CIAT in the 1980s revisited

A medium-term plan for 1986 to 1990

CIAT

CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The government of Colombia provides support as a host country for CIAT and furnishes a 522-hectare site near Cali for CIAT's headquarters. In addition, the Colombian Foundation for Higher Education (FES) makes available to CIAT a 184-hectare substation in Quilichao and a 73-hectare substation near Popayán; the Colombian Rice Federation (FEDEARROZ) also makes available to CIAT a 30-hectare farm—Santa Rosa substation—near Villavicencio. CIAT co-manages with the Colombian Agricultural Institute (ICA) the 22,000-hectare Carimagua Research Center on the Colombian eastern plains and carries out collaborative work on several other ICA experimental stations in Colombia; similar work is done with national agricultural agencies in other Latin American countries.

CIAT is financed by a number of donors, most of which are represented in the Consultative Group on International Agricultural Research (CGIAR). During 1985 these CIAT donors include the governments of Australia, Belgium, Brazil, Canada, France, the Federal Republic of Germany, Italy, Japan, Mexico, the Netherlands, Norway, the People's Republic of China, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America. Organizations that are CIAT donors in 1985 include the European Economic Community (EEC), the Ford Foundation, the Inter-American Development Bank (IDB), the International Bank for Reconstruction and Development (IBRD), the International Development Research Centre (IDRC), the International Fund for Agricultural Development (IFAD), the Rockefeller Foundation; the United Nations Development Programme (UNDP), and the W. K. Kellogg Foundation.

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CONTENTS

PREAMBLE

The long-range planning process at CIAT is intended to provide guidelines within which the Center will continue to develop its research programs and to provide a clear statement on our role in the research-development spectrum. The first phase of this process began in 1979, culminating with the publication of **CIAT in the 1980's. A Long-Range Plan for the Centro Internacional de Agricultura Tropical** in 1981.[1] This plan was developed through a consultative process involving CIAT staff, the Board of Trustees and representatives from collaborating national research institutions.

The present document represents a rolling five-year version of the original plan, with projections for the final five years of the decade to 1990. The document has been prepared in the light of the 1984 TAC External Program Review recommendations and addresses all of the key strategic issues raised by the review team.

The socioeconomic context of CIAT commodities in the developing world is briefly described in Section I. The Center's objectives, principles and overall strategies are presented in Section II. The research strategies and projections of the commodity research programs and the research support units for the period 1986-1990 are presented in Section III. Section IV deals with emphases and projections in international cooperation activities for this period. Looking to the longer term future, a brief overview of the anticipated planning context for CIAT in the 1990's is presented in Section V. Finally, a summary of the staff projections for the period 1986-1990 is presented in Section VI.

During the past five years, a number of factors have influenced the way CIAT has evolved. Some of these were predicted and accounted for in the original plan; some were not. In this sense the plan for the remainder of the decade represents another look at an evolving organization that seeks to place the projections for growth and the directions of this growth in terms that are more realistic in the present financial climate.

This updated version of the CIAT plan also projects certain changes in focus within the commodity research programs. These changes are

[1] **CIAT in the 1980's, A long-Range Plan for the Centro Internacional de Agricultura Tropical**, CIAT, Cali, Colombia, November 1981.

mainly in relation to the center's greatly increased emphasis on the decentralization of its programs and on the research programs' growing ability to extend their technology development work beyond the narrower geographical boundaries set earlier. These evolutionary changes—which do not represent any basic change in the overall philosophy of the center—were foreshadowed by direct consultation with collaborating national program representatives on those specific issues, as well as through the deliberations of the Board of Trustees. The key recommendations of the 1984 External Program Review (EPR) team have provided an important stimulus to CIAT in making these adjustments at mid-decade.

The most important changes incorporated in the document are as follows: (a) in the Tropical Pastures Program, increased research attention has been given to the development of new pasture technology for less acid soil areas in more favored ecosystems; (b) in beans a major program of regional research cooperation has been initiated in Eastern and Southern Africa; (c) in cassava, there is a stronger emphasis on Asia; and (d) in rice, there is a determined move toward decentralization of the research effort, particularly in relation to the needs and potential of upland rice production systems.

In the first half of the decade, CIAT became involved in a series of what proved to be highly successful applications of biotechnology in the commodity research programs. Expectations for further application of a wider range of new technologies in this field have stimulated CIAT to strengthen this work through the creation of a Biotechnology Research Unit in 1985, which serves all the research programs as a bridge between more fundamental research and its application to plant improvement programs. The present plan projects CIAT's involvement in this field over the remainder of the decade.

As in the original plan, CIAT has again attempted to project the actual senior staff positions that would be essential if the plan is to be fully implemented. The center has been far more conservative with respect to core-funded positions than was evident in our 1981 projections. A senior staff category tentatively identified as "corelike positions" has been projected for funding over the remainder of the decade. This category anticipates expected changes in the way the Consultative Group on International Agricultural Research (CGIAR) system will be financed and takes into account the need to accomodate a large number of extra-core funded positions in Africa which are of a long-term nature.

This plan for 1986-1990 concludes with a discussion on the proposed continuation of the planning process for the decade of the nineties, including the need for a major internal reevaluation of the center and its programs toward the end of the decade, which would probably follow the next external review of the center. As an integral part of this planning effort, CIAT will once again consult with our collaborators in order that the center remains relevant to their needs in a rapidly evolving situation characterized by increasing evidence of vastly improved national research capacity in many developing country institutions.

THE PLANNING CONTEXT

INTRODUCTION

Over 700 million people in developing countries are estimated to have external symptoms of malnutrition, causing a substantial reduction in human capacities, as well as significant welfare losses. Estimates of the number of people with insufficient diets range from 1 to 2 billion people, depending upon the criteria used. Some of the contributing causes of hunger in many countries are insufficient food production and resources to import food, but the more basic cause is poverty—the lack of sufficient income to purchase food for an adequate diet. A solution to the world food problem, although dependent upon producing more and cheaper food staples, must, in the end, be based on raising the income levels of the poorer segments of the population.

Although improved agricultural technology adapted to the socio-economic and agroclimatic conditions of the developing world is by no means sufficient, it is an essential component of a world food strategy. In recognition of the key role of agricultural technology in increasing food production in the tropics, the CGIAR system was formed in 1971, co-sponsored by the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO), and the World Bank (WB). The CGIAR system sponsors ten international agricultural research centers (IARCs) including CIAT and three international institutes, which are all integral parts of the global agricultural research system made up by national and international centers and institutes. Improved production technology is the final product of the collaborative research efforts of these centers with national and regional programs; nevertheless, the CGIAR system recognizes that technology can be a means of achieving more basic socioeconomic goals; namely:

1. Improving the production, quality and stability of supply of basic food commodities in developing countries.

2. Improving the nutritional status of those segments of the urban and rural population below minimal nutritional requirements.

3. 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 and distribution is complex, and their impact on nutrition and income is quite variable across time and space. Improved technologies alone are not enough to 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. In order to choose and develop the most appropriate technological alternatives, it is necessary to have an understanding of the socioeconomic structures and how technologies that are compatible with such structures and the three basic goals might be designed.

SOCIOECONOMIC CONTEXT OF CIAT COMMODITIES IN THE DEVELOPING WORLD

Within the present division of responsibilities among the IARCs, CIAT has the global mandate for beans and cassava, and a regional mandate for rice, tropical pastures for beef and milk production on acid infertile soils, and seed technology for Latin America and the Caribbean. Understanding the socioeconomic context in which these commodities are produced and consumed in the different continents becomes important to define the role of the Center and the particular commodity research strategies for the different regions.

The Latin American Context

Because of the importance of all four commodities in CIAT's mandate (beans, cassava, rice and tropical pastures) in Latin America and the Caribbean, circumstances affecting the agricultural sector in this region will continue to influence research planning at CIAT considerably. Major trends in agricultural production and food consumption in tropical America and their implications for commodity choice and research strategies within the regional socioeconomic context were reviewed and discussed in Chapter I of CIAT's Long-Term Plan.[2] Such trends will be reviewed only briefly in this section in terms of more recent developments.

[2] CIAT In the 1980's, 1981, Op. cit.

Agricultural production in Latin America has grown during the last two decades at an average rate of 3.1% per year[3], about 0.5% above population growth. This production growth, although higher than in Africa and Asia, was insufficient to meet demand growth as evidenced by the sharp increases in food and feed imports.[4] Whereas food production growth accelerated during the 1970's for developing countries as a whole, the rate of increase in food production declined rather sharply in Latin America, dropping from approximately 4.2% per year in the 1960's to only 1.7% during the 1970's (Table 1). This sharp decline in food production growth is mostly due to a sharp decline in crop area expansion, attributed to:

1. The increase in production and transportation costs associated with the increases in domestic oil prices.

2. The overvaluation of domestic currencies and the increase in food and feed grain imports permitted by the easy availability of foreign credit, which in turn made possible the adoption of cheap food price policies in many countries resulting in low price incentives to producers.

While in the 1960's two-thirds of the production growth in major food crops was attributed to crop area expansion, in the 1970's only one-third of the much lower production growth was due to increases in crop area (Table 1). This phenomenon is to be expected when relative input/output prices increase because it is less profitable to produce on marginal lands that (a) require more soil amendments and private investment and/or (b) imply high transport costs to and from markets.

Production growth and sources of growth, however, have varied considerably among subregions and countries. In regions where underutilized land resources are less abundant such as in temperate South America, Mexico, Central America and the Caribbean, the

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[3] FAO, **Agriculture Toward 2000: Latin America's Problems and Options**, FAO, Rome 1981.

[4] During the period 1961-65 to 1973-77, major food imports increased at an annual rate of 6.9%, whereas food exports increased at a rate of 3.5%. (See A. Valdés, **Latin America's Food Situation and Perspective within a Global Context**, paper presented at the Club of Rome Budapest Conference on Food for Six Billion, Budapest 1983; International Food Policy Research Institute, IFPRI, 1983, Table 2.)

Table 1. **Average annual growth rates of production, area harvested and output per hectare of major food crops[a] in Latin America: 1961-80, 1961-70 and 1971-80.**

Country Group	Period	Average annual growth rate: Production	Area harvested	Output per ha	Relative contribution to production growth: Area harvested	Output per ha
Latin America	1961-80	2.79	1.47	1.30	53	47
	1961-70	4.26	2.75	1.47	65	35
	1971-80	1.66	0.61	1.04	37	63
Mexico, Central America & Caribbean	1961-80	3.34	0.58	2.74	18	82
	1961-70	5.75	2.15	3.53	38	62
	1971-80	2.65	-0.08	2.73	(b)	100
Tropical South America[c]	1961-80	2.81	2.59	0.22	92	8
	1961-70	4.60	3.73	0.84	81	19
	1971-80	1.77	1.83	-0.06	100	(b)
Temperate South America[d]	1961-80	2.31	0.14	2.17	6	94
	1961-70	2.52	1.60	0.90	64	36
	1971-80	0.65	-1.42	2.10	(b)	100

a Major food crops here include cereals, roots and tubers, pulses, and groundnuts.
b Negative.
c Includes Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname and Venezuela.
d Includes Argentina, Chile and Uruguay.

Source: L. Paulino. **Food in the Third World, Past Trends and Projections to 2000.** International Food Policy Research Institute, Washington, D.C. (in press). Basic data from FAO Production Yearbook tapes.

increase in food crops production in the 1970's is attributed exclusively to increased yields; whereas in tropical South America, where there exist large underutilized areas of land, total production increase is attributed to area expansion. These different subregional patterns of food production growth in the 1970's reflect structural differences among countries, particularly in terms of relative land endowments, which need to be taken into consideration in designing agricultural technologies and policies.

Associated with the slowdown in production growth in the 1970's, there has been a significant change in the product mix, with staple crops such as roots, tubers and pulses having low or negative growth rates; cereals such as wheat and rice having moderate growth rates; and a feed grain such as sorghum and export crops such as soybeans and citrics having very high growth rates (Appendix 1). These changes in the product mix and the overall inability of production to match food demand growth in the 1970's suggest that such changes were, to a significant degree, demand led.

Concessionary imports in the form of food aid, which were significant for Latin America during the 1960's, encouraged changes in food consumption patterns.[5] The high rates of rural-urban migration observed in Latin America during this period eased slightly during the 1970's, with urban growth still averaging 3.7% annually, well above population growth.[6] Urban growth rates were above 4.5% in large countries such as Brazil and Mexico. Food aid, increased urbanization, rising incomes under relatively skewed income distribution circumstances, and cheap food price policies made feasible by increased foreign exchange availability resulted in expanded demand for those food commodities with high income elasticity of demand; e.g., most preferred and consumed by middle- and high-income groups.

As a response to high demand growth, production of those commodities has increased rapidly, sometimes at the expense of more basic food crops consumed mostly by the poor. This is the case of poultry and, indirectly, feed grains. Poultry production in tropical Latin America grew 9.2% annually from 1968 to 1975 and 10.5% annually from 1976 to 1983, implying a 6.4 and 7.9% increase, respectively, in per capita production (Appendix 2). Production growth of sorghum and soybeans for feed, exports and vegetable oil was even more rapid (Appendix 1). The dramatic expansion of soybeans in southern Brazil helped push dry bean and cassava production onto more marginal and less productive lands.

Market and policy incentives for production of more basic staples consumed by the low income strata of the population have been inferior

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5 Valdes, 1983, op. cit.

6 CIAT, 1981, op. cit.

to those for high-demand crops. Growth in production of food staples such as maize for direct consumption, rice, wheat, cassava, beans, beef and milk have been much slower (Appendices 1 and 2).

Projected Trends

In recent years, Latin American countries have had to make major adjustments in their exchange rate policies to cope with the economic recession and foreign debt problems, which are exacerbated by depression in the international markets of important export commodities such as sugar, coffee and minerals. Strong and sustained devaluations of domestic currencies, when not fully compensated by export taxes or import subsidies, imply significant changes in relative domestic prices of traded agricultural commodities versus nontraded ones. Although the situation varies from country to country, it is expected that price increases in imported or exported commodities will lead to significant substitution in both production and consumption patterns.[7] Although increased production of export crops provides necessary foreign exchange, they compete with production of staple food crops which are expected to be further displaced to marginal lands (e.g., beans, cassava, rice in some countries, and beef).

Imports of feed grains have risen considerably during the last two decades (Appendix 3). Increased production of feed grains led by relative price increases in importing countries are also expected to lead to further displacement of staple nontraded crops to more marginal lands. Even though substitution in consumption induced by relative price changes will partially offset such changes, the overall expected scenario is one in which production of domestic staple foods consumed by the low-income population will tend to grow at a slower rate than those consumed by middle-and high-income groups and than traded commodities (i.e., exported or imported).

At a time of restrictions in public spending, rising unemployment and real wage reductions, the urgency to increase production of staple foods becomes even more critical to attain equity and improve the nutrition of

[7] J. Lynam, Consistent Policy Formulation Within a Skewed Farm Size Distribution: The Small Farmer in Latin America, in CIAT, **Latin America Agriculture: Trends In CIAT Commodities,** Internal Document Econ. 1.10, May 1985.

the large segments of the population that have access to an insufficient diet. Although improved technology cannot be expected to solve these problems, it can certainly contribute to their solution.

Recent projections of the food staples production-demand gap to the year 2000 indicate that tropical Latin America is expected to increase its net food deficit from about 16 million tons in the 1976-80 period to more than 40 million tons at the end of the century.[8] This projected two-and-a-half-fold increase in the food deficit undoubtedly represents a significant challenge to both agricultural policymakers and agricultural research institutions in the region.

Nutritional Status

Aggregate per capita food supplies are significantly higher in Latin America than in Asia or Africa, and the quality of the diet is also somewhat better.[9] However, because of disparities in food production among countries and inequalities in the distribution of income, substantial segments of the population are undernourished in Latin America. The most serious problems of malnutrition are found in Central American and Caribbean countries, followed by the Andean countries.[10] Undernutrition and malnutrition are more urban than rural problems in Latin America.[11] This is attributed to the large size and growth of the urban sector, the absence of urban household food production, the more diverse expenditure pattern of urban families (e.g., housing, transportation and recreation), and because of increasing urban unemployment and underemployment. In addition to inadequacies in food intake, other factors determining malnutrition such as deficient health, drinking water and hygiene conditions are extremely important.[12]

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8 L. Paulino, **Food in the Third World, Past Trends and Projections to 2000**, International Food Policy Research Institute, Washington, D.C (in press); and FAO, 1981, op. cit.

9 D. Pachico and C Seré. Food Consumption Patterns and Malnutrition in Latin America:Some Issues for Commodity Priorities and Policy Analysis; in CIAT, **Latin America Agriculture: Trends in CIAT Commodities**, Internal Document, Econ. 1.10, May 1985.

10 Valdés, 1983, op. cit.

11 Pachico and Seré, 1985, op. cit.

12 Valdés, 1983, op. cit.

Estimates of under- and malnutrition based on comparisons of apparent nutrient intakes with estimated requirements, though varying considerably depending upon the criteria used, clearly indicate an extremely large proportion of population with inadequate diets. Using total calorie availability, income distribution, and the statistical relationship between income and calorie consumption, as much as 36% of the total population of Latin America has been estimated to have a calorie consumption below recommended levels in 1975, which implies about 112 million people undernourished.[13] Estimates of undernutrition varies considerably among countries, ranging from 30% of total population in Chile, Uruguay, and Costa Rica to 50 to 70% in some Caribbean and Central American countries. Estimates of malnutrition (below 90% of recommended caloric levels) range from 10 to 40% of the total population.[14] A similar study made by FAO estimated a malnourished population in Latin America of 46 million people in 1972-1975, or 15% of the total population.[15] A recent study on food consumption of urban and rural consumers in Colombia documents the low calorie and protein intake of low-income groups. Estimates of income elasticities of demand of cereals, dairy products, eggs, beef and milk among low-income groups are quite high, providing evidence that the problem of malnutrition is still large, even in countries well endowed with land resources such as Colombia.[16] It is most probable that those commodities for which production in the 1970's and early 1980's increased more rapidly—i.e., principally export crops, feed grains and poultry meat (Appendices 1 and 2)—had more impact on the diets of middle-and high-income groups than on the diets of the poor. In summary, malnutrition was a grave problem in Latin America and the Caribbean in the early 1970's and, most probably, remains as serious in the mid 1980's.

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[13] S. Reutlinger and M. Selowsky, **Malnutrition and Poverty: Magnitude and Policy Options**, John Hopkins Press, Baltimore, 1976.

[14] 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.

[15] FAO, **The Fourth World Food Survey**, Rome, 1977.

[16] L. Sanint, , L. Rivas, M.C. Duque and C. Seré, Food Consumption Patterns in Colombia. A Cross Sectional Analysis, 1981, in **CIAT, Latin America Agriculture: Trends in CIAT Commodities**, Internal Document Econ 1.9, April 1984.

Priority on Major Staples

The relative average contribution of different commodities to apparent caloric and protein consumption in Latin American countries is summarized in Appendices 4 and 5.

Because of the heterogeneity of Latin American agriculture, no one crop—which was 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. Table 2 summarizes the importance of principal commodities in terms of nutrition and demand growth in the region. Each commodity listed (except sorghum and soybeans) has either regional or subregional importance as a source of calories and/or protein.

In terms of contributing to the major nutritional problem (caloric deficits), maize, wheat, rice, sugar, milk, beef, beans and cassava are important. The first two are under the mandate of the Centro Internacional de Mejoramiento de Maíz 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 sugarcane. Cassava is also a cheap caloric food and is particularly important in Brazil and Paraguay, which account for 40% of the population in tropical America. Potatoes, which are important as a caloric source in the Andean Region and Southern Cone only, are under the mandate of the Centro Internacional de la Papa (CIP). Sorghum and soybeans are other important crops in terms of production, agricultural growth and foreign exchange, particularly in Brazil; but they are of lesser significance in achieving equity and nutritional goals directly as increased production would tend to benefit primarily the middle and high-income consumers and large farm producers. Nevertheless, both are displacing food staples grown in good soils.

Except for the Southern Cone, beans are important throughout the region in terms of both calories and protein contribution and are the most inexpensive protein source. Rising bean prices in many countries indicate that growth in demand has exceeded supply growth in recent years. Rice, beef and milk are already important in providing calories and proteins in most of Latin America. Urban households with lowest income spend a large percentage of their food budget in beef and milk.

Table 2. **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	P[a]	
Soybeans								X
Beef		X	X				X	
Milk	X		X				X	

a Potentially important.

b Few countries only.

Source: CIAT in the 1980's, A Long-Range Plan for the Centro Internacional de Agricultura Tropical, CIAT, Cali, Colombia, November 1981.

