4	14.7
Ecuador	13.8	10.6	8.1	4.4	8 3
Peru	9 3	22.5	6.6	3.8	6.6
Paraguay	17 0	10.0	2.5	12.0	19.8
Brazil	8.2	11.4	12.2	20.1	13.8
Temperate South America	1.1	28.5	1.3	1.4	29.8
Argentina	0.8	23.3	1 2	0.6	34 4
Chile	1.6	43.6	1 8	4.1	8.3
Uruguay	1 6	23.1	2 3	0.5	28.9

SOURCE: Food and Agriculture Organization of the United Nations (FAO), *Provisional Food Balance Sheets, 1972-74*, (Rome, 1977)

NOTE Since not all food commodities are included, rows will not sum to 100%.

APPENDIX 8

Percentage of Total Family Food Budgets Allocated to Commodity Groups in Ten Andean Cities, 1967-69

City	Income categories[a]	Commodity group allocations (%)									
		Beef	Milk	Chicken	Pork	Bread and related products	Wheat	Rice	Maize	Potatoes and similar tubers	Dry vegetables
Bogota	0	11.3	10.2	0	0.1	9.6	0.8	5.7	2.5	10.9	1.5
	1	14.6	9.3	0.1	0.01	10.1	0.5	6.1	1.9	11.2	2.1
	2	15.2	9.9	0.2	0.4	9.9	0.5	5.6	2.0	8.8	1.7
	3	14.6	11.1	1.3	0.3	8.7	0.6	5.1	1.0	3.4	1.5
	4	12.7	10.8	3.0	1.3	7.8	0.3	2.3	1.0	3.4	1.5
Barranquilla	0	17.8	9.3	0.2	0.6	6.7	0.1	11.1	1.9	5.0	1.8
	1	17.3	10.1	0.4	1.0	6.3	0.1	10.3	1.6	4.2	2.0
	2	18.0	10.2	0.8	0.8	6.9	0.1	9.2	1.5	3.6	1.7
	3	19.1	10.8	2.7	0.8	6.9	0.1	7.5	1.4	3.0	1.9
	4	18.7	11.0	3.5	0.9	6.9	0.3	6.3	1.2	2.5	1.9
Cali	0	24.2	5.8	0.1	0.9	5.3	0.2	9.6	2.2	5.8	5.6
	1	21.5	8.1	0.6	0.5	6.1	0.2	8.6	2.0	5.1	4.6
	2	22.1	9.8	1.1	1.4	5.5	0.4	6.9	1.5	3.8	3.9
	3	21.0	12.3	1.6	2.4	6.4	0.2	5.5	1.1	3.3	3.0
	4	16.9	13.0	3.0	2.5	6.2	0.3	4.5	1.1	2.2	2.3
Medellin	0	21.1	9.5	0	0.3	3.9	1.8	7.0	6.3	6.0	6.8
	1	21.6	11.1	0.02	0.7	5.2	0.2	5.7	4.7	6.0	5.9
	2	21.2	10.6	0.3	2.5	5.4	0.3	5.1	4.4	4.7	5.3
	3	18.8	12.3	0.6	4.2	6.0	0.4	4.2	3.3	3.7	4.4
	4	15.0	13.4	2.5	6.3	5.9	0.6	2.8	2.0	2.6	2.7
Santiago	0	10.2	6.4	2.0	0.2	16.8	1.2	2.4	0.2	4.1	1.8
	1	9.8	7.8	2.4	0.6	15.7	1.4	2.1	2.3	4.2	1.9
	2	9.9	8.1	3.3	0.5	13.7	1.1	1.9	0.3	3.4	1.4
	3	9.3	8.7	4.5	0.7	12.1	1.0	1.7	0.2	2.9	1.3
	4	5.5	7.3	3.9	1.0	9.7	0.6	1.1	0.03	1.2	0.7