In 12 cities of tropical countries, beef expenditures among low-income groups range from 9 to 24 percent of total food expenditures, and milk expenditures range between 6 and 18 percent.[17] Moreover, a rapid increase in demand is expected for these commodities, especially beef.

In brief, within the division of responsibilities among the IARCs, most of the important staple food crops in developing countries of the western hemisphere are covered. CIAT's research commodity basket includes beans and cassava, both principally produced by small farmers and consumed by the poor, and rice and tropical pastures (indirectly beef and milk) both mostly produced in middle and large-scale farms, but significant within the food basket of the low income urban and rural consumers throughout the region.

A Combined Growth Strategy

An agricultural growth strategy for Latin America that efficiently utilizes both land and labor resources has to consider explicitly the distribution of these resources, as well as the very marked differences in land quality. Three very different growth strategies emerge:

1. Intensification of production by large farmers who control the more fertile areas, primarily through mechanization and higher input use.

2. Expansion of agricultural production on the less fertile frontier land.

3. Intensification of production by small farmers through higher, more stable yields.

The possibilities of implementing one or more of these strategies vary from one country to another. Some countries, especially in the Caribbean, Central America and Mexico, do not have large, under-utilized frontier areas. For these countries the major options are (1) and (3); while (2) is a viable option in all countries of tropical South America, as well as in some Central American countries.

17 E. Rubinstein and G.A. Nores, **Gasto en Carne de Res y Productos Lácteos en Doce Ciudades de América Latina**, CIAT (mimeo), Cali, Colombia, 1980; and Sanint et al., 1981, op. cit.

Each growth strategy implies a different agricultural 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 an international center such as 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 the large-farm agricultural sector, 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, serious social stresses develop. Although not necessarily from the private sector standpoint, in aggregate social terms small farmers in labor-surplus economies are in general the most efficient producers in the combined utilization of land, labor and capital resources.[18] ECLA[19] estimates that in Latin America about 40% of agricultural production for domestic consumption originates in the small farm sector, including the family type unit. This contribution is obviously significant, and for crops such as cassava, beans and potatoes small-scale units dominate in the production process.[20]

Enough public and private resources are being directed to large-scale agriculture to assure its future dynamism. An efficient growth strategy should thus include expansion on the extensive frontier existing in much of Latin America with intensification of production by small farmers. However, the compatibility of the three strategies rests on each group specializing in those crops for which it has a comparative advantage in order to avoid competition between large and small farmers in the same product market. Research investment should therefore concentrate on strengthening these comparative advantages by matching crop choice and technology design to the particular resource constraints of each country and farm group.

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[18] Q. A. Berry and W. Cline, Agrarian Structure and Productivity in Developing Countries, John Hopkins Press, Baltimore, 1979.

[19] L. López Cordovez, Trends and Recent Changes in the Latin American Food and Agricultural Situation, CEPAL Review, No. 16, April 1982.

[20] Lynam, 1985, op. cit.

For CIAT, this implies that technology design in beans and cassava should focus on the small farm sector; in tropical pastures on the more extensive frontier; and in rice in both irrigated and upland mechanized production systems, thereby strengthening through appropriate technology the comparative advantages of the respective production sectors and thus providing for an efficient utilization of land and labor resources in the region as well as contributing to increase staple food supplies.

The African Context

Sub-Saharan Africa faces the gravest food problem of any region in the world. Per capita food production has fallen some 20% since the early 1960's; whereas Asia and Latin America have achieved increases in per capita food production. In most Sub-Saharan countries aggretate per capita caloric availability falls below minimum nutritional standards. Serious malnutrition is the result, with some 60% of the population estimated to suffer from insufficient protein-energy intake.[21]

The region's food crisis is due to three major factors: an unsurpassed rate of population growth that fuels demand; poor macroeconomic and export performance that limits purchasing power; and the slowest expansion of food production among the world's regions.

The food and nutritional situation in Sub-Saharan Africa is deteriorating as the rate of population growth continues to rise and is not expected to level off until it reaches about 3% yearly in the 1990's.[22] An urban population growth rate exceeding 5% yearly in most countries in the region puts additional pressure on food production as marketable surplus will have to increase at an even higher rate due to typically more rapid income growth in the urban sector.

While demand growth continues to accelerate due to rising population and urbanization growth rates, food production growth rates in the 1970's fell off sharply from those of the 1960's. Yields of major food crops were stagnant over the past two decades, and production

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[21] Reutlinger and Selowsky, 1976, op. cit.

[22] United Nations, **World Population Trends and Policies: 1977 Monitoring Report**, United Nations, New York, 1979.

increases in the 1960's were achieved solely through area expansion. As the rate of growth in area cultivated slowed in the 1970's, annual production growth declined by more than three-fourths,[23] falling to 1.2%, well below the population growth rate of 2.9%.

Food consumption has fallen less drastically than the gap between production and population growth as food imports have risen rapidly. From being a net exporter of food staples as recently as the early 1960's, the region now depends on ever-increasing food imports. Despite escalating food imports, per capita food consumption has fallen as low incomes and slow economic growth deny many of the region's countries the capacity to import. Even within those few countries that may be able to afford food imports, poor consumers often lack the purchasing power for additional food.

Financing food imports to make up for production shortfalls has become increasingly difficult because prices of principal African exports have been declining and are expected to remain depressed. Food aid and food imports at concessional prices have been important in supplementing regional production and commercial imports; but besides being insufficient for meeting food needs, they do not represent a long-term solution.

Sub-Saharan Africa's food production has been poor because of a variety of factors, both natural and socioeconomic. Poor infrastructure, high transportation costs, and inefficient marketing systems have kept food prices low and input costs high at the farm gate level. Low farm prices and high costs of purchased inputs have been important factors in limiting food production and productivity. Not only is productivity low, but productivity improvements have also been sluggish during the last two decades. African cereal yields are less than half those of Asia, and yields of pulses, roots and tubers are about two-thirds of Asian yields.[24] As food production in the region is fundamentally based on rainfed farming systems, productivity is both low and quite variable over time.

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[23] J. W. Mellor, The Changing World Food Situation—A CGIAR Perspective, paper presented at International Centers Week, Washington, November 1984, mimeo, IFPRI, 1984

[24] C Christensen, A. Dommen, N. Horenstein, S. Pryor, P. Riley, S. Shapouri, and H. Steiner, Food Problems and Prospects in Sub-Saharan Africa, USDA Foreign Economic Report No. 166, Washington, D. C., 1981.

Most food production occurs within the subsistence sector, thereby sharply limiting the availability of variable capital to purchase agro-chemicals. Because of the scarcity of both draft power and mechanical traction, there is a widespread dependence on hand labor, which makes labor supply a severe bottleneck for area expansion, particularly at seasonal peaks of labor demand. Frequently, this situation is intensified by the division of labor, in which women are principally responsible for food production and men, concerned primarily with cash crops. Labor productivity in Sub-Saharan Africa is very low even when compared to Asian standards.[25] The low land and labor productivity places farm families within the subsistence sector under serious nutritional risk in the face of high variability due to agroclimatic conditions.

Generating improved agricultural technologies for Sub-Saharan Africa is made difficult, not only by intense natural stresses and socioeconomic constraints, but also by the tremendous variation in the relative importance of different crops and farming systems across countries and regions. Consequently, no single technological change in any one crop can be anticipated to have the widespread impact that irrigated rice had in Asia. In the Sahel, for example, millet and sorghum are the principal staples, sometimes supplemented by cassava, maize and rice. In coastal West Africa, cassava, yams, maize and rice are the dietary mainstays. Cassava is by far the most important source of calories in Central Africa; whereas maize-based systems that typically include dry beans as an associated crop, provide leading staples in Kenya and Tanzania. In the densely populated highlands of Rwanda, Burundi and southern Uganda, bananas, beans, cassava and maize are the most important foods. In southern Africa maize is the dominant food, with cassava, sorghum and beans being important subregionally.

CIAT's involvement in improving the productivity of Sub-Saharan African agriculture is derived from two factors: (a) CIAT's long experience with its two world-mandated crops—beans and cassava. Cassava, for which IITA has an African regional responsibility, is the leading carbohydrate source in the continent, while beans are a significant source of both calories and protein in much of eastern and southern Africa (Appendix 6).

[25] C. L. Delgado and J. W. Mellor, A Structural View of Policy Issues in African Agricultural Development, reprinted from the American Journal of Agricultural Economics, 1984, 66 (5).

Cassava's adaptation to relatively marginal soil and rainfall conditions; its high productivity per unit of land or labor; the certainty of obtaining some yield even under adverse conditions; the fact that the product (i.e., the roots) is not used as seed and thus does not need to be saved for the next season planting as is the case of most other crops; and the possibility of maintaining continuity of supply throughout the year have made it a basic component of the farming system in large areas of Africa. In a number of countries cassava provides over a fifth of all calories consumed; and in countries such as Zaire, this figure rises to over half of total calorie consumption. Famines do not occur in areas where cassava is widely grown, as it provides a stable base to the food production system.

In many food-deficit areas such as the over-crowded highlands of Central Africa, or regions where there is severe drought stress, or where soils are particularly acidic or high in aluminum, food production may be increased or stabilized through improved cassava productivity. Such a strategy, however, depends on a significantly wider germplasm base than currently exists in Africa. Besides backstopping IITA's cassava research and cooperation efforts in the various specialized fields, CIAT has a key role to play in this regard by making available to Africa through IITA the cassava germplasm adapted to the various specific agroecological environments found in the continent.

Sub-Saharan Africa is second only to Latin America among the world's leading producers of beans, with an average annual output of some 1.7 million tons. Beans play a central role in the diet of many African countries. In Burundi and Rwanda over one third of total protein consumption is from beans, while in Kenya and Uganda as much as one fifth of protein comes from beans (Appendix 6). For 110 million people beans are the leading source of quality protein in the average diet. Moreover, in Burundi, Kenya, Rwanda and Uganda beans make a notable contribution to caloric, as well as protein consumption. Besides the consumption of dry beans, young green leaves are frequently consumed as a vegetable, especially at times of particular food scarcity.

Despite the great nutritional importance of beans in much of Sub-Saharan Africa, recent sluggishness in production growth has led to declines in per capita bean consumption in over 70% of bean-producing countries in the region with consequent serious implications for human nutrition. Since 1962 half of the bean-producing countries have experienced expansion of bean production at least 1% per annum less than population growth.

In many countries growth in bean production was fairly buoyant in the 1960's, mostly due to strong increases in the area cultivated (Appendix 7). In the 1970's, however, almost all bean-producing countries experienced a marked decline in bean production growth rates, largely as a result of slowdowns in area growth. Average bean yields vary considerably among countries as well as over time due to variability in production and weather conditions; yet, with counted exceptions, national average yields are rather low and are essentially stagnant (Appendix 8). Future output growth must come increasingly from productivity improvements. For CIAT this implies that technology design should focus on increasing both yields and yield stability.

The Asian Context

If the world food "problem" has an origin, it is Asia. The combination of the bulk of the population residing in the rural sector, high population densities and extremely limited farm size, widespread underemployment and poverty, and growth in food production barely keeping pace with population growth all created a sense of dispair about Asia's ability to feed itself in the first decade and a half of the post-war period. The advent of the Green Revolution—in a sense the conquest of Asian irrigated agriculture—created a sense of progress, a notion that growth was possible even under very severe land constraints. Although the Green Revolution significantly increased per capita rice production, it did not eliminate poverty nor dispense with the food problem. It did, however, create a sense of confidence that Asian countries could work steadily toward their resolution.

Nevertheless, the rice economy is about the only homogenous element that runs through the different agricultural sectors of tropical Asian countries. Rice is the major calorie source in the diet, the major source of farm income, and the crop that dominates the irrigated areas of Asia. A principal means of improving rural employment, farm incomes and nutrition over a relatively widespread and homogeneous target area was through increased productivity of irrigated rice. Yet, as irrigated rice research turns more to maintenance activities, quality improvement and cost reduction, the search for productivity gains and for a way to correct the regional imbalances in income distribution turns to the upland areas and upland crops.

This broadening of the agricultural development focus, however, will necessarily lead to trade-offs in policy goals. No other crop can benefit both producers and consumers to the same degree as rice. Research investment for the upland crops will shift much more to meeting producer income and rural employment goals, which in most cases will also aid foreign exchange objectives.

That the policy focus should be on producer incomes and agricultural wages follows from the fact that the agricultural sector will continue to employ the bulk of the population for the foreseeable future. Over 60% of the total population still depends directly on the agricultural sector for its livelihood. Average agricultural income is low at around US$230 per year, and a large portion of the small, average farm is devoted to subsistence production. Unlike other continents, a large portion of the rural population is landless, making much of the rural population dependent upon wage income for their food. As a result an estimated 63% of the population[26] are undernourished.

Although the bulk of the poverty problem still resides in the agricultural sector, its solution is not purely dependent on just this sector. Rapid structural change through export-oriented industrialization is occurring in many of the economies of Southeast Asia. This has been most noticeable in Taiwan and South Korea but the phenomenon has also taken hold in the Philippines, Malaysia and Thailand. The urbanization and income changes inherent in this process induce rapid diversification in food demand and in turn, new demands and opportunities for the agricultural sector. The most striking trend in this process is the rapidly rising demand for livestock products and in turn for feedgrains. The growth in demand for carbohydrate sources is being fueled more by this change in food demand than by actual population growth. In most countries in tropical Asia these nonrice carbohydrate sources are a significant source of cheap calories for the poor, so that maintaining adequate supplies of both food and feed becomes crucial to ensuring the

[26] Reutlinger and Selowsky, 1976, op. cit.

ability of the lower income strata to feed itself adequately. In many cases to maintain growth in these supplies, countries have turned increasingly to imports.

There is thus an emerging imperative for a more balanced approach to development of the agricultural sector in tropical Asia. Raising agricultural productivity in as heterogeneous a region as the upland areas of tropical Asia will require a more diverse strategy than was the case for irrigated rice. Moreover, the upland areas reflect much more the very diverse structural and economic conditions that characterize the different agricultural sectors of the various countries. Finally, although the motivation for development of the upland areas is increased farm income and a more equitable distribution of income, growth in production will be most successful when linked to changing demand. There is thus a need to focus research investment on crops with a significant degree of flexibility to adapt to both diverse production and demand conditions.

After rice, cassava is the most important carbohydrate staple grown in tropical Asia. The closest competitor is maize. In the Philippines more maize is produced than cassava; however, in Malaysia, Sri Lanka, Thailand, Indonesia, Vietnam and southern India, cassava production is greater. Cassava must compete for land with export crops, especially tree crops, in many of these countries. In these cases the development of the upland areas is linked to the interplay between export growth, increasing domestic markets, and competition from imported substitutes. Cassava is grown under a wide range of upland conditions in Asia. Because of cassava's high yield and yield responsiveness under upland conditions, it is grown in areas where farm size is a major constraint on farmers' crop production, such as Kerala (India) and Java (Indonesia). On the other hand, cassava is well adapted to more land-extensive production systems, such as occur in frontier areas. Cassava is a dominant crop in frontier areas in Sumatra (Indonesia), Mindanao (Philippines) and the remote parts of the Northeast of Thailand. Cassava's multiple-use characteristics likewise give the crop significant flexibility in adapting to changing demand conditions. Unlike Latin America and Africa, a multiple market structure has developed for cassava in Asia. In Indonesia and the south of India cassava is a major food source, especially for low-income consumers. A cassava starch industry exists throughout tropical Asia; and Thailand, China, Indonesia and Malaysia produce cassava pellets or chips for animal feed. Most of this is currently exported because of the relatively high prices in the protected market of the European Community.

Increased productivity and further market diversification of cassava can be a basis for increasing the income of the small farmer in the upland areas of tropical Asia. Further market diversification will in most cases focus on meeting either rising domestic demand for carbohydrate sources for feed or serving the growing regional import market for livestock feed. Development of such a market will in effect put a price floor under more traditional markets, so that for at least India and Indonesia there will as well be a nutritional impact on the low-income consumer. However, research on improved cassava production technology and appropriate processing technology must be balanced in many countries with a broadening of the extension system and input and credit support services as they are currently directed principally at rice production and irrigated areas. Thus, while cassava can play an important role in the development of the upland areas of tropical Asia, the research and development strategy must reflect both the diversity that exists and the need to integrate production, processing and market development.

OBJECTIVES, PRINCIPLES AND STRATEGIES

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 food commodities in the tropics—principally countries in 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 is meant to provide a condensed overview of CIAT's philosophy and operating objectives. A brief analysis and explanation of its main features follow.

Technology Development Orientation

CIAT concentrates on the generation and transfer of agricultural technology. The underlying assumption of this orientation is that modern science can contribute significantly to solving food production problems in developing countries through the development of appropriate technology designed to fit varying production circumstances. This statement does not negate the importance of institutional, social and policy changes; rather it emphasizes the center's role in technology development.

Collaborative Nature of CIAT's Activities

The statement of objectives emphasizes the center's conviction that in order to accomplish the desired results, close collaboration among national, regional and international institutions is required. Of the various institutions involved in different types of research, none is more important than the national agency involved in agricultural research and development. Only through strong national programs can new technology be designed for and evaluated under varied local conditions, modified as necessary, and transferred to farmers along with the essential support services to make the technology useful. Thus the center is dedicated to activities that strengthen the capacity of these institutions so that they may carry out their function as full partners effectively.

Focus on Basic Food Commodities

Tropical export crops that provide valuable foreign exchange to developing countries have received due research attention; however, relatively little research effort has been dedicated to those tropical 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 toward overcoming the large agricultural technology gap that still exists.

Quality-of-Life Orientation

CIAT has identified limited-resource producers and consumers as the principal beneficiaries of its work. This orientation clearly associates quality-of-life objectives with production goals, thereby influencing commodity choice and technology design. Beans and cassava, for example, are specifically adapted to smallholders and are produced worldwide by small farmers. Development of production technology for this target group requires a sustained, focused effort. As production fragmentation has prevented producer organizations and most national programs from engaging in systematic, sustained research on these commodities, research input is best provided by a publicly funded international institution.

Increased food production to benefit the low-income urban and rural consumers and improve their nutrition is the ultimate goal. Beans and cassava are important components in the diets of many developing countries in the tropics; in addition, rice, beef and milk are staple foods in most of the tropical and subtropical regions of the Western Hemisphere. In terms of these last commodities, CIAT concentrates on developing technology that is adapted to the land resources of the countries in the region with the purpose of benefiting low-income consumers through increased availability and lower prices of rice and—through tropical pastures—of beef and milk.

Geographic Focus

CIAT's work focuses on the tropics—the region in which the fastest population growth and the largest food gaps are observed. During the last decade the center directed most of its attention toward the American tropics, a region in which all four CIAT commodities are basic staple foods.

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. With respect to beans and cassava, the Center has been given world responsibility within the CGIAR system. Because of the importance of cassava in Africa and Asia, and beans in Africa and the Middle East, CIAT has increasingly exercised its world responsibilities for these crops by designing its centralized activities of germplasm collection, breeding, training and documentation to respond to its global mandates in these two crops. In close coordination with IITA, which has regional responsibilities for cassava in Africa, CIAT's activities in cassava are designed to backstop and complement IITA's work. As projected in the Long-Range Plan, decentralized activities for in situ evaluation and transfer of technology for beans in Central and Eastern Africa and for cassava in Southeast Asia were started during the first half of the decade, mostly with special project funding. The present revised plan projects increased efforts in beans and cassava in Africa, the Middle East and Asia throughout the rest of the decade. These efforts, however, cannot detract attention from the task of consolidating CIAT's endeavors in the tropical and sub-tropical areas of the Western Hemisphere, where, for reasons of proximity and past involvement, CIAT maintains very special relationships with national institutions that must be developed further to achieve common goals.

CIAT's PLACE IN THE AGRICULTURAL TECHNOLOGY DEVELOPMENT PROCESS

Agricultural research encompasses a wide range of activities, ranging from conducting basic research to assessing the performance of improved varieties and cultural practices on farmers' fields. Figure 1 depicts the agricultural technology development process as four successive, but inter-related stages: basic research, applied research, adaptive research and production. It also illustrates the approximate

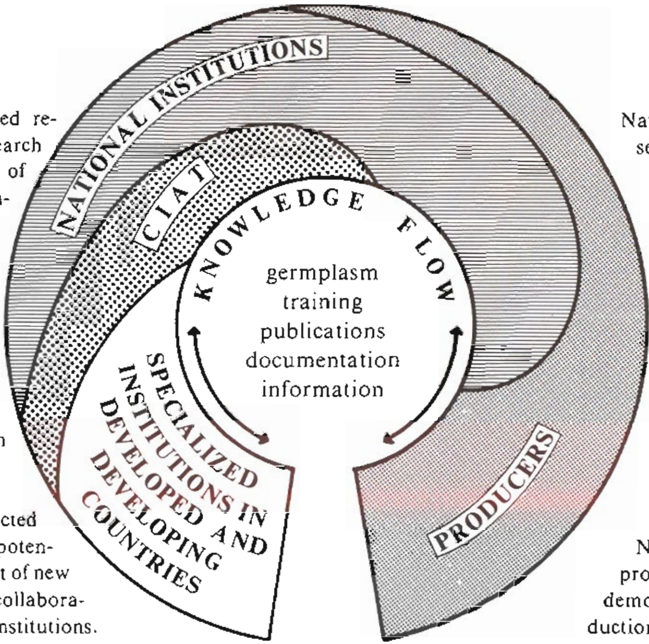
APPLIED RESEARCH

National institutions conduct applied research. CIAT emphasizes applied research and development of basic elements of technology in collaboration with national research institutions. CIAT's activities are primarily found in this quadrant.