APPENDIX 8 – *Continued*

Quito	0	8.7	8.1	0.5	0.4	9.8	0.8	5.7	2.7	7.8	0.6
	1	12.9	10.6	0.07	0.4	12.2	0.7	7.2	1.9	7.4	0.5
	2	13.6	10.4	0.8	0.3	11.2	0.6	5.7	1.6	6.2	0.6
	3	15.7	13.3	2.0	0.7	10.9	0.5	5.5	0.9	4.3	0.7
	4	14.1	14.1	2.0	1.3	9.0	0.6	3.7	0.7	3.0	0.7
Guayaquil	0	14.0	6.0	0.5	0.2	8.0	0.4	13.9	1.1	3.3	1.6
	1	17.6	10.0	1.4	0.2	7.5	0.3	14.2	0.1	3.1	1.2
	2	18.1	11.8	2.0	0.3	7.1	0.3	12.4	0.2	2.8	1.9
	3	18.1	12.5	3.1	0.6	6.6	0.2	10.1	0.2	2.4	1.8
	4	15.7	12.7	4.9	1.1	6.0	0.3	6.3	0.2	1.9	1.5
Caracas	0	11.3	13.7	2.5	1.8	6.8	0.1	4.0	2.5	2.2	2.6
	1	11.3	13.8	3.4	2.1	6.4	0.1	3.3	0.1	2.6	3.1
	2	11.9	13.1	4.1	2.4	6.7	0.1	2.3	2.6	2.5	2.3
	3	11.5	13.3	4.4	2.4	6.8	0.1	2.2	1.6	2.1	1.8
	4	12.5	13.2	4.3	2.6	5.8	0.1	1.7	1.0	1.6	1.0
Maracaibo	0	9.0	17.8	3.4	1.3	7.8	0.1	4.1	4.0	1.6	1.7
	1	10.6	18.2	3.6	2.1	7.0	0.1	3.7	3.5	1.7	2.0
	2	11.3	17.4	5.0	1.5	7.0	0.1	3.4	3.0	1.7	1.7
	3	11.6	18.2	5.6	1.5	6.3	0.04	3.0	2.1	1.5	1.2
	4	11.9	18.4	7.9	2.6	6.6	0.1	2.4	1.6	1.8	1.7
Lima	0	22.8	10.5	2.8	0.3	8.4	0.2	5.8	1.2	3.7	0.5
	1	15.4	13.2	2.5	0.7	10.0	0.3	6.9	1.0	4.6	0.8
	2	17.3	12.3	4.7	0.4	9.2	0.1	6.9	0.8	4.2	1.0
	3	17.0	11.4	4.8	0.3	8.0	0.2	5.6	0.7	3.4	0.8
	4	17.5	11.9	4.1	0.4	6.6	0.2	4.2	0.7	2.5	0.5

SOURCE Survey data from the Estudios Conjuntos sobre Integracion Economica Latinoamericana (ECIEL)-Brookings Institution survey of consumption patterns in Latin American cities.

a Family income category codes: 0 = 0-$1025 (U.S. dollars) annually; 1 = $1026-1652; 2 = $1653-2759, 3 = $2760-4866, 4 = more than $4866.

APPENDIX 9

Food Expenditures by Food Groups for Different Income Strata, in Northeastern Brazil, 1975

	Food expenditures (cruzeiros)								
	Income strata (cruzeiros per year)								
Food groups	Less than 4500	4500 6799	6800-8999	9000 11,299	11 300 13 599	13 600 15,799	15 800 22,599	22 600 31 599	More than 31,599
Cereals and derivatives	274	586	855	1069	1319	1454	1368	1803	2143
Rice	131	273	396	455	530	624	564	569	604
Maize	62	135	171	160	228	185	149	122	140
Wheat products	77	168	275	430	530	618	802	1019	1209
Others	5	11	13	24	32	26	53	93	190
Tubers	260	413	489	467	523	544	438	460	442
Potatoes	1	3	5	11	16	24	38	67	133
Fresh cassava	11	23	26	24	28	30	23	22	21
Cassava flour	229	351	400	320	406	414	306	282	182
Other tubers	19	36	58	62	72	77	70	88	106
Sugars	107	181	228	250	300	324	336	363	450
Legumes	314	493	557	565	633	587	525	158	435
Field beans/cowpeas	282	443	511	516	579	538	492	133	408
Other legumes	32	50	46	49	54	49	33	25	27
Vegetables	47	106	152	183	231	271	329	457	703
Fruits	50	98	152	180	239	268	391	538	711
Meat and fish	514	992	1360	1712	2058	2364	2705	3472	4759
Beef	175	359	563	711	919	1051	1420	1830	2730
Pork	96	175	218	258	265	335	285	335	302
Chicken	50	114	181	234	306	331	295	540	742
Canned meats	2	5	9	15	19	41	34	62	114
Fish	128	221	241	266	298	318	405	372	473
Others	63	117	148	199	252	288	267	333	398
Eggs	25	51	82	96	128	142	164	217	297
Milk and cheese	78	183	284	366	497	522	582	824	1235