BASIC RESEARCH

National institutions, especially the more developed ones, also engage in basic research.

CIAT assumes responsibilities for selected aspects of basic research with a high potential for payoff later in the development of new technology. This research is done in collaboration with appropriate basic research institutions.



ADAPTIVE RESEARCH

National institutions involved in commodity research and development conduct adaptive research based on their own applied research or technology developed by others, including international centers.

Although producers are predominantly involved in production per se, to varying degrees, they also conduct applied and adaptive research. Their research activities range from the private seed producer who develops new hybrid varieties to producers associations which maintain their own experimental farms and stations.

PRODUCTION

National institutions are involved in selected production activities including on-farm trials, demonstration projects, and certified seed production.

Figure 1. *CIAT's role in the agricultural research and development process.*

extent to which CIAT and its principal counterparts—the national institutions—are involved in the different types of research.

Originally CIAT conducted both applied and adaptive research in a large number of commodities.[27] As the center learned more about the relative socioeconomic importance of the different commodities, the varied ecological and socioecological conditions under which they were grown, and the nature of the constraints to be overcome through biological research, it progressively refined its objectives and the scope of its activities. The number of commodities in the mandate was reduced, and the ecological foci of the research programs were narrowed. Similarly, the nature and scope of international cooperation activities, including training and communication/ information, were progressively redefined and focused to adjust to the nature of the center's research activities and to address the needs of national research programs.[28]

This focusing/sharpening process was guided, on the one hand, by the need for achieving complementarity with the activities of existing institutions; and on the other, by CIAT's need to concentrate on those activities for which it had a clear comparative advantage vis-a-vis other institutions on the research continuum.

At present CIAT's activities are mostly in the area of applied research, focusing on the development of components to overcome particular biological constraints in relevant production systems. Although emphasis is placed on applied research, CIAT also assumes responsibilities for contributing to more basic research on selected strategic aspects with high potential payoff in terms of technology development. Similarly, CIAT is engaged in adaptive research, developing methodology for those selected areas that have a direct bearing on the effectiveness of its commodity research strategies such as assessment of production systems or on-farm testing of technological components.

Given the present stage of development of most national research institutions in developing countries, one of CIAT's roles in the

[27] CIAT, 1981, op. cit., Chapter 3.

[28] As an example, until 1974 CIAT offered one-year crop and livestock courses, which were "adaptive research" oriented. These courses gradually evolved into short, intensive commodity courses (1-2 months) that are "applied research" oriented.

agricultural technology development process is to provide a link between the more basic research institutions and collaborating national programs. On the one hand, CIAT must relate its technology generation efforts to developments in basic research conducted by other institutions; identify those aspects that have high payoff potential (i.e., strategic research); and then stimulate the carrying out of research in these areas or assume responsibility for it. On the other hand, all of CIAT's activities, whether in research or in international cooperation, must be designed and adjusted continually to support and supplement activities of collaborating regional and national agricultural research institutions.

OPERATIONAL PRINCIPLES

Certain basic operational principles have evolved at CIAT and have proven useful in defining the Center's general strategies in research and in international cooperation in the 1980's.

Commodity Focus

In order to increase food production and resource productivity, a better understanding of a given crop's potential and its production circumstances is needed. Because of the heterogeneity of farming conditions across countries and regions, national and local research and development institutions are in a better position to understand and deal with location-specific farming system problems than international institutions are. International centers can contribute with insights into the potential of individual crops and how to manipulate their genetic makeup to overcome the principal production constraints within major growing environments. To achieve this, CIAT's efforts in both research and cooperation activities focus along commodity lines. The center's commodity research programs are multidisciplinary in nature. In close collaboration with scientists from other institutions, the program teams strive to understand the genetic variability of a given crop in order to manipulate its genetic potential to achieve specific goals. An appropriate mix of disciplines and a minimum critical mass of scientists are needed to accomplish program goals. Cooperation activities are carried out parallel with those of research. By integrating these activities along commodity lines into combined strategies, the needs of individual countries and specific regions can be served in a most direct and effective manner. These strategies are designed to evolve as advances are made and as the circumstances in which national programs find themselves change.

Relevance

The success of the center's research will always be measured by its contribution to increased food production rather than to the body of scientific knowledge per se. Research in the four commodities is focused on solving the most important production problems in the countries served by the center. Both the identification and the solution of the most relevant production problems require a well-defined interface with national programs, including effective feedback mechanisms. Similarly, other elements of international cooperation, such as germplasm exchange, training, documentation, communication and information transfer, are based on the principle of relevance to the needs of national programs vis-a-vis CIAT's activities.

Complementarity

A basic premise underlying CIAT's strategies is that the center represents only a small segment in the agricultural research and development matrix. Consequently, all the center's activities are designed to be complementary to those of other organizations.

Comparative Advantage

CIAT concentrates on those problems and activities for which it has a clear comparative advantage as an international research center vis-a-vis national programs, basic research institutions, and related regional and international institutions (including other IARCs). Comparative advantages originate in some combination of the following circumstances: CIAT's nature as an autonomous, international institution; its location in the tropics; the existence of economies of scale in the development of given activities at the international level; the continuity of funds available for its operation; and its ability to move materials and information across national borders. Activities for which CIAT has a comparative advantage include the assembly of large germplasm banks, large-scale germplasm screening, crossing and selection for relevant major ecosystems, development of methodology, applied interdisciplinary research, in-service training, catalysis of horizontal cooperation activities, and international networking.

Consultation

To ensure relevance and complementarity in its activities, regular consultation with national programs is an essential and critical part of its strategy. Periodic consultations are held both across and within countries. At the international level, this occurs among centers and country programs; at the subnational level, among policymakers and commodity research programs.

Consultation across countries

At the center level, overall plans and research/cooperation strategies of the centers, as well as special topics of general interest, are discussed at triennial workshops with the participation of directors of national programs of countries served by each center. These workshops provide invaluable information for adjusting/focusing strategies in accordance with the needs of CIAT's collaborators.

At the program level, regional networking activities are important as leaders from national programs in a given region are given the opportunity to meet and share insights/experiences into regional research and development problems, as well as to establish priorities and responsibilities for collaborative research and development activities.

Consultation within countries

At the subnational level, consultations are carried out through various channels, including periodic visits of CIAT's directors and program leaders to collaborating countries to determine research and development priorities. National planning staff and leaders of national programs also visit CIAT. Close contact is maintained with former CIAT trainees; and in general, every opportunity to interchange ideas is taken in order to assure that the center is responding to country needs.

At the commodity program level, consultations on individual research and cooperation strategies of commodity programs are held during triennial commodity network meetings, which are organized on both regional and subregional bases. These meetings are complemented with frequent workshops on specific subjects, ranging from methodological issues to the interpretation of results and the design of the various network nurseries.

INTERNATIONAL COOPERATION STRATEGIES

CIAT's activities necessarily interface with those of other institutions in the agricultural research and development matrix. Such institutions include: (a) basic research institutions; (b) related regional and international institutions; and (c) national research and development institutions.

There are certain types of research and related activities that can be carried out most effectively through collaborative efforts between CIAT and regional institutions such as the Centro Agronómico Tropical de Investigación y Enseñanza, CATIE (e.g., pastures research in Central America) or the Caribbean Agricultural Research and Development Institute, CARDI (bean trials in the Caribbean). Similarly, selected problems or activities can be addressed best through joint efforts between CIAT and other international institutions such as the International Board for Plant Genetic Resources, IBPGR (germplasm); IRRI (rice); IITA (cassava germplasm, mealybugs and mites); ILCA (pastures); the International Center for Agricultural Research in the Dry Areas, ICARDA (beans); or the International Fertilizer Development Center, IFDC (phosphorus research). Frequently, the problem requires the active participation of several national programs. CIAT's philosophy in these cases is to act as a catalyst and foster a joint effort. Examples of these are some of the CIAT co-sponsored and/or backstopped regional and international research networks (discussed in Section IV). When only one national program is involved, it is dealt with as a bilateral project.

Although CIAT may carry out some types of basic research activities that are regarded as strategic by its commodity programs, other scientific institutions from developed or developing countries are often better equipped to conduct basic research in terms of specialized facilities and the technical/scientific skills needed to address a specific problem. Where basic research can be done entirely at another research institution, CIAT encourages such an approach, assisting, if necessary, in the procurement of special project funds. Certain basic research problems can be addressed more effectively through collaborative projects with participation of national programs, basic research institutions and CIAT. In those cases where CIAT carries out the field research component, the center assists in seeking special project funds to carry out said research.

Guided by the principles of consultation, relevance, complementarity and comparative advantages, the center seeks the most appropriate way to cope with strategic/basic research needs through individual projects financed through appropriate combinations of core and special project funding.

Certain types of research and related activities, because of complementarity and institutional comparative advantages, can be most effectively carried out in close collaboration with regional or international institutions. CIAT's approach in these cases is one of fostering joint efforts through mutual consultation.

STRENGTHENING COMMODITY RESEARCH AT THE NATIONAL PROGRAM LEVEL

As can be seen from the foregoing, the most critical institutional interface is that between national programs and CIAT. CIAT's cooperation strategy takes on the form of two complementary, coordinated approaches:

1. **The country approach,** which is bilateral in nature. Backstopping is provided to national programs to strengthen their respective commodity research programs so that they may fully participate, within their areas of comparative advantage, in collaborative research activities.

2. **The network approach,** a multilateral strategy in which international and regional commodity research networks that can deal with problems shared by several countries are fostered and backstopped.

The Country Approach

While CIAT does have a role to play in institution building, it recognizes that other institutions (such as the International Service for National Agriculture Research, ISNAR; the Instituto Interamericano de Cooperación para la Agricultura, IICA; and Winrock International, among others) are better equipped in terms of mandate, organization and expertise to assist national institutions in the evaluation, design and reorganization of their research institutes and systems. CIAT's role is limited to assisting in the strengthening of commodity research and seed technology programs.

National commodity programs vary in scope, size and stage of development. The mix of cooperative activities and services provided to a national counterpart organization generally depends on the level of development of its research programs. Levels of program development can be grouped 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 respective CIAT commodity, but whose country has good potential for producing that commodity.

Group V: National commodity programs that because of economic and/or other circumstances are not progressing and need revitalizing.

One situation that is not covered by these five groups is that of small countries that can only afford to carry out adaptive research/extension activities. In these cases CIAT's support is channelled through regional research institutions and/or is geared toward the development of regional commodity research networks/systems.

Table 3 provides a general overview of activities and services provided to the collaborating national programs according to the aforementioned groupings. CIAT's efforts to strengthen national commodity research are designed to meet the ever-evolving needs of national programs as they develop, assisting them in and providing support to their own development process. CIAT can fulfill the role of catalyst, accelerating their development, provided it does not overextend itself beyond its capabilities and resources. The five basic cooperation principles (i.e., commodity focus, relevance, complementarity, relative comparative advantage and consultation) are helpful in defining both the geographic scope and the extent of CIAT's involvement in strengthening national commodity research programs. Both scope and level of involvement are, however, influenced by national research priorities, as well as by the resources available to CIAT. When a country assigns low priority to a given commodity, there is no reason for cooperation. In the event a country assigns high priority to a commodity, but CIAT's human and financial resources are the limiting factor, CIAT seeks to assist obtaining the necessary funding from third parties. In the absence of the necessary resources, CIAT can still provide certain services (e.g., germplasm, training, information and documentation) to regions or ecosystems for which it does not carry out research; however, it is evident that the value of these services could be very limited in the absence of supporting research, feedback and follow-up. Thus CIAT assigns low priority to such unstructured support activities. One way to provide some structure for these activities is the outposting of regional cooperation staff. Section III details the plans of the commodity programs for consolidating/expanding activities in regions and ecosystems that are presently being addressed on a limited basis only.

The Network Approach

A complementary approach to that of providing direct support to research programs of individual countries is that of fostering the development and support of regional commodity research networks.[29]

[29] In the context of this discussion, a distinction is made between regional projects and regional networks. The former are normally designed to carry out specific and finite tasks, often including specific research activities. To a large extent they represent an extension of CIAT headquarters activities into the region. A regional network, on the other hand, refers only to the activities of the participating institutions and scientists interacting with each other. A regional project can be designed to support a network, but never to replace it.

	Technical consultation		Information Services			Consultation on national program planning	
ll	Research staff visits	Workshops and conferences	Network news-letters	Program publica-tions	Documen-tation services	Research	Economic analyses
L	L	H	Yes	H	H	L	VL
L	M	M	Yes	H	H	M	M
H	H	L	Yes	M	H	H	H
L	O	VL	Yes	L	L	L	M
M	L	M	Yes	M	H	L	L

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Table 3. **A generalized scheme for CIAT international cooperation services with national p**

Program classification[a]	PhD or MS thesis	In-service	Methodology and special techniques	Short research courses at CIAT	Short production courses in countries	Ge E I
			Training			
Group I	H[c]	VL	M	VL	H	H
Group II	M	L	L	L	M	L
Group III	VL	M	VL	M	O	O
Group IV	O	O	O	VL	O	O
Group V	L	M	VL	L	L	VL

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

a For definitions, see p 35.

b Levels: I = Germplasm bank accessions; II = Segregating populations; III = Finished varieties.

c Relative emphasis. High = H, Medium = M; Low = L; Very Low = L; None = O.

Networks for commodity research can be synergetic and increase the effectiveness of individual national programs for the following reasons:

1. Applied biological research requires a multidisciplinary and team approach to the identification of problems and technical solutions.

2. Networks provide the basis for horizontal transfer of experiences and knowledge among participants.

3. Economies of scale in methodology and technology development for solving common problems reduce the cost of addressing such problems individually by network participants.

By focusing on common problems (e.g., Golden Mosaic Virus, *Apion*, or rust in beans; anthracnose in *Stylosanthes* species), network members can profit from the relative comparative advantages of the participating institutions and scientists, as well as the economies of scale derived from the division of labor and the efforts (e.g., nursery evaluations in the various countries). CIAT-sponsored or co-sponsored international commodity networks in beans, cassava, pastures and rice have been very successful in identifying and addressing regional and/or ecosystem-specific problems.

These international networks are gradually being decentralized into regional networks in accordance with the evolution of each program's research strategy. Nevertheless, the strength of a network depends, to a great extent, on the strength of the individual country programs. Consequently, the country approach and networking are highly complementary. CIAT can provide significant support to regional networks in research, training and communication/information services from headquarters; but to be effective these networks need to have, from the beginning, a minimum degree of technical and logistic autonomy and self-sufficiency. A major restriction to the effectiveness of the decentralization process continues to be the absence of outposted CIAT personnel in the various regions.

In order to provide for effective cooperation through the activities and services listed in Table 3, a critical mass of outposted regional cooperation and research staff is needed that is commensurate with the task. Whether core or special project funded, they need to be largely selfsufficient and depend on CIAT only for critical backstopping not available in the region. When feasible, CIAT will develop such regional projects jointly with existing regional institutions, thereby partially reducing the needs for providing all the required logistics support from CIAT headquarters.

OUTPOSTING OF PERSONNEL

CIAT staff members play a number of roles in different international cooperation activities and services. Where there are no regional research networks, the principal responsibility for the generation of region-specific technology lies with national institutions. Outposted personnel—i.e., CIAT staff stationed outside of Colombia—play a particularly critical role in backstopping national commodity research programs; thus the number of outposted personnel is expected to increase during the remainder of the present decade.

Outposted personnel can be grouped into three categories: research, regional cooperation, and bilateral staff, the first two of which are integrated into regional teams.

Research Staff

Given the need to maintain a minimum critical mass of scientists within each commodity program to conduct research and backstop collaborative research with national programs, there is a limit to the extent to which the Center can outpost research staff. Outposting is done only when three conditions are met: (a) the research problems to be solved are of significant importance to a given region; (b) the research problems occur under environmental conditions not adequately represented in Colombia; and (c) there is a 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.

Although outposted research staff are chiefly devoted to research activities, they also serve an in-service training function. They participate in in-country and regional training courses and select candidates for specialized training at CIAT headquarters. While outposted research staff play key supportive roles in national research programs, they play an even more important role in fostering regional commodity research.

Outposted research staff differ from headquarters staff in that their role is not usually considered a "permanent" one. It is expected that sufficient regional research strength will develop as a result of national programs working together in a regional network and/or strengthened regional institutions, thereby making it possible to phase out outposted research staff. Thereafter, continued liaison between the regional efforts and CIAT headquarters is maintained by the regional cooperation staff (Fig. 2). As many of these assignments are of a medium-to long-term nature (at least five years), such positions should, ideally, be corefunded. However, budget constraints continue to limit unrestricted core funding; therefore, some of these positions in Section III are projected to be filled temporarily through special projects. Every effort will be made to secure special project funding for these positions as long as core funding is not available.

Regional Cooperation Staff

Regional cooperation staff (i.e., "regional liaison scientists") are outposted to strategic locations in order to serve regions where a particular CIAT commodity is important. These staff members are assigned to a specific regional program to assist participating national commodity

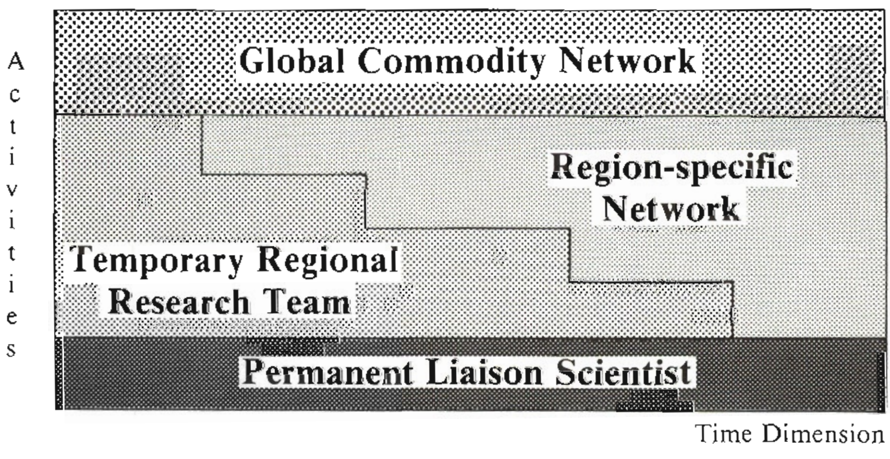

Figure 2. *Illustration of the philosophy on regional cooperation strategy in relation to staffing and the development of regional commodity research networks.*

programs in program planning and to coordinate collaborative activities with CIAT, including germplasm evaluation and feedback to the research process. They help plan and organize international, regional and other specific nurseries/collaborative trials and support their implementation. They also assist in selecting participants for CIAT training and in developing in-country and regional training courses. Moreover, they also play an important role as a liaison between programs in the region and the respective CIAT programs. In those disciplines where adequate regional training is not available, they select candidates for research training at CIAT. As their activities are of a continuing nature, all regional cooperation staff positions should, in principle, be core-funded.

Regional Commodity Research Teams

The concept of regional commodity teams refers to a scaling up of CIAT activities in a region where a particular set of conditions are present that make a temporary, intensive CIAT involvement propitious. Critical conditions are as follows:

1. The commodity in question should be economically important in the agricultural sector of a group of countries with somewhat similar agroecological conditions and that can be considered for sociopolitical reasons to have a reasonable level of cohesion.

2. The national research programs in the countries making up the regional grouping should be in a position to benefit from more direct research collaboration that would stimulate a stronger national effort and improved intraregional research cooperation within a network.

3. The constraints to increased productivity of the commodity can be more efficiently researched through a regional approach, particularly where the critical constraints are more region-specific; i.e., common to the countries in the region and/or cannot be effectively researched at headquarters.

Given the above set of circumstances, the establishment of regional projects—whereby a CIAT multidisciplinary team is located in the region, usually within one of the national programs—is considered to be the most appropriate response. The size and disciplinary composition of the team will naturally depend on the researchable constraints common to most of the countries.

In creating such regional projects, it is essential to consider the role of the CIAT outposted scientists in their interaction with national program personnel. CIAT considers it vital that the regional team does not duplicate national efforts and does not operate in a way in which the national scientists are relegated to the role of technicians. The CIAT approach, which is vital to the success of such regional efforts, is one that stimulates and complements the national scientists by working **with** them rather than as a substitute for national initiative.

The overall duration of such regional efforts and of the individual outposted staff in a particular project depends entirely on the stage of development of the national programs at the initiation of the project and their subsequent evolution, aided by intense in-service training and research collaboration. CIAT does not consider such regional teams to be permanent; funding is sought to provide sufficient time for the job to be accomplished; i.e., national self-sufficiency in research and a high level of regional cooperation. At that stage, a scaling down of operations to one of a regional liaison role for CIAT (see above) is an obvious second phase of activity. These concepts are described graphically in Figure 2.

Bilateral Contract Staff

These staff members are appointed temporarily (usually three to five years) as local components of national teams. Appointments are made at the request of individual 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 are provided full support by the respective CIAT commodity program. Due to the management and support load placed on headquarters, some restrictions must be imposed on the expansion of this category. The reasons for entering into a new bilateral arrangement must always be carefully assessed against established criteria and priorities.

Hosting of Outposted Staff from Other Institutions

Another important part of CIAT's strategy is to host activities of sister centers of the CGIAR system and of related institutions when these activities clearly complement the center's work and fall within its overall objectives.

Thus far, this strategy has been implemented through the hosting of 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; the regional team from CIP; a team from IFDC working on the development of technology for the efficient utilization of rock phosphates in Latin America; scientists from ICRISAT and the International Sorghum and Millet Program (INTSORMIL), who will develop sorghum germplasm for acid, infertile soil conditions; and scientists from the International Soybean Program (INTSOY) who are developing soybean technology for Latin American conditions, particularly the acid infertile soils.

RESEARCH STRATEGIES AND PROJECTIONS: 1986-1990

Commodity Programs

THE RICE PROGRAM

Introduction

Annual growth rates for rice in Latin America during the past two decades have averaged 3.3, 2.3 and 1.0% for production, area and yield, respectively. Per capita consumption of rice has been rising and is currently about 35 kg of milled rice annually. Rice provides an average of about 9% of the total calories in the Latin American diet. Countries with the highest rice contribution to total caloric intake are Panama, Dominican Republic, Cuba, Brazil, Costa Rica, Colombia and Peru.

From 1980 to 1982, net imports of milled rice came to 220,000 tons, or 2% of apparent consumption. The largest exporters were Uruguay, Surinam, Argentina and Guyana; the major importers, Cuba, Brazil and Peru.

If demand continues to grow at the annual rate of about 3.5%, as it has over the last 20 years, production will have to nearly double by the year 2000 to satisfy internal demand at current relative price levels. This indicates an increase from the current 17 million tons to over 30 million by the end of the century. Land and water resources are more than ample to permit this growth. The task ahead is to identify the ecologies and areas where growth will predominate in order to orient and intensify research and training toward the physical and biological constraints found in these areas.

The CIAT Rice Program focuses on the Western Hemisphere including Mexico, Central America, the Caribbean and South America. It collaborates closely with the IRRI's efforts in global rice research and with IITA in areas of mutual interest. Research on major regional constraints is encouraged through an active network of rice specialists who cooperate in the IRTP, coordinated by an IRRI scientist located at CIAT.

Program History and Accomplishments

In addition to benefiting from the strength of the IRRI program, the CIAT Rice Program has, from its very inception in 1967, received excellent collaboration from the Instituto Colombiano Agropecuario (ICA), which has facilitated making a rapid impact, both in and out of Colombia. For example, as the direct result of its cooperative program with CIAT, ICA has released several dwarf varieties with high yield potential, all of which are now grown internationally.CIAT breeding lines have resulted in more than thirty other dwarf varieties being released by national programs in the region. A recent impact study[30] has shown that these varieties are now grown on about 2.5 million hectares of irrigated, highly favored and moderately favored upland systems in the Western Hemisphere. These new varieties, together with improved cultural practices, annually produce an additional 3 million tons of rice with a value of over $800 million. The surge in production in countries with these farming systems has equaled or exceeded population growth; thus most of these 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[31] 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.

CIAT hasprovided professional training in production agronomy, breeding and pathology to about 300 rice researchers from 23 countries. Consequently, an effective regional network of cooperators for exchanging information and evaluating technology is fully operational. The Program's regional activities include IRTP nurseries, monitoring tours, production courses within countries, and biennial conferences at CIAT for research workers, organized jointly by CIAT and IRRI under the auspices of the IRTP.

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[30] Muchnick de Rubinstein, E. The diffusion and economic impact of high-yielding semi-dwarf rice varieties in Latin America, CIAT, Cali, Colombia, 1984.

[31] Scobie, G.M. and Posada, R.1977. The impact of high-yielding rice varieties in Latin America with special emphasis on Colombia, CIAT, Cali, Colombia, 1977.

Research over the next five years and beyond should lead to a continued increase in rice production in the region in irrigated and upland tropical ecologies and in irrigated temperate areas.

Production Systems and Constraints

Trends in rice production, area planted and yield vary widely among countries and over time. The major contribution to production from 1965 to 1975 was due to an increase in area, particularly in Brazil. More recently (1967-1982), this trend has been reversed, and essentially all regional growth came from yield increases. The unfavored upland area in Brazil began to decline, but was offset by increased productivity from irrigated areas in Rio Grande do Sul and Santa Catarina.

Fourteen of the 23 more important rice-producing countries now have average yields of over 3 t/ha. The Latin American average of 2 t/ha reflects the massive impact of the national average of 1.5 t/ha in Brazil. The basic causes for this variability are found in the predominant production system in each country.

Rice production is usually divided into two main systems—irrigated and upland— although there are several distinct production systems in the region. In 1981-82 irrigated rice covered 2.1 million hectares (24% of the area), averaged 4 t/ha and contributed 52% of regional production. Essentially the remainder came from the upland sector covering 6.2 million ha with an average yield of 1.1 t/ha. This simplistic division obscures the actual productivity of distinct upland farming systems and the potential productivity achievable with research on specific constraints.

Ongoing work in agroecosystem analysis at CIAT is identifying and classifying current Latin American rice production systems. Several fairly distinct upland ecologies are apparent, despite forming a continuum from highly favored to unfavored in terms of productivity. In general terms upland productivity is highest when soils are fertile and rainfall is heavy and well distributed. Unfavored upland rice suffers severe water stress and is normally grown on relatively infertile soils.

Irrigated Rice

This system receives high CIAT priority because of its major contribution to regional production and its comparative advantage in maintaining and further increasing productivity and stability of supply. It is found in all countries, predominating in southern Brazil, Colombia, the Caribbean area, Guyana, Nicaragua, Peru, Suriname, Venezuela and the Southern Cone countries. Average national yields range from 3 to over 5 t/ha. Important constraints include increasing production costs, weeds, water control, rice blast and other diseases, lodging and, in some countries, the availability of suitable grain quality for export markets.

Highly Favored Upland Rice

This system is generally confined to flat areas with slightly to moderately acid, well-drained alluvial soils, which receive over 2000 mm of rainfall in 8 or 9 months of the year. Normally, there are no marked dry periods during the rainy season. This system uses modern dwarf varieties and improved agronomic practices. Yields average 2.5 t/ha, but better farms consistently produce 4 to 5 t/ha. This system is found in parts of Brazil, Central America and Colombia and is expected to expand in tropical Central and South America. Major constraints are grassy weeds and diseases. CIAT also assigns high priority to this system.

Moderately Favored Upland Rice

Most of Central America, Venezuela and part of Brazil employ this system. It differs from the preceding one in having a shorter wet season with less 37 overall rainfall and with a dry period during the growing season. Dwarf varieties predominate in Central America, yielding about 2 t/ha. Brazil grows tall varieties, yielding an average 1.5 t/ha. Irregular rainfall causes high variances in yield. Constraints include weeds, mild to moderate droughts, mineral stresses and diseases. This system is also included within CIAT's priorities.

Unfavored Upland Rice

Much of Brazil's rice is produced with this system, in areas characterized by relatively infertile, moderately acid soils and irregular, low total rainfall. Tall varieties, planted at low densities, produce an average yield of less than 1 t/ha. Yield variance is extremely high. CIAT does not conduct research directly on unfavored upland rice as the system is mainly utilized in Brazil and at present the Program has no comparative advantage for working in this area.

The main system constraint is the occurrence of dry periods during the growing season. This stress is compounded by poor root development, which is associated with aluminum toxicity in the subsoil. The degree of drought enhances the severity of fungal diseases, particularly blast. Phosphorus and other mineral deficiencies constitute a serious overall constraint. The main unfavored upland rice system areas in the region have two main environmental constraints:low and/or unreliable rainfall and infertile arid soils. In the tropical lowlands of the Americas, there are vast areas of well-watered savanna lands that have not been opened up for arable agriculture. In these areas rice does have a future potential, provided the problems of adaptation to low soil fertility and acidity conditions can be successfully resolved. CIAT has commenced research on these problems.

Rainfed Lowland Rice

This system—a transition between irrigated and upland—utilizes rainwater trapped and held by field levees. Nevertheless, water deficits and/or deep flooding are common. Although dwarf varieties can be grown when water control is provided, tall varieties predominate. Yields average 2.0 to 2.2 t/ha. The crop may be transplanted or directly seeded; few purchased inputs are used. Rainfed rice is important only in coastal Ecuador, the North Coast of Colombia, and the Dominican Republic. The main problem in this system is inadequate water control, which forces farmers to use tall varieties. Because of the risks involved, low levels of purchased inputs are used. CIAT does not directly do research on this system.

Program Objectives

Rice Program activities, in collaboration with national institutions in the Western Hemisphere, include the following specific objectives:

1. To continue developing germplasm-based technology designed to overcome the principal constraints to increased production of irrigated rice and the more favored upland production systems.

2. To develop widely applicable production technology, including the introduction and evaluation of appropriate farm machinery, oriented toward weed control and other related cultural practices to reduce costs and increase stability of supply.

3. To strengthen national rice research programs in the region through training, conferences and technical collaboration activities, thereby stimulating further the highly effective regional rice research network which is now in place.

General Research Strategy

Since its inception in 1967, the 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 prior to 1968, when IR8 was introduced. An immediate increase in productivity of 2 t/ha confirmed the decision to work exclusively on dwarf materials for this system. Research has sought varieties combining dwarfism, strong stems, insensitivity to photoperiod, long grain with clear endosperm, resistance to the *Sogatodes* leafhopper and blast. Earliness and improved adaptability to acid soils are more recent varietal objectives.

In recent years a number of fungal diseases apart from rice blast (i.e., dirty panicles, brown spot, leaf scald, eye spot, narrow brown leaf spot and sheath blight) have increased in severity and now constitute yield constraints, partially as a consequence of increased fertilizer use and expansion of upland rice and irrigated rice to infertile soils. These problems, along with the resurgence of the hoja blanca virus, have intensified the need for resistance breeding for all ecologies.

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. Farmers have learned to manage modern varieties, but severe deficiencies in cultural practices remain; for example, red rice and weed infestations, seed quality, land preparation and water control, and lack of simple, appropriate equipment for small farm operations.

As a result of the unexpected adoption of the newer dwarf varieties in the highly and moderately favored upland systems in recent years, the Program modified its original strategy. Entries for nurseries and regional yield trials, especially for the more favored upland systems, were selected from the advanced irrigated breeding lines and distributed to national programs for continued local selection and evaluation. Thus it was possible for CIAT to contribute directly to upland systems while focusing on irrigated varieties. In 1981 CIAT began to intensify its activities in upland rice. Allocation of program resources and general research emphases for the irrigated and upland sectors will be approximately equal during the coming decade.

In the irrigated sector, the number of crosses has increased substantially in response to new disease problems, need for iron toxicity tolerance, and the specific requirements for the temperate Southern Cone, where rice production is expanding rapidly now that dwarfs are known to be well adapted throughout the temperate production areas and anther culture technology permits large volume production of fixed lines for these conditions.

Breeding for the more favored upland ecologies and high rainfall, acid soil savanna upland has increased dramatically. Crossing is currently focused on disease tolerance, grain and plant type, earliness and general adaptability to upland soils. Work must be undertaken on the multiple mineral nutrition stresses of upland soils, with specific breeding attention to tolerances to zinc, phosphorus, iron and manganese deficiencies, as well as aluminum and manganese toxicities in acid soils. It seems clear that one way to reduce fungal disease pressure in upland rice is through breeding for tolerance to mineral nutrition imbalances.

Specific research strategies for the remainder of the decade of the eighties and beyond have been developed for the various production systems identified for priority attention.

Irrigated Rice

This system will continue to receive major attention. Enhanced disease tolerance to blast, other fungal diseases, hoja blanca and soil problems including iron toxicity and the straighthead disease would increase yields, lower production costs and increase production stability. The approach will combine breeding directly for disease resistance with breeding for tolerance to soil stresses, as well as emphasis on weed control and lower seeding and fertilizer rates. Lowered inputs should result in decreased fungal disease severity. In addition, breeding will focus on better lodging resistance, simultaneously seeking a modest gain in yield capacity.

Improvement in cultural practices is indispensable to narrow the gap between varietal yield potential and farm productivity. Research on cultural practices has lagged behind varietal development. New technology in tractor wheels will be linked to recent advances in low-volume sprayers with the goal of increasing terrestrial farm operations, i.e., seeding, fertilizer, herbicide and pesticide applications. This should reduce costs, increase weed control efficiency, permit reduction in seeding rates, and lessen dependence on the inefficient airplane.

Many new irrigated rice areas are coming into production, principally by small producers who lack appropriate small machinery to facilitate the transition from transplanting to direct seeding when labor is scarce. Such machines (hand seeders, boom sprayers, harvesters and threshers) are available commercially. The Program will emphasize the introduction of appropriate machinery through national programs.

More Favored Upland Systems

Selected lines from the irrigated breeding program can contribute to the varietal component for expanding this system in the region. Nevertheless, a breeding program is designed to address the peculiar stresses of upland soils, particularly moisture and mineral nutrition, and their interaction with fungal diseases, in several sites reflecting a range of ecologies from moderately to highly favored upland. Vigorous dwarf varieties, tolerant to problem soils, diseases and short dry periods, should increase and stabilize yields at an average of 3 t/ha, one ton higher than existing average productivity.

Weed infestations are a massive yield constraint in upland rice and are more difficult to control than in irrigated rice. Because available herbicides are relatively effective, research will focus on appropriate terrestrial delivery systems to improve timing and reduce dosages.

New Production Systems

The vast savanna regions of Colombia, Venezuela and Brazil are favored by abundant, well-distributed rainfall; but the soils are extremely acid and infertile. Although little upland rice is produced on these soils, there is a clear need for a crop component in the pasture system being developed by the Tropical Pastures Program to facilitate and finance land preparation for pasture establishment. Upland rice could become a pioneer crop, thereby encouraging the economically sound development of acid, high rainfall savannas.

A minimum-input upland rice system using cultivars with tolerance to acid soils and diseases appears attainable. Initial research with soil-adapted cultivars consistently gives plot yields of 3.5 to 4.5 t/ha without soil amendments or chemical protection. Thus a 3-ton commercial yield seems reasonable and economically viable. A high-volume crossing program is under way with upland materials from Africa, Brazil, Japan and other sources. Specific breeding objectives are identified and parental sources are available. Although typical high-yielding irrigated germplasm is not useful for this ecology, many cultivars are well adapted to infertile, acid soils having over 80% aluminum saturation. Breeding will stress tolerance to Mn and Al toxicities, as well as P, Zn and other deficiencies. The ideal plant type remains unclear; but intermediate grain quality, multiple fungal tolerances, hoja blanca, sogata and sugarcane borer resistance are requirements.

Research on cultural practices will concentrate on weed control, methods of seeding and applying fertilizer, and conversion into pastures after one or two rice crops.

Research Sites

Research has been largely decentralized, leaving only the crossing program, quality laboratory, germplasm storage, sogata and hoja blanca screening, and IRTP at CIAT headquarters in Palmira.

Three locations in Panama were made available by the Instituto de Investigaciones Agropuecarios de Panamá (IDIAP), within a collaborative program for selecting segregating generations of upland and irrigated materials. In 1983 CIAT acquired the Santa Rosa experiment station in the Colombian Llanos near Villavicencio, which is now the central breeding location for favored upland and irrigated rice. Also in 1983, ICA provided long-term use of 16 ha of acid savanna on its La Libertad station adjacent to Santa Rosa. Irrigated and upland selection and evaluation work continues in Peru under a cooperative project with the Instituto Nacional de Investigación y Promoción Agropecuaria (INIPA). Implementation of the Caribbean Regional Network will add the Juma Experiment Station in the Dominican Republic as an additional research site in the latter part of 1985.

Staffing Projections

A summary table of the staffing projections for the Rice Program is shown in Table 4. The Rice Program projects that a core team of seven scientists, including the new position of Program Leader, will be sufficient to study the production constraints in irrigated rice and alternative systems. As these production problems are not entirely mutually exclusive, concentrated attention on the more favored systems is expected to produce useful results for the most difficult farming systems that are not being addressed directly—subsistence upland rice, unfavored upland rice and rainfed lowland rice. The Program will be alert to research findings directly applicable to those systems.

The Rice Program recognizes that important yield and production constraints never operate singly, but invariably are complexes of interacting factors. Problems are attacked at the level of the crop, not as single factors. Thus all team members have deep appreciation of the complexity of rice biology, and specific talents complement each other to give a broad insight focused on problem solving. The prioritized rice agroecologies may increase with further refinement in agroecosystem analysis, and present definitions are oversimplified. Thus staff responsibilities are defined more by geography than by ecologies. The seven-man team is organized around the following activities:

Rice Breeder (CIAT-Palmira)

This CIAT-based position will have major responsibility for both upland and irrigated materials for Central America and Mexico, and will eventually provide materials for the irrigated and rainfed requirements in the Caribbean. These activities will continue on IDIAP stations in Panama and expand to additional evaluation sites, possibly

Table 4. **Approved senior staff positions in the CIAT Rice Program for 1980-85 and projected positions for 1986-1990 from core funding (CF), corelike projects (CL) and special projects (SP).**

Positions	Funding source	80	81	82	83	84	85	86	87	88	89	90
		Years										
Headquarters based												
Leader	CF	-	-	-	-	-	1[a]	1	1	1	1	1
Breeder (Palmira)	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder (Santa Rosa)	CF	-	1	1	1	1	1	1	1	1	1	1
Breeder/Physiologist (Sta. Rosa)	CF	-	-	-	-	1[b]	1	1	1	1	1	1
Pathologist	CF	1	1	1	1	1	1	1	1	1	1	1
Production Systems Agronomist	CF	1	1	1	1	1	1	1	1	1	1	1
Economist[c]	CF	-	-	-	-	-	-	1	1	1	1	1
IRTP Liaison Scientist[d]	IRRI	1	1	1	1	1	1	1	1	1	1	1
Decentralized Regional Programs												
Caribbean Network Coordinator	CL	-	-	-	-	-	1[e]	1	1	1	1	1
CIAT-IRRI-EMBRAPA Liaison	SP	-	-	-	-	-	-	1[f]	1	1	1	1
Total Headquarters		4	5	5	5	6	7	8	8	8	8	8
Total Decentralized		-	-	-	-	-	1	2	2	2	2	2
GRAND TOTAL		4	5	5	5	5	5	10	10	10	10	10

a **Leader.** This full-time position was created in 1985 in response to the EPR's recommendations for year before.

b **Breeder Physiologist.** This position is presently filled by a Visiting Scientist, and recruiting is in progress to fill the position formally during 1985.

c **Economist.** This core position is budgeted for 1986.

d **CIAT-IRRI-IRTP Liaison Scientist.** This staff position is funded by IRRI through its IRTP program, and CIAT provides support for the networking activities.

e **Caribbean Coordinator.** This senior staff position will be funded by IRRI through the IRTP. CIAT is negotiating with donors for project funding to support the networking activities in the region.

f **CIAT-IRRI-EMBRAPA Liaison.** This outpost position is projected for Brazil when special project funding can be identified.

in Guatemala, tropical Mexico and elsewhere. This breeder will also take primary responsibility for anther culture breeding for the Southern Cone, sogata resistance breeding, quality analysis and the crossing program.