APPENDIX 9 – *Continued*

Oils and fats	49	119	175	234	304	366	392	564	805
Beverages	150	239	293	338	369	416	476	605	894
Food outside the house	91	161	229	347	387	469	570	722	1027
Total food expenses	1959	3622	4837	5807	6988	7726	8477	10 482	13 942
Food expenses as a percentage of total expenses	64	64	61	57	54	52	44	48	17

SOURCE: Fundacao Instituto Brasileiro de Geografia e Estatistica (FIBGE), *Estudo Nacional da Despesa Familiar, Despesas das Familias,* Regiao V, (Rio de Janeiro, 1978) p. 82

APPENDIX 10

Diet Composition and Consumer Costs for Calories, in Northeastern Brazil, 1975

Food groups	Calories per person per day	Proportion of total calories (%)	Annual cost to consumer of maintaining consumption of 100 calories per day from each food[a] (cruzeiros)
Cereals and derivatives	518	26.8	34
Rice	242	12.5	29
Maize	108	5.6	24
Wheat products	161	8.3	46
Others	7	0.4	80
Tubers	496	25.7	16
Potatoes	2	0.1	175
Fresh cassava	13	0.7	22
Cassava flour	454	23.5	14
Others	27	1.4	36
Sugars	210	10.9	21
Legumes	311	16.1	34
Field beans/cowpeas[b]	280	14.5	31
Other legumes	31	1.6	27
Vegetables	10	0.5	364
Fruits	35	1.8	110
Meat and fish	179	9.3	172
Beef	74	3.8	191
Pork	46	2.4	88
Chicken	13	0.7	323
Canned meat	2	0.1	175
Fish	23	1.2	207
Others	21	1.1	157
Eggs	10	0.5	182
Milk and cheese	67	3.5	99
Oils and fats	84	4.4	52
Beverages	10	0.5	630
Total	1930	100	53

SOURCES: Calculated from Fundacao Instituto Brasileiro de Geografia e Estatistica (FIBGE), *Estudo Nacional de Despesa Familiar. Despesas das Familias.* Regiao V, (Rio de Janeiro, 1978), p. 82, and from FIBGE, *Estudo Nacional da Despesa Familiar, Consumo Alimentar Antropometria.* Regiao V, (Rio de Janeiro, 1978), p. 21.

APPENDIX 10—*Continued*

a. Calculated from the ENDEF data on annual expenditures per family by dividing these expenditures by the number of people in the average family (five) and then dividing these expenditures by the average number of calories per day. When multiplied by 100 these are the cruzeiro costs of obtaining 100 calories per day of each item during the entire year for each person. Expenses on meals outside the house were not itemized; hence, they could not be categorized. However, they were only 5.7% of total food expenditures and would probably be biased towards the higher quality food and beverages. Hence, their omission would bias downward expenditure data on high-quality foods and beverages but not substantially affect the comparisons of the low-cost caloric staples. The calculation is made in the following manner:

$$\frac{\text{Expenses/Family-Year}}{\text{Persons/Family}} \times \frac{1}{\text{Calories/Person/Day}} \times 100 = \frac{\text{Expenses/Year}}{\text{100 Calories/Day}}$$

b. Field beans and cowpeas are given the same Portuguese word. Cowpeas predominate in northeastern Brazilian production but field beans are preferred by urban consumers. Consumption is probably about equally divided between the two in the Northeast.

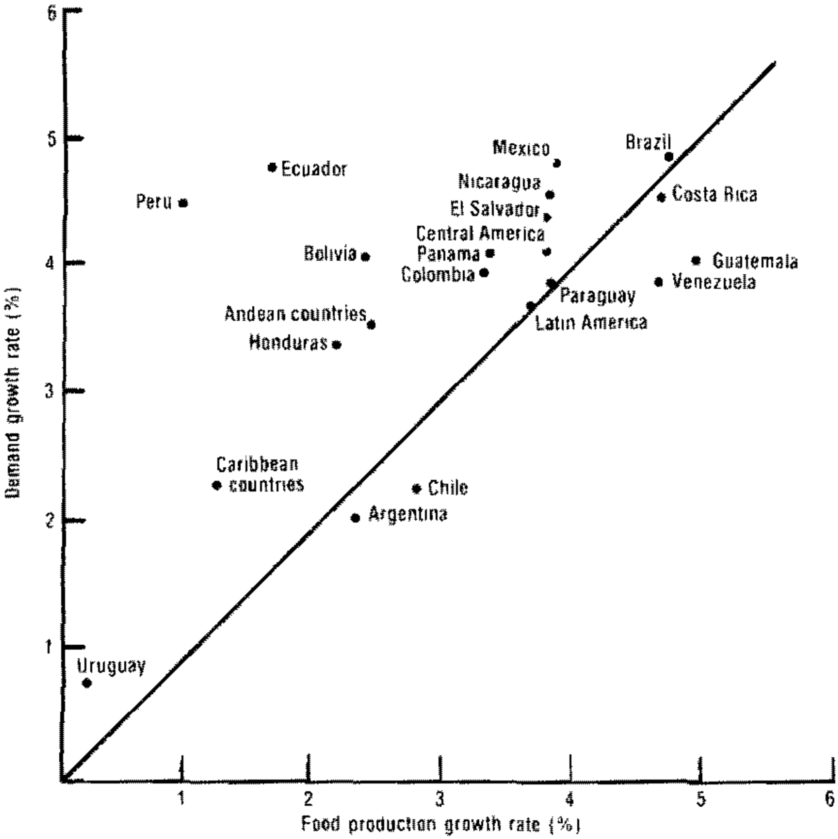
APPENDIX 11
Diet Composition and Consumer Costs for Protein, in Northeastern Brazil, 1975

Food groups	Protein per person per day (grams)		Proportion of total protein (%)		Annual cost to consumer of maintaining consumption of one gram of protein per day from each food[a] (cruzeiros)	
Cereals and derivatives	13.20		21.7		13	
Rice		5.12		8.4		14
Maize		2.81		4.6		10
Wheat products		5.10		8.4		14
Others		0.17		0.3		34
Tubers	2.59		4.3		32	
Potatoes		0.05		0.08		70
Fresh cassava		0.07		0.1		60
Cassava flour		2.11		3.5		30
Others		0.36		0.6		27
Sugars	0.08		0.1		553	
Legumes	21.23		34.8		4	
Field beans/cowpeas		19.09		31.3		4
Other legumes		2.14		3.5		4
Vegetables	0.40		0.7		91	
Fruits	0.51		0.8		75	
Meat and fish	18.04		29.6		17	
Beef		7.46		12.2		19
Pork		1.69		2.8		24
Chicken		2.23		3.7		18
Canned meats		0.13		0.2		27
Fish		4.45		7.3		11
Others		2.08		3.4		16
Eggs	0.79		1.3		22	
Milk and Cheese	3.43		5.6		20	
Oils and fats	0.20		0.3		217	
Beverages	0.51		0.8		124	
Total	60.98		100		17	

SOURCES: Calculated from Fundacao Instituto Brasileiro de Geografia e Estatistica (FIBGE), *Estudo Nacional de Despesa Familiar, Despesas das Familias*, Regiao V, (Rio de Janeiro, 1978), p. 82; and from FIBGE, *Estudo Nacional da Despesa Familiar, Consumo Alimentar Antropometria*, Regiao V, (Rio de Janeiro, 1978), p. 21.

a. For calculations, see footnote 1, Appendix 10.