Rice Breeder (CIAT-Santa Rosa)

This position will be based in Villavicencio, with responsibility for favored upland and irrigated breeding for tropical South America. In addition, this breeder will interact with the CIAT-based breeder on planning of crosses and interchange of materials for evaluation in Central America, Mexico and the Caribbean, and with the Breeder/ Crop Physiologist for iron toxicity screening at La Libertad. Work at Santa Rosa will stress disease tolerance in dwarf backgrounds. This breeder will visit Peru, Bolivia and tropical Brazil during the slack period of January to March to evaluate materials generated from both breeding programs.

Breeder/Crop Physiologist

This position will also be based in Villavicencio, to concentrate on methods for improving breeding efficiency for aluminum and manganese toxicities, as well as phosphorus and minor element deficiencies, in relation to fungal disease tolerance in acid upland savannas; and to develop screening methods for iron toxicity in irrigated acid soils. This scientist, who will interact with the Villavicencio-based breeder on evaluation of parents and crosses for upland savannas, will have responsibility for germplasm selection in that ecology. He will interact with the pathologist and agronomist on agronomic practices to reduce disease intensity in upland conditions. Germplasm evaluation in acid upland ecologies in Mexico, Panama, Venezuela and Brazil will also correspond to this scientist.

Production Systems Agronomist

The production systems agronomist based at CIAT will address the improvements required in cultural practice to permit maximum yield expression in all ecologies, focusing on herbicide delivery systems and appropriate small-scale machinery for land preparation, seeding, input applications, harvesting and drying. New rice production systems will be developed for such areas as Tabasco, Mexico; the Bolivian savannas;

and Brazilian *varzeas* and high rainfall, acid savannas. Close interaction with both breeders, the breeder/physiologist and the pathologist will be emphasized in accordance with the team's philosophy of dealing with complex crop problems, not single specific factors.

Pathologist

The CIAT-based pathologist will evaluate new sources of disease resistance, develop methods to screen segregating populations and participate in progeny evaluation in Villavicencio and other selection sites. This position also includes a major responsibility for formulating fungal disease control through integration of resistance, cultural practices, tolerance to soil humidity, nutritional stresses and use of fungicides.

Economist

This position, proposed on the forward list for 1986, will be based at CIAT. The economist will assist in determining the best allocation of research resources among different rice cropping systems. Classification of the cropping systems and delineation of their environmental boundaries will be carried out in conjunction with the Agroecological Studies Unit. The economist will evaluate rice production potential at the country level and conduct surveys of the main production areas, area planted, and yield and production by cropping system, as well as evaluate how production increases will affect prices and potential benefits to be received by the various income strata in both urban and rural areas. International trade possibilities associated with expanded rice production in selected countries will also be analyzed.

Leader

The full-time program leader, effective 1985, is responsible for the overall management of the research and training activities, the increasing regional responsibilities, and the projected growth in decentralized activities.

IRRI-CIAT-IRTP Liaison Scientist

Although not a CIAT-budgeted staff member, the IRRI liaison scientist fulfills a critical role in maintaining close collaboration with IRRI on the IRTP. Duties include the selection, distribution and evaluation of germplasm nurseries. Materials created for distinct ecologies are sent to all countries in the Western Hemisphere. The IRRI scientist also plays an important leadership role in organizing conferences and field selection workshops. This position entails extensive international travel to promote national use of promising materials developed by the network.

Decentralized Regional Programs

In addition to the senior staff based in Colombia, two outposted regional positions are projected for Latin America and the Caribbean. One position would be based with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) as a CIAT-IRRI-EMBRAPA liaison scientist and the other in the Caribbean, as coordinator of the proposed regional network.

A 1984 regional workshop approved the establishment of a Caribbean Regional Network and authorized CIAT-IRRI to seek funds for supporting the regional coordinator, who would organize germplasm introduction and evaluation, regional training courses, and research on irrigated and rainfed production constraints. This position should be filled in 1985.

The proposal for a CIAT-IRRI scientist in Brazil was developed in joint discussion among CIAT, IRRI and EMBRAPA (Centro Nacional de Pesquisa de Arroz y Feijao, CNPAF) in view of the need to make a greater impact on rice production in Brazil, which accounts for 75% of the rice area in Latin America. Preliminary analysis of the potential for expanded production in tropical Brazil indicates that the underutilized *varzeas* will provide a major contribution to future rice production. Brazilian breeding objectives for *varzeas* are similar to CIAT objectives for irrigated rice. Hence improved germplasm is now available for evaluation and varietal release. The liaison scientist could concentrate on identifying new varieties for *varzeas* in cooperation with the national program, as well as act in an overall capacity as liaison scientist between Brazilian rice scientists and those at CIAT and IRRI.

TROPICAL PASTURES PROGRAM

Introduction

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 coexistence of intensive farming, both large- and small-scale, and abundance of underutilized land can be 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. Under these poor fertility conditions, productivity is low and soil amendments are not economical due to high input and transportation costs. Crop production with available technology is unprofitable without sizable subsidies.

Tropical and subtropical areas of Latin America have some 800 million hectares of significantly underutilized savannas and forests, two-thirds of which have acid, infertile soils (Oxisols and Ultisols). The tropical savanna areas (some 250 million hectares) have great agricultural potential because of their abundant solar radiation, adequate rainfall and favorable temperature regimes for extended growing seasons. Topography and soil physical properties are also generally favorable. Parts of the forest areas (100 to 150 million hectares) also have high agricultural potential. They are, however, at high environmental risk, given current practices and available technology.

In order to contribute to the development of ecologically sound and stable productive systems for these areas, CIAT 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, climatic and biotic conditions. Tropical pastures are the Center's major effort in these areas. Associated efforts in upland rice and cassava are also described in this plan.

Beef and Milk: Staple Food Commodities

Tropical Latin America has an estimated 204 million head of cattle, about 17% of the world total. In this region beef consumption per capita of 16 kg 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.[32] As a result, in most countries beef prices increased in real terms during the period. These price increases have serious implications since the proportion of family income spent on beef is becoming extremely high among low-income urban consumers.[33] In the lowest income quartile of the population, beef expenditure shares ranged from 12.4 to 26.0% of total household expenditures while expenditure shares for milk and dairy products ranged from 7.0 to 13.0%. Recent studies in Colombia indicate that food expenditure shares for beef and milk are also high for the rural population: 24.4% as compared to 28.2% for urban areas.[34] These same studies also documented high income elasticities at all income levels for beef and dairy products throughout Latin America. In the lowest quartile, income elasticities ranged from 0.79 to 1.28 for beef and from 0.78 to 1.55 for dairy products. The lower income elasticity observed at higher income levels indicates that increased supplies of these commodities will particularly benefit the low- and middle-income families in both urban and rural areas.

Potential for Livestock Improvement

Appropriate livestock production technology can be developed for the region's vast underutilized land resources. These areas have an extremely high potential for cattle production with little or no opportunity costs. The current average stocking rate in the acid soil savannas of 0.1 to 0.2 animal/ha can potentially be increased about tenfold. In addition, annual beef production per animal could be more than doubled. Milk production could also be improved significantly in these areas. Most milk and dairy products consumed in the region come from small dual-purpose herds, usually crosses of native and Zebu

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[32] CIAT, Latin America: Trend Highlights of CIAT Commodities, Internal Document Econ. 1.6, CIAT, Cali, Colombia, 1981.

[33] E. Rubinstein and G. Nores, Beef expenditure by income strata in twelve cities of Latin America, Internal Document, CIAT, Cali, Colombia, 1979.

[34] L. R. Sanint, L. Rivas, M. C. Duque and C Seré, Food consumption patterns in Colombia: A cross sectional analysis, 1981, paper presented at Internal Workshop of the Agricultural Research Centers on Selected Economic Research Issues in Latin America, 1984.

breeds. This type of dual-output production system is found not only in the densely populated areas with relatively fertile soils, but also in frontier areas with acid, infertile soils.

In tropical America, it is recognized that animal health is not a major problem (as is the case in Central Africa) and that better breeds and better animal management will only be profitable after availability and quality of forages and feedstuffs are improved for better animal nutrition. The critical factor limiting animal production in tropical America, especially in the frontier lands, is the primary production (pastures and feed) of the animal production system. In the savanna ecosystems, native grasslands provide quality forage for only a few weeks after burning. The forage accumulated afterward is only sparingly consumed and essentially constitutes fuel for the next burning (1 to 2 years later). In the more humid environments, pastures are normally established successfully after clearing and burning of the forest and can initially support more than 2 animals/ha; thereafter, they rapidly degrade, losing productivity in 3 or 4 years and reaching severe degradation in a few more years. This process strongly affects animal productivity since low-quality species and weeds dominate the degraded areas. This degradation has strong ecological and economic implications as the net effects are destruction of native forests, very low levels of productivity per animal and per hectare, and a reduced carrying capacity (less than 0.5 head/ha).

The development of an appropriate pasture technology to improve availability and quality of forage on offer, as well as the stability of pastures over time in these marginal and frontier lands, is expected to have a large impact on beef and milk production in the region, while maintaining or improving soil fertility through soil coverage and nutrient recycling.

Program History and Accomplishments

The Tropical Pastures Program has evolved through three stages. During the formative stage (1969-1974), the then 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 under the assumption that significant gains in animal productivity could be achieved through improved management practices. A relatively small proportion of program resources was devoted to pasture and forage evaluation during this period. 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 mineral supplementation and good quality, year-round forage were identified as the most common critical constraints to increased productivity.

From 1975 to 1977, the renamed Beef Production Program focused attention 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 to pasture evaluation with the goal of removing the principal production constraints in the savanna ecosystem.

Grazing experiments in the Colombian Llanos documented the limited potential of 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 related disease susceptibility. Overall productivity, both per unit area and per animal unit, was extremely low.

The use of edaphically well-adapted exotic grasses such as *Melinis minutiflora* provided for moderate increases in carrying capacity and production per unit area. However, production per animal continued to be disappointing. Protein supplementation in the form of concentrates was successful at the experimental level, but was too costly.

Preliminary experimental results obtained during this period with grass-legume pastures clearly indicated that persistent grass-legume associations under low-input conditions could provide an economically attractive solution to the problem. During 1978, the Program consolidated its research emphasis in the development of germplasm options for a low-input, low-cost grass-legume pasture technology for the acid soil savannas (Llanos and Cerrados). To reflect this new focus, the Program was renamed the Tropical Pastures Program in mid-1979.

After determining the genotype-by-environment interactions defining adaptation of germplasm, the need was perceived for developing strong cooperative activities with the national programs in the region for in situ pasture evaluation and development. The program and the national research institutions jointly launched the International Tropical Pastures Evaluation Network (RIEPT in Spanish) in 1979. This network screens large numbers of experimental materials at selected sites, covering the lowlands of tropical America. The network approach has made it possible to achieve important economies of scale, allowing national research programs to advance promising germplasm rapidly into pasture evaluation under grazing and into farmers' systems.

The most important achievements the program has made toward its present objectives are as follows:

1. Classification of tropical American land resources in terms of climate, soils and landscape, providing a geographically oriented ecological perspective to define the target area and the data base on which to build a cost-effective outreach strategy.

2. Identification of major farm constraints to cattle production in savanna ecosystems and in-depth characterization of cattle production system in Brazil, Colombia, Venezuela and Panama (a project partially supported with German funds through BMZ-GTZ).

3. Inventory of pasture pests and diseases, by forage species and ecosystem, with an assessment of current relative importance and control strategies for several of the most important problems.

4. Assembly of a large germplasm collection of 14,000 accessions including 12,500 legumes and 1,500 grasses; and identification of key promising species for the different ecosystems.

5. Identification of a large number of materials with low nutrient requirements and tolerance to soil acidity and high aluminum levels for the "Llanos" and "Cerrados" savanna ecosystem in collaboration with ICA at CNIA-Carimagua for the Llanos in Colombia and with EMBRAPA/CPAC at Planaltina for the Cerrados in Brazil.

6. Development of simple, low-cost pasture establishment methods adapted to savanna conditions. These low-cost methods range from conventional land preparation to minimum tillage for establishing grass-legume pastures, and from rapid to gradual replacement of native vegetation utilizing the attributes (adaptation and aggressiveness) of selected new germplasm, minimum fertilizer inputs and appropriately modified machinery for maximum economical and biological efficiency.

7. Testing of highly promising materials at both on-station and on-farm production system levels, evaluating several options ranging from complete replacement to the strategic supplementation of the native savanna to measure their biological and economic impact.

8. Release of several new cultivars including (a) the grasses *A. gayanus* CIAT 621, commercially available in Brazil and Colombia since 1980 and in Venezuela, Peru and Panama since 1983; (b) the legumes *Stylosanthes capitata* CIAT 10280 in Colombia and *S. guianensis* var. pauciflora (CIAT 2243) and *S. macrocephala* (CIAT 1582) in Brazil in 1983; and (c) *S. guianensis* (CIAT 184) for the humid tropic areas of Peru in 1985. Initial seed multiplication at official and commercial levels is also under way.

9. Training of more than 300 researchers from national programs, which has been instrumental in the rapid expansion of the tropical pastures network throughout the lowland tropics of Latin America.

Program Objectives

The primary objective of the Tropical Pastures Program is to develop low-input pasture technologies for the acid soil lowlands of the humid and sub-humid tropics, with primary responsibility for tropical America. In close cooperation with national research programs, the Program seeks to develop appropriate pasture-based animal production technology for the largest agricultural frontier of the continent. The specific objectives of the program are as follows:

1. To increase beef and milk production and productivity on currently marginal lands.

2. To contribute to the economically and ecologically sound expansion of the agricultural frontier lands.

3. To release more fertile lands presently under grazing systems for the expansion of crop production.

Agroecological Zones and Their Research Priorities

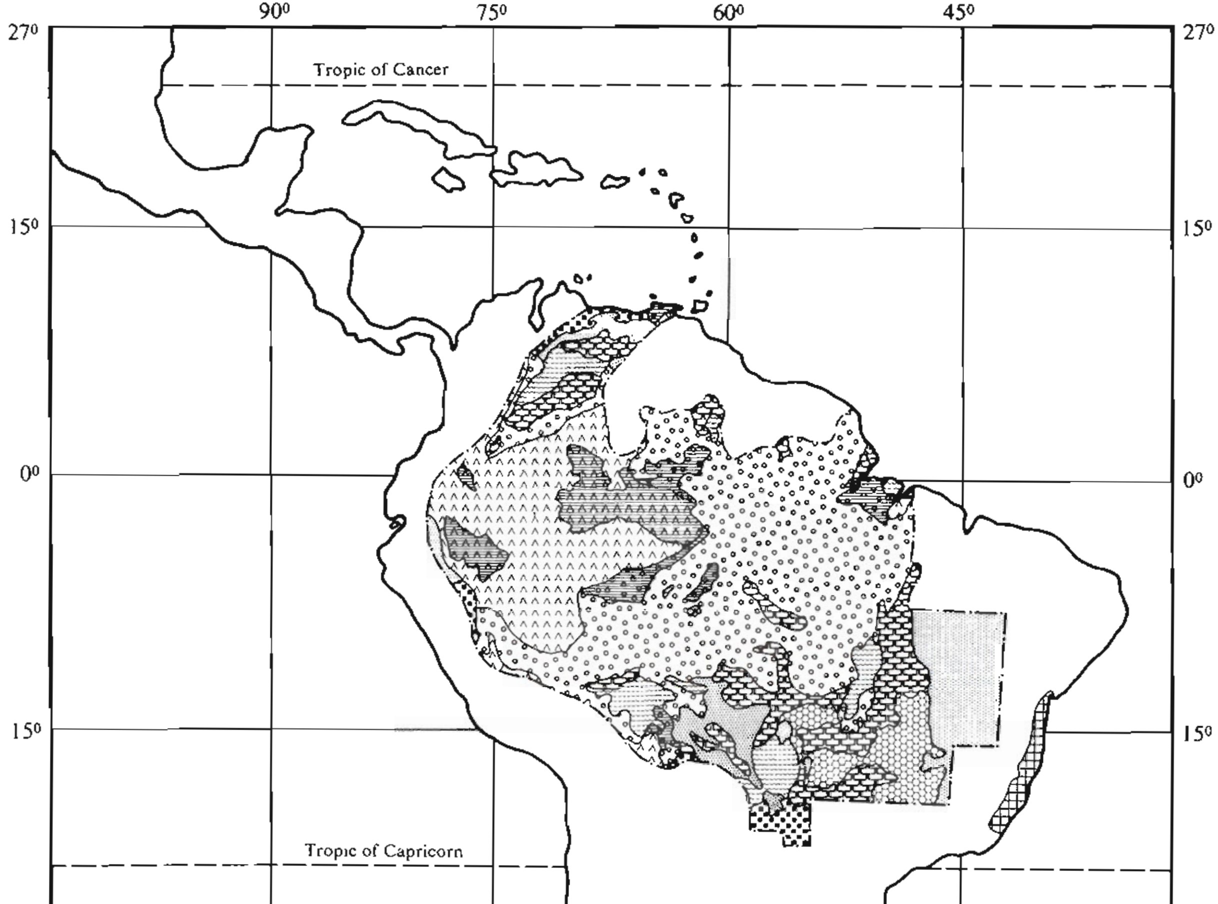
An in-depth survey of tropical Latin American regions with acid, infertile soils was finished in 1981, the final publication of which will appear in 1985,[35] thereby making it possible to divide the region into several major agroecological zones (Fig. 3) in order to design research strategies for developing the new pasture technology within a decentralized approach. This classification of land resources in terms of climate, landscape and soils provides a geographically oriented ecological perspective to the program's areas of interest. Distribution of native vegetation is measured quantitatively on the basis of total wet season potential evapotranspiration (TWPE), a measure of solar energy available for plant growth during the wet season (when water is not restrictive for plant growth). Wet season mean temperature (WSMT) was also used as a parameter to divide the area of interest further into relevant ecosystems for pasture growth and vegetation.

Major Ecosystems

The three main ecosystems and their priorities within the program's area of interest are as follows:

1. **Well-drained tropical savannas.** This important ecosystem is composed of two large groups: (a) the **"Well-Drained Isohyperthermic Savannas"**; i.e., the lowland areas (Llanos) close to the equator in Colombia, Guyana, Surinam, Venezuela, and northern Brazil (Roraima and Amapa), with a TWPE of 901 to 1060 mm, 6 to 8 months wet season, and wet season mean temperature (WSMT) over 23.5°C; and (b) the **"Well-Drained Isothermic Savannas"**; i.e., areas at higher latitudes and/or elevation (about 1000 masl) with

[35] T. T. Cochrane, Land in Tropical America (3 Vol.), CIAT, Cali, Colombia (in press).


90⁰
75⁰
60⁰
45⁰
27⁰
27⁰
Tropic of Cancer
15⁰
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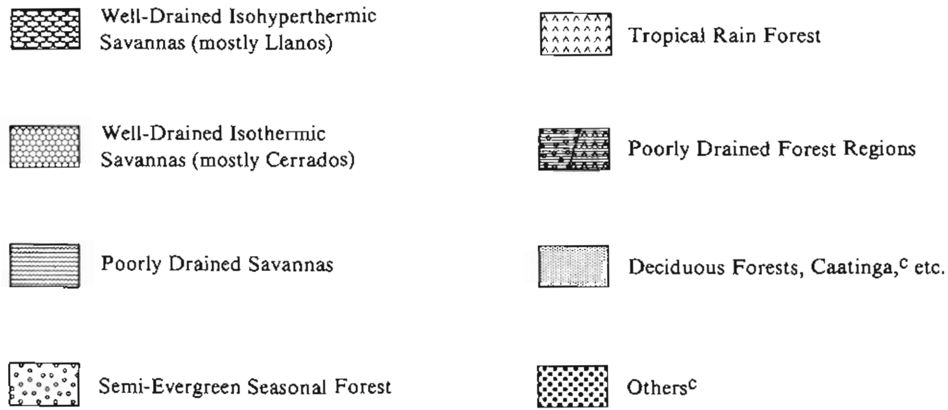
Tropic of Capricorn



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

Figure 3. *Main ecosystems of tropical South America.*

the same TWPE and wet season, but with WSMT under 23.5°C, represented primarily by the **Cerrados** of Brazil, which extend into Paraguay and Bolivia (Fig. 3).

These regions support extensive livestock systems (0.1 to 0.2 AU/ha) on native pastures. The extreme acidity and low fertility of the soils result in poor-quality native grassland vegetation. As only young regrowth can be grazed, the pastures have to be burned regularly; therefore, only a small proportion of primary production is available for animal feed.

The program's research effort has focused primarily on this ecosystem, for which a large number of materials, both legumes and grasses, are in advanced stages of evaluation. Several are being evaluated under grazing on research stations throughout the region and on commercial farms; and some have already been released. During the rest of the decade, there is a need to consolidate the development of new cultivars for a wider range of pasture options.