APPENDIX 12
Growth Rates of Food Demand and Production in Latin American Countries, 1966-77



APPENDIX 13

Agricultural Research Expenditures: Total and as a Percentage of the Value of Agricultural Product, in World Regions, 1965-74

	Total annual expenditures (millions of 1971 constant U.S. $)			Percentage of total research expenditure to value of agricultural product		
Region	1965	1971	1974	1965	1971	1974
Western Europe	407	671	733	1.4	2.0	2.2
Eastern Europe and U.S.S.R.	627	818	861	1.5	1.7	1.8
North America and Oceania	806	1203	1289	1.9	2.6	2.7
Africa	114	139	141	1.3	1.4	1.4
Asia[a]	356	610	646	1.2	1.8	1.9
Latin America	73	146	170	0.6	1.1	1.2
Total	2383	3588	3841			

SOURCE: J. K. Boyce and R. E. Evenson, *Agricultural Research and Development Programs*. Agricultural Development Council (New York, 1975).

a. Excluding People's Republic of China.

APPENDIX 14

Research and Extension Manpower Resources Relative to the Value of Agricultural Product, 1951-71

Region	1951	1959	1965	1971
	"Quality Adjusted" scientist/man-years per ten million U.S dollars of agricultural product			
	(in constant 1971 U S dollars)			
Western Europe	0.85	0 94	0.89	0 91
Eastern Europe and U.S S.R.	0.22	0.39	0 70	0 86
North America and Oceania	0.91	1.90	1 17	1.10
Latin America	0.26	0.26	0.33	0.34
Africa	0.46	0.46	0 55	0.63
Asia[a]	0.56	0.69	0.84	0.92
	(extension workers per ten million U.S dollars of agricultural product)			
Western Europe	–	7.36	7 14	7 71
Eastern Europe and U.S.S.R	–	–	–	–
North America and Oceania	–	3.75	3.33	3 64
Latin America	–	3.24	4 29	9 05
Africa	–	29.46	53 16	63.89
Asia[a]	–	41.30	47.76	53.31

SOURCE: J K. Boyce and R. E. Evenson, *Agricultural Research and Development Programs*, Agricultural Development Council, (New York, 1975) (Table 1.6).

a. Excluding People's Republic of China

APPENDIX 16
Methodology Used for Projections of Budgets in CIAT's Long-Term Plan

OPERATIONS

Budgets for the research programs and units are assumed to increase in direct proportion to the increased man-years. No account is taken of whether the extra positions are for research staff, research support units or regional cooperation staff. This may be a little generous since regional cooperation staff are not expected to cost as much as a fully supported research scientist. On the other hand no increases are assumed for research support functions (i.e., laboratory services and seeds) other than when a senior staff member is added; in those years the increase is probably too generous thereby compensating for other years when some increase may be needed.

Through 1988, International Cooperation (excluding the regional cooperation personnel who are budgeted in the research units) is assumed to increase by U.S.$200,000 annually for increases in training and communication needs due to the extra staff and the expanded regional cooperation activities.

The Board of Trustees, Director General's office and the senior staff costs for the Controller and Executive Officer are assumed to stay constant. The other costs in the Controller's office are assumed to increase in proportion to the total senior staff. The other costs for the Executive Officer are assumed to increase in proportion to the headquarters-based senior staff.

General operating expenses are also assumed to increase in proportion to the headquarters-based staff.

CAPITAL

Budgeted and projected amounts for years to 1985 have been adjusted to reflect the different pattern of senior staff increases in the long-term plan. No major construction is anticipated at headquarters. Since most of the increases in senior staff are for outposting, it is assumed facilities will be provided by host institutions or rented.

Capital funds for the normal equipment requirements of existing activities are assumed to be U.S.$500,000 annually. Additional amounts are included in the years when new senior staff are added.

APPENDIX 17

Selected Assumptions and Methodological Procedures Underlying the Estimates of the Economic Benefits of CIAT Technology

GENERAL ASSUMPTIONS FOR ESTIMATING SUPPLY AND DEMAND

1. It was assumed that in the absence of CIAT-generated technology, supply and demand would increase at identical rates throughout the period under analysis. This implies that real prices are assumed to remain constant at 1981 levels. Since during the last decade and in the cases of most crops – except rice – production growth has been well below growth in demand, this assumption implies an underestimate of potential benefits.

2. For demand projections, per capita income growth during the period to which the calculations apply was assumed to be constant at the low rate of 2.5% annually across countries, and income elasticities were assumed to decline as income rises over time.

3. Demand and supply price elasticities were assumed to be below the level of available estimates; in those cases where estimates were not available, the values of these elasticities were extrapolated from estimates for other countries.