Carimagua (ICA/CIAT), located in the Eastern Plains of Colombia, is the major screening site for the well-drained isohyperthermic savannas and will continue to be the central research site for the program due to its representativeness of acid soil conditions and proximity to headquarters. However, screening new materials at Carimagua will be gradually reduced, and greater emphasis will be placed on outreach through networking activities, with slightly increased emphasis on breeding for selected characters in several promising species *(Centrosema* spp., *Desmodium ovalifolium, Zornia* spp., etc.), as well as both on-station and on-farm testing of materials under grazing.

Activities in Planaltina (Centro de Pesquisa Agropecuária dos Cerrados, CPAC, EMBRAPA/CIAT), the major screening site for the isothermic savannas **(Cerrados),** will continue during the decade. Emphasis will be given to selecting promising new grasses and legumes; networking; developing pasture establishment techniques; and both on-station and on-farm testing promising pastures under grazing.

2. **Poorly drained tropical savannas.** These areas occur throughout the South American lowlands, the largest areas being found in Bolivia (Beni), Brazil (Pantanal de Mato Grosso and Ilha do Bananal), Colombia (Casanare), and Venezuela (Apure). The poorly drained savannas usually have a somewhat higher natural fertility and higher cattle inventory than the well-drained savannas, and cattle productivity is usually higher. On the other hand, distance to markets and limited infrastructure due to seasonal flooding seriously limit production system intensification, particu-larly crop production.

   Native species (*Leersia hexandra, Hymenacme amplexicaulis, Eriochloa* spp. and *Echinochloa* spp.) are of relatively high quality and productivity. This forage resource is available to cattle in abundant quantities during the drier, unflooded periods; however, during the extended flooded periods, the quality and availability of forage in the slightly higher, unflooded areas are limited, thus becoming the major constraint to increased production and productivity. Some CIAT materials that tolerate high grazing pressure are considered promising for these unflooded areas.

   Very limited germplasm exists in the CIAT collection for poorly drained and flooded conditions. Strategies to solve the problem of excess water in the soil would imply either substantial infrastructure development or a significantly different genetic base (germplasm) and focus of the program. Because of difficulties in developing infrastructure in these areas, these savannas are considered as having limited potential for crop production in the near future and will probably continue to be devoted to extensive livestock production systems. In terms of program focus, these areas are regarded as the most distant frontier of the continent. No specific germplasm collections or establishment of major screening sites are planned, but regional trials in the higher, unflooded areas will be continued and slightly expanded.

3. **Tropical forests and humid tropics.** This ecosystem is comprised of two large areas:(a) the "**Semievergreen Seasonal Forest,**" character-ized by a short, but defined dry period (8-9 mo wet season, TWPE 1061-1300, WSMT over 23.5°C) and found in vast areas of the

Amazon and Orinoco basins of Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru and Venezuela, as well as sizable areas in Central America and the Caribbean; and (b) "**Tropical Rain Forests,**" which are higher in total rainfall and with no defined dry period, occurring in the Andean Piedmont of the Amazon in Colombia, Ecuador and Peru, as well as in the west central lowlands of the Amazon Basin including southeastern Colombia, northeastern Peru and northwestern Brazil.

The tropical forests and humid tropics are characterized by (a) an accelerated process of spontaneous colonization, which is supported by the policies of the countries concerned, to orient or promote colonization of the region in response to demographic, socioeconomic and geopolitical pressures; (b) the possibility of introducing more intensive agricultural and/or livestock farming systems (dual-purpose systems in particular), justified by the high land-clearing costs and the higher soil fertility levels available after clearing and burning; (c) a strong and continuously growing demand for beef and milk as a consequence of population growth and increased incomes in most countries in the region; (d) an accelerated process of degradation of the ecosystem due to lack of ecologically stable pastures in farming systems; and (e) a continued and accelerating land-clearing process for pasture establishment to compensate for current degradation of pastures and the growth of the herds. Pastures are not, at present, a stable land use alternative due to the lack of germplasm adapted to edaphic, climatic and biotic conditions of the ecosystem. At present it is estimated that 30% of the 8 million ha in pastures in the Amazon forests, established after clearing, are in advanced stages of degradation and that about 50% are in the process of degradation.

New grass and legume germplasm options are urgently required to reclaim these degraded pastures. The promise of several grasses and legumes selected by CIAT for poor acid soils has been demonstrated by the RIEPT. In addition to the herbaceous germplasm with which the program is presently working, leguminous trees and shrubs should play an important role in the future within an agrosilvopastoral ecological approach. With better adapted grasses and herbaceous and shrubby legumes, the options for assembling and managing productive and stable pastures will greatly improve, thereby optimizing nutrient recycling.

In an effort to reduce the pressure to clear even more native forests, the program is concentrating its research on the development of new germplasm options and pasture technology in order to improve productivity in formerly degraded areas.The program is thus initiating a major screening effort for this ecosystem in the Peruvian Amazon, in collaboration with two Peruvian institutions, the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA) and INIPA. CIAT will outpost two senior scientists, and additional part-time involvement from other headquarter's staff is planned. This implies a substantial increase in involvement in this ecosystem from the present level, which is limited to backstopping the network of regional trials.

The aforementioned ecosystems occur in large areas of tropical South America, where low fertility, acid (pH 3.5-4.5) soils (Oxisols and Ultisols) predominate. Somewhat similar ecosystems also occur in Central America and Caribbean countries; however, soil acidity tends to be less (pH 4.5-5.5) and fertility is frequently better. These slightly better soil regions are also found in piedmont areas of the Magdalena, Orinoco and Amazon basins in Bolivia, Colombia, Ecuador, Peru and Venezuela.

4. **Moderately acid soils.** Regions with moderately acid soils (pH 4.5-5.5) are found across major ecosystems, scattered across tropical South America and in large areas of Central America, have rainfall patterns ranging from subhumid to humid tropic types. Because of their slightly higher soil pH and fertility, these areas support more intensive farming systems. The importance of small farms and dual-purpose systems is much greater than in the low-fertility savannas. Because of higher human population densities, infrastructure is also better than in the savannas, and the cattle numbers are substantial.

   Since 1979 the RIEPT has provided preliminary evidence of the high degree of adaptation of many species to these distinct subhumid and humid, moderately acid soil environments. This and several other experimental results suggest that CIAT germplasm selected under more stressful conditions frequently responds very well under these conditions. This leads to the hypothesis that the potential for short- and medium-term adoption of improved materials in these areas may be higher than in the savannas. On the other hand, other aspects of pasture management and weed control are as important as new improved germplasm.

One senior staff position, as well as headquarter's support for this ecosystem, is projected from 1987 onward to screen germplasm systematically and develop management techniques for this environment. It is expected that this will result in a gradual shifting of more of the benefits of CIAT's work to smaller dual-purpose farms.

Major Regions in CIAT's Mandate

CIAT has thus far concentrated its pasture research and cooperation efforts in tropical Latin America and the Caribbean; however, humid and subhumid ecosystems with acid, low-fertility soils are not restricted to the tropical American lowlands. In Africa and Southeast Asia, there are extensive areas with similar characteristics and demands for pasture improvement.

1. **Africa.** This continent has extensive areas of forest and savannas in the subhumid and humid belts where moderately acid to acid soils predominate. Trypanosomiasis and other cattle and small ruminant diseases constitute the major livestock production constraints.

   ILCA and African national programs are interested in developing pasture research network activities throughout the continent. Some CIAT germplasm has already been tested in an exploratory way at a few locations, and its performance seems to be promising, especially with respect to tolerance to diseases and pests (e.g., anthracnose of *Stylosanthes* spp.). Thus CIAT's germplasm and network organization could represent important contributions, especially for the humid and subhumid regions of Africa.

   On the other hand, Africa is the center of origin and diversity of most grass species utilized in the tropics as commercial cultivars. This wide variability in grasses has yet to be thoroughly collected and evaluated. During 1984-85, a major collection effort undertaken in cooperation with ILCA and IBPGR yielded a substantial number of accessions with a wide range of variability in *Brachiaria* spp., a genus so far only superficially explored despite its great importance for the tropical American lowlands, where spittlebug is a devastating pest of *B. decumbens*, a single cultivar which is widespread.

Consequently, it is envisaged that, in the future, cooperative activities with ILCA will be expanded to the point where a liaison scientist will be necessary in order to facilitate the movement of germplasm in both directions and to conduct network activities with ILCA on the African continent. Although this position figures in CIAT's projections for 1988, it will depend on a joint ILCA/CIAT decision.

2. **Southeast Asia.** Humid and subhumid zones predominate in Southeast Asia. Most of these areas range from acid to moderately acid soils. Vast areas of the unproductive *Imperata* grasslands are the result of burning and shifting cultivation on the poorer acid soils. Some national pasture research programs are successfully testing CIAT germplasm, for which there has been an increasing demand; however, it should be kept in mind that most cattle in S.E. Asian countries (cattle and buffaloes) are predominantly for working (drafting) in farmers fields; and the role of pastures in these farming systems is strongly contrasted with that of pastures in extensive savanna farming systems where CIAT has accumulated its germplasm options and experience. CIAT will continue providing germplasm to national programs in the region upon request. It is envisaged, however, that at the end of the decade (after gaining experience and selecting pasture plant germplasm for the more intensive farming systems in the humid tropics and moderately acid soils), the program will be in a position to develop stronger cooperative activities with national programs in Southeast Asia. The possibility of outposting any liaison scientist in the region, however, will be considered at the end of the decade.

General Research Strategies

Basically, the Program's strategy will remain the same: generating new germplasm options for pastures adapted to the multiple subhumid and humid ecosystems and suitable for the range of farming systems that predominate in the tropical lowlands. The emphasis will continue to be on germplasm and pasture technology development. The program's general research strategy is based on the following principles, which are in compliance with its general objectives:

1. **Low-input technology based on indigenous resources.** Given the long-term nature of pasture research, the future economic framework within which farms in the target area will operate should be taken into account. Forecasts point to limited availability of fertilizer and lime and high transportation costs, as well as political pressures for low beef and milk prices. Given these perspectives and the present characteristics of frontier production systems (i.e., extensive operations, limited capital and credit availability, and limited managerial resources), research needs to be focused on low-input systems based on adapted germplasm and efficient utilization of available local resources rather than correcting soil deficiencies with large amounts of amendments and fertilizers.

2. **Exploitation of natural genetic variability.** Program emphasis is on collecting, characterizing and evaluating a wide range of species, especially those that have not been domesticated, in order to provide genetic alternatives for use in acid soils. Thus emphasis is on selecting materials based on natural variability rather than on plant breeding although specific constraints of otherwise promising materials are being dealt with through breeding.

3. **Use of grass-legume mixes.** The introduction of forage legumes into traditionally grass-based pasture systems is emphasized. Legumes in symbiosis with rhizobia are expected to contribute directly to the diet of animals in terms of protein (particularly during the dry season) and to improve the yield, quality and persistence of grasses due to enhanced nitrogen availability in the system.

4. **Development of frontier systems.** Consistent with the land resource base of tropical America and the demand for low-cost beef and milk, the program works with national programs on the joint development of pasture-based technology that will allow for the intensification of livestock production on frontier lands with low opportunity cost. Emphasis is being placed on various options of

pasture technology for different farming systems, ranging from extensive cow-calf operations in the distant frontier areas to small-scale dual-purpose systems in areas closer to markets.

5. **Collaboration with national programs.** In collaboration with the national programs, CIAT has developed a research strategy that includes: (a) developing a broad germplasm base; (b) undertaking basic germplasm characterization research; (c) multilocational screening of germplasm for each distinct ecosystem; (d) assembling promising germplasm into legume-grass associations and evaluating their management and productivity under grazing; and (e) exposing promising pasture technology to relevant farming systems.

Recent developments such as the significant on-station and on-farm increases achieved in terms of stocking rate and animal productivity have effected a radical change in land and capital productivity, thereby opening up completely new production possibilities. In particular, substantially smaller production units become viable under these conditions. Furthermore, research results from the program and the RIEPT indicate that many of the highly promising materials selected under extremely poor conditons perform very well under somewhat more favorable conditons; i.e., in the humid tropic and moderately acid soil environments, often in areas closer to markets, where smaller farms frequently have dual-purpose cattle and crops. These regions normally benefit from more favorable input/output price ratios due to proximity to markets; however, land prices are higher, making more intensive land use necessary. Milk production increases the return on investment in improved pastures and improves cash flow, thus facilitating the financing of pasture improvements.

The program will continue to focus its attention on the development of germplasm and technology for the frontier lands with acid infertile soils while allocating some resources to testing materials for smaller farms on acid and moderately acid soils. In the long run, major benefits are expected from the increased beef supply from the frontier regions; moreover, sizable additional benefits are expected, in the short to medium term, from the intensification of smaller dual-purpose (beef and milk) farms closer to markets with positive income distribution effects.

Program Organization

The multidisciplinary Tropical Pastures Program team has been organized on the basis of three groups of researchers to integrate activities and communication and to achieve the program's objectives more effectively (Fig. 4). The three groups are (a) **Germplasm Development,** including germplasm specialists, breeders, a pathologist, an entomologist and agronomists; (b) **Pasture Evaluation,** including the soil/plant nutritionist, soil microbiologist, pasture development specialist, ecophysiologist, animal nutritionist; and (c) **Farming System Research,** including the animal scientist-farming systems specialist, seed production specialist and economist.

The basic strategies and structure of the program will remain the same for the rest of the decade. However, with new developments and consolidation of the present research approach, changes in emphases are expected.

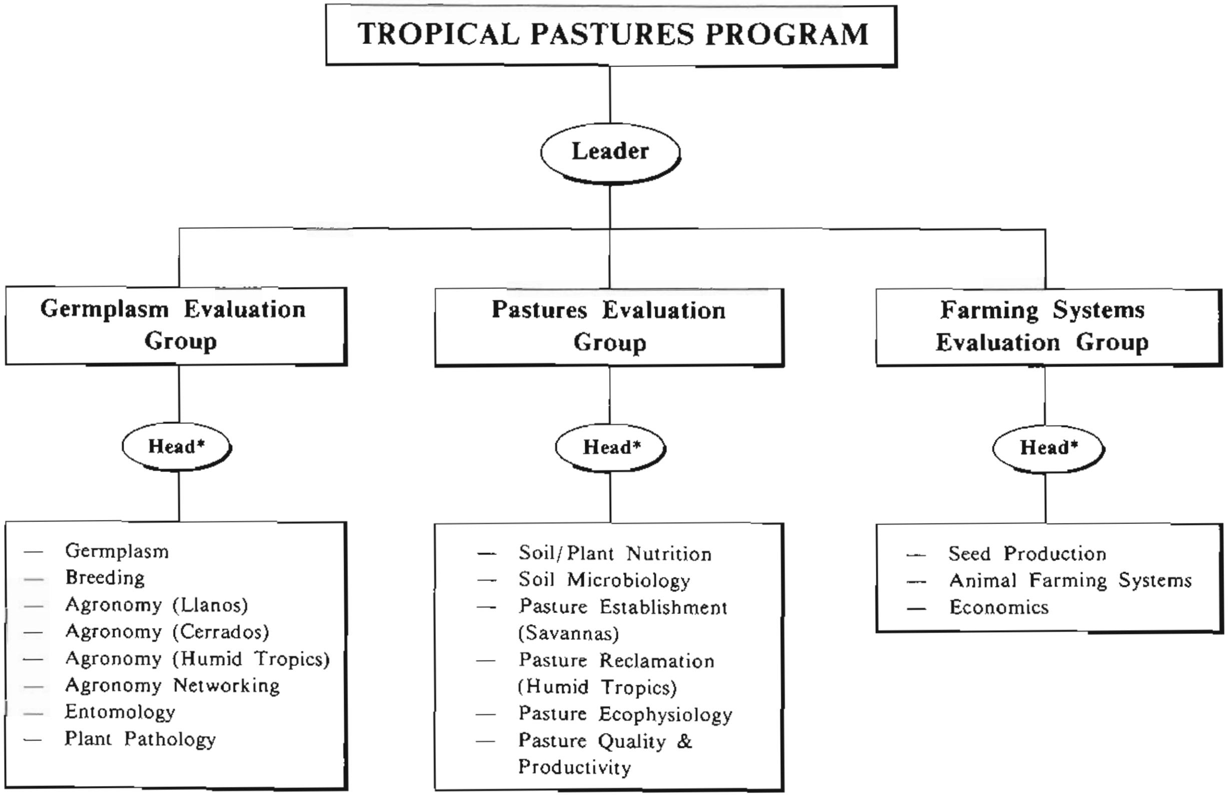
Germplasm Development Group

Upon extending the program's activities from savanna ecosystems to the humid tropics (1985) and moderately acid soils (Central America in 1987), the germplasm group will have the following changes in emphases and strategies:

1. Increased emphasis on collecting grasses and shrubby legumes in tropical America, Asia and Africa. Future collection activities will be highly specialized to increase the variability of key species.

2. Greater decentralization of germplasm screening, establishing major screening sites for the humid tropics (INIPA/IVITA, Pucallpa, Peru), as well as for moderately acid soils (Central America).

3. Further decentralization of the network (RIEPT) activities in four parallel subnetworks in the continent: (a) the **Llanos** in Colombia, Venezuela, northern Brazil, Guyana and Surinam; (b) Central America and the Caribbean (Mexico, Nicaragua, Costa Rica, Panama, Guatemala, Honduras, Jamaica, Cuba, Dominican Republic); (c) the humid tropics of Ecuador, Peru, Bolivia, Brazil and Colombia; and (d) the **Cerrados** and Beni (Brazil, Bolivia,



* The position of Head corresponds to one of the scientists in the respective group.

Figure 4. *Organizational Chart of the Tropical Pastures Program.*

Paraguay, northeastern Argentina). A similar networking approach would eventually be developed for Africa and Southeast Asia.

4. Increased breeding activities over time in order to solve specific problems of highly promising germplasm after specific characters have been defined and parental donor material identified. In addition to the current breeding program in *Stylosanthes,* the potential for breeding has already been identified for the following legumes and grasses: *Desmodium ovalifolium* for the combination of resistance to stem gall nematode and higher forage quality; *Centrosema* spp. for tolerance to various diseases (bacteriosis, Cercospora and virus) and seed production; *Zornia* spp. for tolerance to Sphaceloma scab and drought; and *Brachiaria* spp. for resistance to spittlebug.

Pasture Evaluation Group

The group working on pasture evaluation and development will continue its research based at Carimagua and Quilichao. In addition to current responsibilities of evaluating and managing the soil/plant and plant/animal interactions for the savanna ecosystems, they will also be responsible for developing grazing management techniques and research methodologies to be used in the humid tropics and the moderately acid soils ecosystems.

Emphasis will be placed on nutrient recycling in pastures under grazing (integrating soil/plant nutrition, soil microbiology and grazing systems) to understand fully the ecophysiology of pasture associations in order to optimize productivity and persistence.

A second scientist is projected to be outposted in the humid tropics ecosystem (Pucallpa, Peru) specifically to address the problem of pasture reclamation of degraded areas. Pasture establishment and reclamation research will follow two strategies: (a) development of low-cost techniques by making effective use of naturally available resources and low levels of inputs (e.g., minimum tillage, fertilizer placement, use of colonizing legumes or grasses, etc.), and (b) integrated establishment of pastures with trees and annual crops, particularly in the humid tropics and moderately acid soils ecosystems.

Farming Systems Research Group

The economist and the production system specialist have been providing important feedback to the program, especially for the savanna ecosystems. The team has accumulated experience in the monitoring and evaluation of improved technology at the farm level in extensive systems.

With the expansion of activities to the humid tropics and the moderately acid soils, the program will face more intensive farming systems [e.g., mixed (pasture-crops) and dual purpose (beef and milk)], where the roles of pastures and forages are different. The group will carefully select a few case studies of relevance to the program to produce the required feedback and simultaneously develop on-farm research methodologies for technology validation by national programs. With the release of new cultivars, the group, which includes a seed technology specialist, has an important role in providing seed production recommendations and monitoring the adoption and performance of these new pastures jointly with national programs.

Staffing Projections

The foregoing changes require some modifications in the discipline structure and location of senior staff positions in the program. These are included in the staff projections 1985-90 (Table 5). Currently, the program has 16 senior staff positions, heavily concentrated at Palmira headquarters. Over the next five years, total core positions are projected to return to the previous level of 20.

Because of the need to decentralize activities, particularly for the new ecosystems, the number of headquarters positions is expected to be reduced to 14 (Fig. 5). Staff will be outposted to the **Cerrados** screening site, the humid tropics and moderately acid soils ecosystems. At the same time, the advance of germplasm will require increased networking activities to test these materials over a wider range of locations. Consequently, the agronomists as well as other program scientists will gradually increase their involvement in networking activities (Fig. 5). Finally, one further position is projected outside of Latin America as a liaison officer with ILCA to support germplasm exchange with Africa. This position is tentatively planned for 1988.