4. A closed economy was assumed in all cases.

PROGRAM-SPECIFIC ASSUMPTIONS FOR ESTIMATING SUPPLY AND DEMAND

Cassava

Potential cassava markets included in the calculations are: fresh roots (urban), fresh roots (rural), "farinha" or flour (Brazil only), and animal feed concentrates. Other potential markets such as alcohol fresh feed processed food, or industrial markets (e.g., composite flour starch, etc.) were excluded. In the model the concentrate market sets a floor price which remains constant under the restrictive assumption that cassava supplies only replace feed grain imports up to a maximum of 20% of the feed mix, and therefore do not affect equilibrium prices of maize and sorghum. Some of the other assumptions regarding the adoption process and the expected average yield increases are presented in Table 17-1. It should be noted that expected yield levels, while implying a large percentage increase are still well below those obtained in international yield trials. Only those benefits expected to be accrued in Latin America were included. Africa and Asia – regions producing 40 and 30% of the world total, respectively – were excluded from the calculations.

Beans

Expected improvement in national average bean yields are on the order of twice the current yields (Table 17-1). It is anticipated that this will be achieved largely by reducing yield variability at the lower end of the yield distribution. However, projected levels remain substantially below yields registered in international yield trials, and are 33% lower than those achieved in North America in the late 1970s. Other important bean production regions such as East Africa and the Middle East, were excluded from the analysis, thereby underestimating total potential benefits.

TABLE 17-1

Selected parameters on adoption and yield increases assumed in the estimation of benefits

Commodity	Initiation of adoption from 1981 (years)	Adoption period[a] (years)	Adoption ceiling[e] (%)	Estimated benefits: Without CIAT technology	Estimated benefits: With CIAT technology
				(Average percentage yield increase)	
Cassava	1-10	10	90	[b]	66-130[c]
Beans	2-10	8	90	—[d]	100
Rice					
Irrigated	0	7	90	[b]	15
Favored upland	4	12	90	[b]	20
Unfavored upland	9	12	90	—[b]	50
				(Percentage increase in calving rates)	
Tropical pastures					
Well-drained acid savannas	3-5	15	60[e] (12)	16	34
Poorly drained acid savannas	6-7	17	60[e] (10)	20	34
Humid tropics	7-10	15	60[e] ([illegible])	16	34
Rest of country	—			16	

a Logistic curves are arbitrarily used to simulate the adoption pattern.

b Area is assumed to increase in order for production to meet demand growth and maintain prices at 1981 real levels

c. Depending on the country

d Area and/or yields are assumed to increase in order to meet demand growth at 1981 price levels.

e Percentage of existing stock in each ecosystem. Percentage of total area in improved pastures is indicated in parenthesis

Rice

Three major rice production systems are included. irrigated, favored upland and unfavored upland. Expected average yield increases were assumed to be 0.5 t/ha in each of the systems, representing increases of 15, 20 and 50%, respectively. Adoption of high-yielding varieties is already underway in the case of irrigated systems, and is expected to start in 1985 in favored upland, and in 1990, in unfavored upland (Table 17-1). It was estimated that twelve years are required to reach the adoption ceiling. Area increases are projected at historical rates. Benefits due to the increased production of rice byproducts are not included. Total costs of rice research for Latin America were calculated by adding to CIAT costs the costs of outposted staff from the International Rice Research Institute (IRRI) and The Rockefeller Foundation, and multiplying this total by an arbitrary coefficient of 1.2 to reflect the indirect contribution of IRRI.

Tropical Pastures (Beef)

The case of beef is somewhat different from crops, since herd growth restrictions have to be explicitly taken into account in supply shift projections. Each country was divided into four major ecosystems: well-drained acid savannas, poorly drained acid savannas humid tropics, and the rest of the country. Estimates for production growth with and without technology were restricted by the existing initial herd in each subregion. Interregional movement of cattle was assumed to be negligible. A similarly conservative route was chosen by assuming: (a) no increase in milk production; (b) no technology spillover effect in the rest of the country (where by far the largest proportion of stock is located in most countries); (c) no benefits from the increased production of cattle products other than beef (e.g., leather, offal, protein concentrates, etc.); (d) no benefits from the increase in land values due to land improvement; and (e) no benefits from the liberation of more fertile land for crop production.