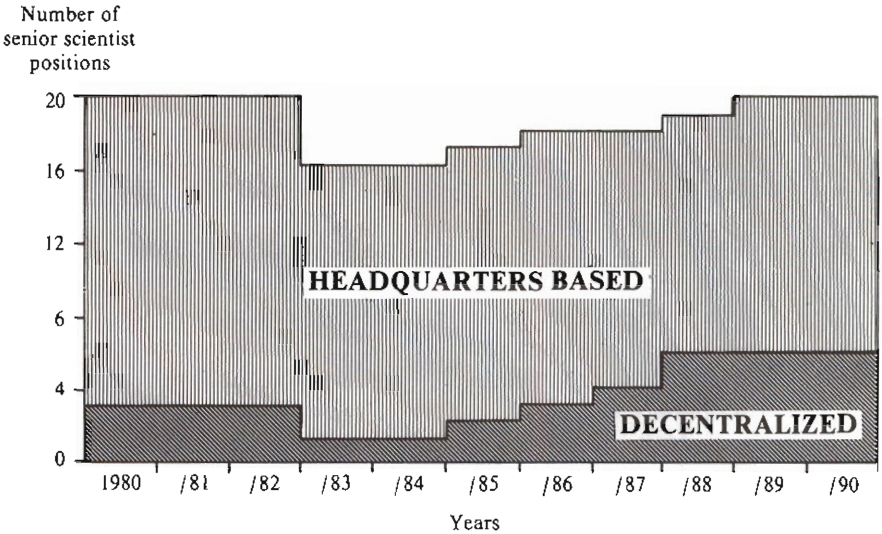


Figure 5. *Development and decentralization of senior scientist positions in the Tropical Pastures Program, 1980-1990.*

The decentralization of activities to cover the program's growing mandate appropriately is shown in Figure 6. At the same time there will be increased networking activities to catalyze and enhance the research and development of national programs. This will be achieved without losing the critical mass of scientists at headquarters, which is essential to the maintenance of the high standard of scientific research for the generation of germplasm and new technology. In the next decade, this critical mass of core staff at headquarters will gradually be reoriented toward more basic research as national programs increasingly take on more responsibilities in technology development.

Tropical South America												
(Humid tropics ecosystem)												
Agronomist (Regional trials)	CF	-	-	-	-	-	1[g]	1	1	1	1	1
Pasture Reclamation Specialist	CF	-	-	-	-	-	-	1[g]	1	1	1	1
Central America (moderately acid soils)												
Agronomist (Regional trials)	CF	-	-	-	-	-	-	-	1[h]	1	1	1
Africa												
Regional liaison (CIAT-ILCA)	CL	-	-	-	-	-	-	-	-	1[i]	1	1
Total headquarters		17	17	17	15	15	15	15	14	13	14	14
Total decentralized		3	3	3	1	1	2	3	4	6	6	6
GRAND TOTAL		20	20	20	16	16	17	18	18	19	20	20

a **Breeder.** This position was discontinued in 1982 due to center-wide budget cuts, but it has been projected to be reestablished in 1989 as the requirements of increased breeding intensify and as more basic research on selected species becomes more critical.

b **Regional Trials.** This position is projected for discontinuation at headquarters in 1986 as research increasingly becomes a decentralized collaborative effort with the RIEPT It will be moved to Central America for screening research and networking activities (see h).

c **Pasture Development Specialist.** This position is projected for discontinuation at headquarters as the research on the Llanos reaches a stage where basic technology components have been developed for this ecosystem. It is projected to be reestablished in the Cerrados in 1988 (see f).

d **Pasture Management and Evaluation.** This position was discontinued in 1984 and the responsibilities reassigned to other scientists in order to allow increased upstream emphasis on pastures ecophysiology, thus providing a better understanding of environmental and management interactions in associations.

e **Animal Health.** This position was discontinued in 1982 as part of centerwide budget cuts. Research in animal health had reached a stage where the basic problems had been described; thus further research and extension became a national responsibility. Monitoring of animal health issues in experiments remains a part of the program's activities at the sub-senior staff level.

f **Soil/Pasture Development Specialist.** This position was discontinued in 1982 due to center-wide budget cuts. The position is projected to be reinstated in 1988 as second-generation problems in the **Cerrados** ecosystem create a need for further research (see c).

g **Humid Tropics Positions.** In line with the expansion of the program into this ecosystem, two positions for 1985 and 1986, respectively, will complete the team required for this outposted research. These positions have been endorsed by the Technical Advisory Committee (TAC) since 1983 and recommended for funding in 1984 and 1986, respectively.

h **Agronomist in Central America.** An outposted regional agronomist position is projected for 1987 as program germplasm research provides appropriate materials for testing in this ecosystem. This position will be moved from headquarters to conduct ecosystem-specific research (see b).

i **Regional Liaison Africa** This outposted regional liaison position with ILCA is projected as a means of increasing germplasm collection and development research collaboration between the two institutions for the more humid and subhumid areas of Africa. The role of this position will be somewhat dependent on the evolution of pasture research at ILCA.

Table 5. **Approved senior staff positions in the CIAT Tropical Pastures Program for 1980-1985 and projected positions for 1986-1990 from core funding (CF) and corelike (CL) projects.**

Positions	Funding source	80	81	82	83	84	85	86	87	88	89	90
Headquarters based												
Leader	CF	1	1	1	1	1	1	1	1	1	1	1
Germplasm Specialist	CF	1	1	1	1	1	1	1	1	1	1	1
Agronomy (Regional trials, Llanos)	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder	CF	1	1	1[a]	-	-	-	-	-	-	1	1
Regional trials	CF	1	1	1	1	1	1	1[b]	-	-	-	-
Pathologist	CF	1	1	1	1	1	1	1	1	1	1	1
Entomologist	CF	1	1	1	1	1	1	1	1	1	1	1
Soil/Plant Nutritionist	CF	1	1	1	1	1	1	1	1	1	1	1
Microbiologist	CF	1	1	1	1	1	1	1	1	1	1	1
Pasture Development Specialist	CF	1	1	1	1	1	1	1	1[c]	-	-	-
Pasture Management & Evaluation	CF	1	1	1	1	1[d]	-	-	-	-	-	-
Ecophysiologist	CF	-	-	-	-	-	1	1	1	1	1	1
Pasture Quality/Productivity	CF	1	1	1	1	1	1	1	1	1	1	1
Seed Production Specialist	CF	1	1	1	1	1	1	1	1	1	1	1
Livestock Systems Specialist	CF	1	1	1	1	1	1	1	1	1	1	1
Economist	CF	1	1	1	1	1	1	1	1	1	1	1
Animal Health	CF	1	1	1[e]	-	-	-	-	-	-	-	-
Decentralized regional programs												
Tropical South America (Cerrados ecosystem)												
Agronomist (Regional trials)	CF	1	1	1	1	1	1	1	1	1	1	1
Soil Pasture Develop.Specialist	CF	1	1	1[f]	-	-	-	-	-	1	1	1

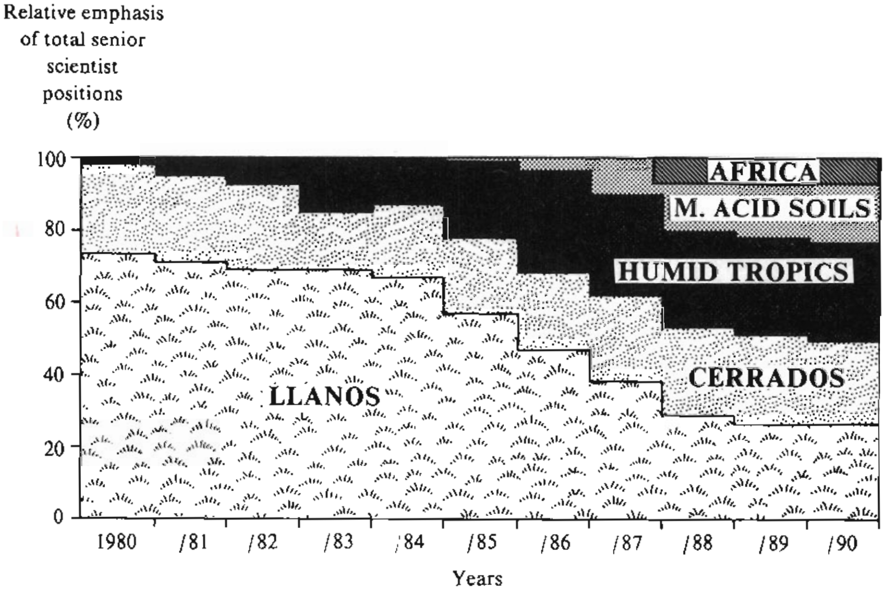


Figure 6. *Relative emphasis of total senior scientists in the Tropical Pastures Program dedicated to the different ecosystems and continents, 1980-1990.*

BEAN PROGRAM

Introduction

The common, dry or field bean *(Phaseolus vulgaris* L.), which is the most important grain legume species for direct human consumption in the world, contains about 25 percent protein. Beans are a traditional food for the lower income strata in Latin America, particularly in Brazil, Mexico, Central America, the Andean Zone and some Caribbean countries. The highest per capita consumption in the world is in Eastern Africa, especially in Rwanda, Burundi and the Kivu region of Zaire. Other important bean-producing countries are Kenya, Malawi, Tanzania, Uganda, Turkey and Iran. Primarily a small-farmer crop, beans are grown in a wide range of cropping systems, where few purchased inputs are used and yields are generally low. Not only has production growth in Latin America been less than half that of population growth over the last decade; but also yields, currently averaging about 550 kg/ha, have declined in some major producing countries.[36] Although area expansion has allowed a slight production increase in most countries, it has not kept pace with population growth, much less with demand. Latin American net imports reached a record level of 400,000 t/year in the 1980-1982 period. Brazil, Costa Rica, Cuba and Venezuela have been traditional importers; only Argentina and, to a lesser extent, Chile have been net exporters, mainly to Europe. In some countries (e.g., Mexico and Colombia) where long-term active bean research programs exist, national average yields have tended to increase. Encouraging trends are also evident in Guatemala and other Central American countries, as well as in Argentina.

Similarly, in about half the countries in Africa for which adequate data exist,[37] bean production growth rates have been at least 1 percent per annum less than population growth. Yield trends have been stagnant, and any production growth has been obtained through area expansion. In many countries, including Rwanda, Burundi and Kenya, land

[36] **Trends in CIAT Commodities,** Internal Document, Economics:1.8, CIAT, March 1983, 163p.

[37] D. Pachico and W. Calderon, **Bean consumption in Sub-Saharan Africa: a preliminary review,** in **Trends in CIAT Commodities,** CIAT Internal Document, Economics: 1.9, April 1984.

suitable for bean production is already limited. An estimated 110 million people in sub-Saharan Africa live in countries where beans are the leading source of noncereal protein; thus an apparent decline in per capita bean consumption since the early seventies may be having a critical impact on protein nutrition in those areas due to the prominence of beans in the diet. Bean prices have tended to increase more rapidly than general inflation in many countries; however, there is no long-term trend as prices are highly variable. In Brazil, for example, real prices of beans tripled between 1972 and 1976; halved by 1978-1979, only to double again in 1980; and halved again by 1982.

Regardless of increased market prices, bean production is characterized by low profitability and high risk. Low and unstable yields, together with seasonal climatic variability and consequent seasonal price fluctuations, have led increasingly to the displacement of beans in traditional areas by higher value crops or crops with a more predictable price structure. In Brazil, for example, 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, where 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 to 4 t/ha in a 90-day crop season are not uncommon. At CIAT, experimental yields of climbing beans grown on artificial supports (monoculture) have exceeded 5 t/ha in 100 days. The large yield gap that exists between farm and experimental situations could be reduced substantially by using improved varieties and production technology. Economic analyses have indicated that if production in Latin America were 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%.[38]

[38] Trends in CIAT Commodities, 1983, op. cit.

Program History and Accomplishments

Formation of a coordinated program focusing only on *P. vulgaris* dates from 1973. The establishment of the world *Phaseolus* germplasm collection, currently containing some 35,000 accessions, forms the base for sources of resistance to major diseases and pests. 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.

The breeders carry out more than 1500 crosses (parental combinations) yearly. Breeding populations (F_2 and F_3) are first evaluated for disease and insect resistance, architecture and consumer requirements.In the second stage, all bean scientists are involved in the testing of selections in successive uniform nurseries to confirm disease and insect resistance and general adaptation at two altitudes. In the third stage of evaluation, the materials are selected for the above characters, as well as for nitrogen fixation, water stress tolerance, low phosphorus tolerance, resistance to minor diseases, protein content and cooking time. From 200 to 300 new advanced lines are evaluated yearly for their yield performance under stress and nonstress conditions at three sites in Colombia. These lines are then made availabe as parental sources to national bean programs.

Approximately one hundred superior lines enter the IBYANs (International Bean Yield and Adaptation Nurseries) each year. As national programs increase their capability to undertake breeding and selection activities, their entries will form part of this program. More than 150 IBYAN trials are shipped yearly to bean-producing countries in Latin America, the Caribbean and other parts of the tropics and subtropics.

Selected highlights of the program are as follows:

1. All lines leaving the second stage of evaluation are resistant to BCMV (Bean Common Mosaic Virus).

2. Multiple-disease resistant germplasm is now being distributed for international testing. Lines resistance to all known races of anthracnose have been identified.

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

4. Yield levels of small, nonblack-seeded experimental lines have been improved significantly and are now equal to or surpass yields of the initially superior black-seeded germplasm.

5. Lines developed collaboratively with the Instituto de Ciencia y Tecnología Agrícolas (ICTA) in Guatemala for tolerance to BGMV (Bean Golden Mosaic Virus) outyielded leading commercial varieties under heavy disease pressure, even when susceptible local lines received heavy insecticide applications. Chemical protection further increased yields of resistant lines.

6. Over twenty lines originating from collaboration with national breeding programs are now being evaluated at the farm level or are being multiplied for seed by national programs in Latin America and the Caribbean. Disease-resistant lines have been released in several countries.

7. Improved agronomic practices have increased yields 50 to 100% in numerous experiments in Colombia. An inexpensive, nontoxic farm-level storage technology employing vegetable oils has also been adapted to beans; diffusion of this technology has begun in Colombia.

8. Through 1984, 529 national program scientists have received training at CIAT, mainly in bean production short courses or intensive discipline-oriented training.

Production Systems

In the tropics and subtropics of Africa and Latin America, bean production tends to be concentrated at intermediate and high altitudes in areas with high rural population densities. A series of cropping systems have evolved as small farmers adjusted to various environmental and socioeconomic constraints.The four major cropping systems[39] can be classified as follows:

1. **Bush beans in monoculture.** This system is common in low- to medium-altitude areas, chiefly in Brazil, Argentina, Chile, the Dominican Republic, Kenya, Mexico, Peru and Turkey.

2. **Bush, semiclimbing and climbing beans in relay systems with maize.** The relay system is mainly found in low to intermediate altitudes of Colombia, Central America and Southern Africa.

3. **Bush beans in direct association with maize.** This system where maize and beans are usually sown at the same time is common in intermediate altitudes in Colombia, Kenya, Tanzania, Zambia, Venezuela, and in many areas of Brazil.

4. **Climbing beans in direct association with maize.** The system is found in higher altitudes (2000 masl) of Burundi, Rwanda, Colombia, Ecuador, Guatemala and Peru, as well as in northern Turkey.

Maize, which predominates as a companion crop in these systems, is a major constraint to increased bean production. Most studies show bean yield reductions of about 50 percent in associated systems with maize. It is obvious that the total return from the two crops in the system is more important for farmers than the individual components.

Data on bean production microregions are being collected by the Agroecological Studies Unit for Latin America to provide an accurate assessment of the relative importance of the various systems and their production problems. This effort is complemented by on-going economic impact studies.

Data obtained thus far on the Latin American bean microregions have been used to classify growing season climates (Table 6) on the basis of average growing season temperature and water balance conditions.

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[39] D. R. Laing, P. G. Jones and J. H. C. Davis, **Common Bean** *(P. vulgaris)*, In: P. R. Goldsworthy and N. M. Fisher (Eds.), **The Physiology of Tropical Field Crops,** Wiley and Sons, London, pp. 305-351.

Table 6. **Classification of bean production zones in Latin America.**

Type	General description of climatic zone	Mean growing season temperature[a] (ºC)	Range in mean daily growing season water balance (WB)[a] (+ mm/day)	Latin American production zone ('000 tons)	(% total)
A	Average temperatures and adequate mean seasonal WB	22	-1.5 to º0.4	661	17
B	Average temperatures and slight excess in WB	23	º0.4 to º4.0	118	3
C	Average temperatures and large deficits in WB (irrigated areas)	23	-5.6 to -5.1	528	14
D	Average to moderately low temperatures with possible deficit in WB toward end of the growing season	20	-2.7 to - 1.6	1672	42
E	High temperatures with possible deficit in WB toward end of growing season	26	-4.1 to -0.3	262	6
F	Moderately low temperatures and moderate water stress	16	-2.3 to -1.9	451	11
G	Low temperatures and adequate mean seasonal WB	13	-.09 to -.05	45	1

a Mean of conditions in microregions constituting each production zone; overall 110 microregions defined.

Each of the seven zones 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). This surprising tendency for production to take place within a narrow temperature range indicates the relatively high sensitivity of the species to temperature. At the same time, 73 percent of the total production occurs in microregions having moderate to severe mean water deficits at some time during the cropping season; but very little of this production is irrigated. Serious water deficits are, therefore, a major production constraint.

Similar data are being collected in eastern and southern Africa to increase understanding of production problems, to determine similarities/differences with respect to the Americas, and to realign research priorities where necessary.

Constraints to Increased Production

Of the major world crops, beans are undoubtedly one of the most susceptible to diseases and insect attack. Drought and infertile soils also contribute to low yields.

In most production areas, diseases and pests are the most common important constraints to increased production and productivity. More than 200 pathogens can affect bean productivity. The more prevalent diseases in the western hemisphere are bean common mosaic virus (BCMV), bean rust *(Uromyces phaseoli),* anthracnose *(Collectotrichum lindemuthianum),* angular leaf spot *(Isariopsis griseola),* and common bacterial blight *(Xanthomonas phaseoli).* In some years web blight *(Thanatephorus cucumeris)* and bean golden mosaic virus (BGMV) are also severe in certain locations. In Africa bean-production constraints from diseases appear to be similar to those in Latin America, which is the center of origin of beans. Insects and virus diseases in Africa are thought to be relatively more important than in Latin America; and fungal and bacterial diseases relatively less important although they cause severe crop losses in many areas.

Most of the commonly utilized cultivars in both continents 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 to 100%. The transmission of BCMV, anthracnose, angular leaf spot and bacterial blights through infected seed has facilitated the spread of these diseases from one region to another.

Among the insect pests, leafhoppers *(Empoasca* spp.) and pod weevils *(Apion godmani)* are the most significant. Leafhoppers have reduced yields of highly susceptible varieties by as much as 90%; and reductions of 20 to 50% are common on many farms even when insecticides are used. Storage insects such as *Zabrotes* and *Acanthoscelides* inflict heavy losses in stored beans; thus farmers are forced to sell their harvest quickly, which contributes to postharvest price declines. The most common insect problem in Africa is the bean fly *(Ophiomya phaseoli),* which causes severe yield losses, especially under dry conditions. Storage insects and aphids are also believed to be more important in Africa than in Latin America.

Physiological defects of currently utilized cultivars (mostly landraces) contribute to low and unstable bean yields. Many cultivars have a poor plant type so that pods come in contact with the soil at maturity, increasing the possibility of attack by soil-borne pathogens, which results in poor-quality seed. Cultivars with a determinate bush habit are characterized by early and intense flowering, which contributes to low and unstable yield. 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. They are grown extensively, however, because of their erectness, earliness and preferred grain type.

Soil-related constraints become important as bean production is increasingly being carried out on more marginal land, characterized by soil acidity and high phosphorus fixation. Associated aluminum toxicity reduces root development and increases sensitivity to water deficits. Nitrogen deficiency is also a limiting factor in many soils where beans are grown; this is complicated by a low capacity for nitrogen fixation in most currently used cultivars. These problems may be more severe in Africa than in Latin America.

All the major environmental and biological constraints to increased bean production can be researched. At the national program level, limited progress has been made toward resolving the problems through new technology because of lack of continuity in research, use of a narrow germplasm base, lack of efficient research methodologies, and insufficient training and information exchange. Those countries with strong national research programs have made considerable production progress, confirming the potential for crop improvement through research.

Program Objectives

The overall goal of the Bean Program is to collaborate with national research efforts to increase and stabilize bean production by conducting research on the principal production constraints. The Program's specific objectives are as follows:

1. To develop—in collaboration with national research institutions—improved technology for beans, which will lead to increased national production and productivity in those countries where the crop is an important food source.

2. To strengthen existing national bean research programs selectively through training and the establishment of a bean research network of collaborating scientists.

In general, production constraints in Latin America appear to be quite similar to those in Africa although they are probably more serious in Africa. Much of the research carried out in Latin America is applicable to Africa and vice versa, but a concerted region-specific research effort will be required on both continents; e.g., on bean flies and improvement of varietal mixtures in Africa and on BGMV and web blight in Latin America.

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 the program has refrained from conducting research aimed at (a) the humid lowland tropics, where disease pressure is excessive; and (b) the highly acid, infertile soils of the agricultural frontier in the Americas, where bean production would be possible only with massive soil amendments. Moreover, the Program has confined its activities to *P. vulgaris* despite pressure to work with other grain legumes such as lima beans *(P. lunatus)*, cowpeas *(Vigna unguiculata)*, or soybeans *(Glycine max)*. Research in other closely related *Phaseolus* species such as *P. coccineus* and *P. acutifolius*, which are of far less importance in human nutrition, has been confined to the study of characteristics likely to lead to genetic improvement in *P. vulgaris*. Germplasm of the other three cultivated species of *P. phaseolus* are maintained in the GRU (Genetic Resources Unit), accessions of which are made available on request.

General Research Strategies

In order to accomplish the broad objective of increased production, the Bean Program focuses primarily on two basic strategies:

1. Genetic improvement of germplasm.

2. Training of national program scientists to develop a strong collaborative network.

Other complementary activities include the development of agronomic practices and collaboration with institutions in the developed world.

Genetic Improvement

CIAT has been assigned the world responsibility by the CGIAR to collect, evaluate, conserve and distribute *Phaseolus* germplasm. The Bean Program's genetic improvement activities find their strength in the world collection comprised of more than 35,000 accessions of *Phaseolus*, held in the GRU, which distributes these materials to collaborators worldwide. Collection expeditions are organized in collaboration with the IBPGR and national programs to complement this collection where necessary. The collection contains the four cultivated species, wild and ancestral forms, and other *Phaseolus* species.

The Bean Program has placed major emphasis on reducing losses from production constraints through genetic solutions, rather than seek technologies based on increased inputs. Initial emphasis has been on breeding for increased resistance or tolerance to diseases and insects. Continuation of this activity is expected throughout the eighties, but emphasis will gradually shift as national programs share responsibilities and become stronger through training. Diseases and pests are evolving biotic production constraints that will continue to require research inputs; nevertheless, time and resources are expected to be freed from primary focus on disease and insect resistance. They will be used to shift to greater emphasis on improvement of other germplasm characteristics, principally yield potential, tolerance to drought, and important soil-related constraints, particularly low phosphorus availability. As a long-range strategy the improved ability to fix nitrogen biologically will be incorporated in desired germplasm. Such germplasm will be made available in a wide range of maturity classes.

Included in this genetic improvement strategy is the improvement of the basic plant type and yield potential. Improvement of yield potential will first be sought under high-input conditions, but eventually the program seeks to combine increased yield potential with multiple disease resistance.

Development of Collaborative Research Networks

Inadequate training of national bean research scientists and lack of bean research and production information have traditionally been cited as among the main reasons why research in beans has not led to increased productivity.The program places heavy emphasis on strengthening national program research through training at various levels, information exchange and collaborative research.

Initially, training concentrated on awareness training, followed by discipline-oriented training, with heavy emphasis on plant breeding and plant protection. It gradually became apparent that lack of research leadership was a constraint to national program development; therefore, increased attention in training will be given to development of research leadership in national programs through the eighties. The efficiency of trained scientists is greatly magnified by proper research leadership. With new technology increasingly available to national research programs, training in on-farm research (OFR) methodologies and technology transfer methodologies, mostly through CIAT-supported in-country courses, will be increasingly emphasized. Although many research results are obtained currently from experiment stations, the on-farm testing and resulting promotion of the new technology is sought through such training effort. OFR at CIAT is mainly conducted to provide feedback to the research process and will further increase knowledge of bean micro-production regions. However, given the wide and variable target area, CIAT cannot fulfill this function alone; thus a major effort is devoted to training national programs in OFR methodology. The program will interact strongly with other IARCs in this area, especially CIMMYT. Discipline-oriented training is expected to concentrate on "maintenance," mostly following staff turnover or for countries just initiating bean research.

Continued emphasis will be placed on decentralized genetic improvement capitalizing on local adaptation and training. This will strengthen the collaborative bean research network and the individual national research teams which form the network. The Program will increasingly concentrate on solving second generation problems, which are particularly difficult to resolve, as well as on research methodology improvement.

As mentioned previously, beans are produced under a wide range of climatic conditions and cropping systems, each with a particular set of production constraints. Superimposed upon this is the region-specific grain type preferences. Only through a decentralized genetic improvement and training program, in which fully developed national programs assume a large part of the research responsibilities, can increased production be realized. The Bean Program increasingly provides early generation materials or makes crosses requested by national programs, from which varieties will be extracted locally. CIAT complements this decentralized genetic improvement scheme by providing: (a) a research team of highly trained scientists to back up the network; (b) the germplasm bank, with its wide range of genetic variability; (c) a massive hybridization program involving these accessions and national cultivars; and (d) the potential to grow four crops cycles per year, thereby advancing generations more rapidly to stages in which local selection is preferable. CIAT has the infrastructure to screen such germplasm efficiently for resistance in early stages for the principal widespread production constraints (e.g., BCMV, rust, anthracnose, bacterial blight, leafhoppers, drought, low soil fertility, etc.) according to the destination of the materials. Such highly variable, but multiple-factor tolerant material is then provided to national programs for selection for local adaptation, resistance to local diseases, etc. The outreach strategy to Africa is based on this principle. The implementation of such a scheme will be a continued challenge for the Bean Program throughout this decade.

The ultimate aim is to help country programs become full and equal partners in the network. CIAT should assume in the long term a research backstopping role. The speed at which this progress occurs will vary considerably among countries, and some attrition is to be expected. The situation in Africa is particularly critical, where large food shortages occur and national research programs are young. During this and the next decade, heavy emphasis will be placed on developing an effective research network in Africa.

Program Evolution

As a result of the aforementioned developments, the second half of this decade will see progressive changes in priorities in the Bean Program's breeding activities, and some change in overall staffing pattern is anticipated. Figure 7 shows the relative emphasis the Program will place on various aspects of technology development through the decade of the eighties. Changes in emphasis will be reflected in the proportion of crosses in the breeding projects designed for specific groups of constraints.

Substantial variation in plant architecture and disease resistance have been obtained in the breeding and germplasm lines developed 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 7 reflects the increasing emphasis to be given to bean plant architecture and yield potential. Work on the improvement of snap beans is also planned during the decade; the Program's degree of emphasis will depend on the outcome of an economic study to determine the importance of snap beans in developing countries and the constraints to increased production and productivity of this vegetable crop.

With most fertilizer prices rising rapidly and the unavailability of credit for small farmers limiting the use of purchased inputs, future elite lines

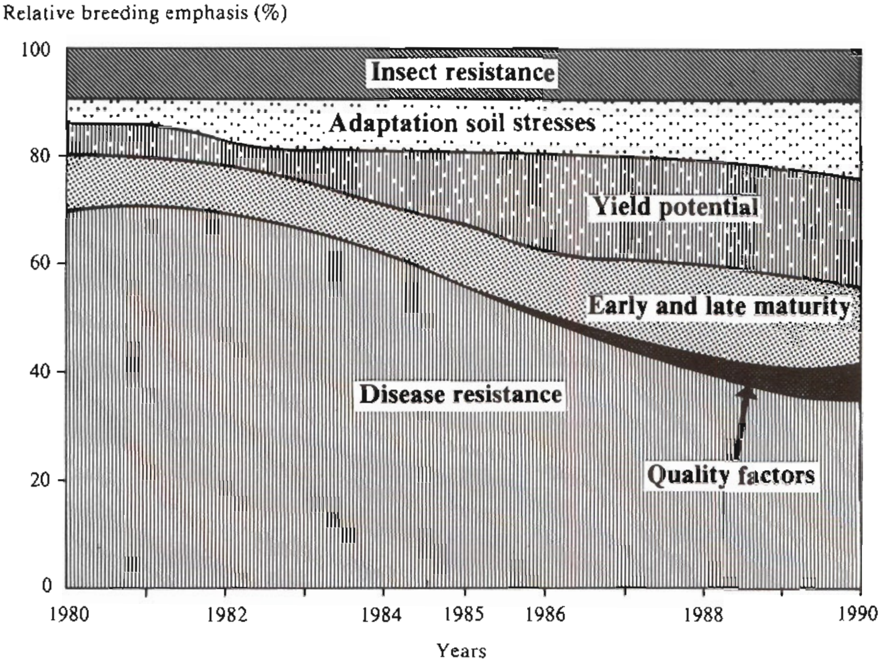

Figure 7. *Evolution of the Bean Program's relative breeding emphasis from 1980-85 and projections for the next 5 years, 1985-90.*

will have to be tolerant to important soil constraints. For regions such as Brazil, Venezuela and many parts of Africa, the Program will need to develop varieties tolerant to moderate soil acidity and low soil phosphorus, which is often associated with drought. Increased capacity for nitrogen fixation is also of critical importance. Incorporating these traits into agronomically acceptable cultivars will require the application of innovative research and research methodologies in soil science, microbiology and physiology to future breeding efforts.

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 research 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 breeding nurseries locally to exploit specific adaptation. Problems of nutrition and consumer preference will also receive attention. The program expects to continue to produce some finished experimental lines into the next decade, as many smaller national programs may not be selfsufficient in the generation and selection of segregating materials.

As the program evolves, the bean germplasm bank in the GRU will be used continually as a source for new variability. New collections will be made during the eighties to add genetic variability from regions that are poorly represented at present or from areas where specific desired variability is most likely to be found. Collaboration with the 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. A seed unit for Africa is presently under discussion by a donor agency. These developments could have an important influence in the availability of bean seed and expedite the adoption of the new varieties by farmers on both continents.

Staffing Projections

Headquarters-Based Staffing Requirements

To achieve the program's objectives and to allow the outlined strategies to be implemented, the program projects the following staffing needs from core funding, corelike projects and special projects. A summary of staffing projections for the period 1986-1990 is shown in Table 7.

Breeding

Genetic improvement responsibilities are divided among the three projected headquarters-based breeders to serve the Bean Program through the 1980s. Large differences in grain-type requirements, growth habit, cropping system and growing environments were the basis on which the assignment of these breeding responsibilities were made. Each grain type is produced under particular ecological conditions and has its specific varietal requirements for disease resistances, yield potentials, cropping system, etc. The main responsibilities of the three breeders are divided as follows:

Brazil, Central America, the Caribbean and Coastal South America. Breeding for these areas includes black-seeded bush and climbing beans generally grown in areas where high temperature adaptation is required such as in Brazil, Central America, the Caribbean and coastal South America; the yellow- and white-seeded types for coastal Peru, Chile and Mexico; the Central American small reds and Caribbean mottled-grain types. BGMV, rust, common bacterial blight and web blight are particularly severe disease problems, which will require continued research attention, as no sources of good resistance are available.

Mexican Central Plateau, Brazil, Argentina and Middle East. The grain types grown in these areas include the bayo, cream and pink types of the Mexican Central Plateau, the nonblack grains of Brazil (e.g., mulatinho and carioca), and the large white-seeded types important in Argentina, North Africa and West Asia. Anthracnose, angular leaf spot and virus diseases (yellow mosaic and bean chlorotic mottle) and acid and salty soils are the principal constraints. In this respect the virus problems are a particularly critical challenge.

Andean Highlands and Eastern and Southern Africa. The grain types for these regions are generally large red (often mottled) and other large light-colored seeds in both bush and climbing growth habits. Anthracnose, ascochyta leafspot (for which no resistance sources are available in beans), halo blight, BCMV, bean flies, low temperature and infertile soils are important production problems. Farmers in the Andean region and in Africa are among the most disadvantaged bean producers because their plots are very small and the soil is infertile; thus production increases must be achieved mainly through an increase in productivity.

As mentioned before, each of these breeders has a decentralized genetic improvement approach, in which multiple-factor bulk segregating

Central Africa (Great Lakes)												
Reg. Coord./Breeder	CL	-	-	-	1[h]	1	1	1	1	1	1	1
Anthropologist	CL	-	-	-	-	-	1	1	1	1	1	1
Pathologist	CL	-	-	-	-	1	1	1	1	1	1	1
Southern Africa												
Coordinator (Africa-wide)	CF	-	-	-	-	-	-	1[i]	1	1	1	1
Breeder	CL	-	-	-	-	-	-	1	1	1	1	1
Agronomist	CL	-	-	-	-	-	-	1	1	1	1	1
Entomologist	CL	-	-	-	-	-	-	1	1	1	1	1
North Africa & West Asia												
Reg. Liaison/Agronomist	SP	-	-	-	-	-	-	1[j]	1	1	1	1
Total Headquarters		9	9	9	10	11	12	11	12	12	12	12
Total Decentralized		4	4	4	5	7	11	16	15	15	15	15
GRAND TOTAL		13	13	13	15	18	23	27	27	27	27	27

a **Leader.** The full-time coordinator position was created in 1985 following the EPR 1984 recommendations.

b **Agronomist** (Soils). This position was transferred to Brazil as a liaison function with (and partially funded by) EMBRAPA during the period 1980-86 and will be reinstated at headquarters in 1987 to continue strategic research on problems of soil adaptation in beans.

c **Physiologist.** This position remained unfilled during the period 1980-82 because of financial limitations.

d **Virologist.** This position will move to the Biotechnology Research Unit in 1986, following recommendations of the EPR 1984.

e **Microbiologist.** This position remained unfilled during the period 1980-83 due to financial restrictions.

f **Breeder** (Central America). This position is projected to terminate in 1986 when the functions of the breeder in this core-funded regional project (transferred special project funded by SDC) become a normal part of national program evolution in the region.

Regional Liaison (Brazil and S. Cone). This position was previously filled by the secondment from headquarters of the Soils Agronomist to EMBRAPA. In 1987 it is projected to fund this position fully, following the phasing out of the breeder position in the Central American Regional Project.

g **Regional Coordinator (Eastern Africa).** The first appointment to the Eastern Africa Regional Program was made on this corelike project funded by USAID/CIDA in 1984; the three others are expected during 1985.

h **Regional Coordinator (Great Lakes).** The first appointment to the Great Lakes Project was made in late 1983 on this corelike project funded by SDC (Switzerland); and the full staff complement of three positions plus two associate staff is now in place.

i **Regional Coordinator (Southern Africa).** A corelike project is presently under negotiation with CIDA and the SADCC countries. The four positions should come aboard in 1986 and 1987. CIAT has placed one of these positions, that of Africa-wide coordinator, on the forward list for core funding in 1986.

j **Regional Liaison (N. Africa and W. Asia).** This project is under negotiation with donors; funds should be available on a special project basis in 1986 or 1987.

Table 7. **Actual senior staff positions in the CIAT Bean Program for 1980-85 and projected positions for 1986-1990 from core funding (CF), corelike (CL) and special projects (SP).**

Positions	Funding source	80	81	82	83	84	85	86	87	88	89	90
Headquarters based												
Leader	CF	-	-	-	-	-	1[a]	1	1	1	1	1
Economist	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder	CF	1	1	1	1	1	1	1	1	1	1	1
Agronomist (OFR)	CF	1	1	1	1	1	1	1	1	1	1	1
Agronomist (Int. trials)	CF	1	1	1	1	1	1	1	1	1	1	1
Agronomist (Soils)	CF	b	b	b	b	b	b	b	1	1	1	1
Physiologist	CF	c	c	c	1	1	1	1	1	1	1	1
Pathologist	CF	1	1	1	1	1	1	1	1	1	1	1
Virologist	CF	1	1	1	1	1	1	d	d	d	d	d
Microbiologist	CF	e	e	e	e	1	1	1	1	1	1	1
Entomologist	CF	1	1	1	1	1	1	1	1	1	1	1
Decentralized regional programs												
Central America & Caribbean												
Reg. Coord./Virologist	CF	1	1	1	1	1	1	1	1	1	1	1
Agronomist	CF	1	1	1	1	1	1	1	1	1	1	1
Breeder	CF	1	1	1	1	1	1	1[f]	-	-	-	-
Brazil & Southern Cone												
Reg. Liaison/Agronomist	CF	1	1	1	1	1	1	1	1[f]	1	1	1
Eastern Africa												
Reg. Coord./Pathologist	CL	-	-	-	-	1[g]	1	1	1	1	1	1
Breeder	CL	-	-	-	-	-	1	1	1	1	1	1
Agronomist	CL	-	-	-	-	-	1	1	1	1	1	1
Economist	CL	-	-	-	-	-	1	1	1	1	1	1

hybrid populations or advanced lines are provided to national programs, depending upon their strength and requests.

Additionally, the breeders have the responsibility for developing high levels of character expression in a variety of grain types. High and stable parental sources are developed for resistance to rust, storage insect pests, nitrogen fixation, earliness and lateness, etc. Such materials with high character expression are subsequently used as parents for varietal improvement by all breeders. An active interchange of germplasm with the gene bank and among the breeders is noteworthy and is an essential part of the breeding strategy in order to avoid duplication of efforts.

Pathology

Development of lines resistant to diseases for which only low levels of resistance have been identified and recombining several of these in one line will continue to be a challenge into the next decade. Diseases in general will remain one of the most important production constraints and will therefore continue to receive attention in research. The pathologist's input for developing multiple-resistant material is essential. Because of the wide variation in diseases and disease race complexes, training national program scientists and backstopping genetic improvement by inoculation and resistance screening methodology will continue to be needed well beyond this decade. As multiple-resistance germplasm becomes increasingly available, more time will be dedicated to developing integrated disease control strategies.

Physiology

Bean physiology research has slowed in recent years following several years of temporary staff vacancy imposed by budgetary constraints. As benefits from increased levels of disease resistance have been realized, demand for lines with improved physiological characteristics has become increasingly apparent. Increasing yield potential, in early- and especially in late-maturing lines, as well as drought tolerance, will continue to be important research activities of the physiologist. Greater insight into the problems of adaptation (including photoperiod and temperature response) will lead to a better understanding of bean phenology across environments and will guide breeding and agronomic improvements.

Virology

The common bean is highly susceptible to a wide range of plant viruses, most of which have several known strains and can be seed borne. The appearance, for example, of BCMV and BYMV necrotic strains over the last five years has required a drastic modification of breeding strategies. In Africa, the monogenic dominant resistance gene, so effectively exploited in Latin America, is broken down readily because of the predominance of a necrotic strain of BCMV on that continent. Additionally, the complex of viruses (BYMV, BClMV, BGMV), which cause severe crop losses in Argentina, Brazil and the Middle East, will continue to require a strong virology input on the team well into the next decade. It is believed that this research is best provided by transfer of this virology position to the Biotechnology Research Unit. This centralized virology pool can share equipment and resources more rationally. Transfer of this position to the BRU is projected for 1986.

Entomology

Ongoing projects to develop resistance to leafhoppers, bean pod weevil and bruchids will continue through the decade, as gradual but slow progress is expected in the development of multiple-insect resistance. Additional requirements for resistance breeding for the leading bean pests in Africa, such as the bean fly and aphids, and the Mexican bean beetle in Mexico will place a high demand on the entomologist in the future.

Economics

As new technology reaches farmers in many countries, economic studies have been initiated on its impact and limitations, initially at the producer level, and will expand as more countries experience technical changes in production by adopting new technology. These studies also generate further information on production constraints and, in addition to consumer preference studies, help refine the program's minimum input strategy, define varietal characteristics needed by farmers, and provide information for the microregion data base. Case studies are undertaken to assess how government policies affect farmer incentives to use new technology. A study has been initiated on the importance of snap beans, as suggested by the External Program Review (EPR), prior to further development of the current limited work on snap bean improvement. The economist continues to support OFR, collaborating with the cropping systems agronomist both in methodology development and training. Specific contributions from the economist include target area description and diagnoses, as well as socioeconomic analyses of trial results.

Cropping Systems Agronomy

Research in beans at the national program level is usually conducted on research stations; thus farmer participation in technology development is inadequate in most countries. The Cropping Systems Agronomist will continue to develop the recently initiated network for OFR to feed back information on new technology to the research scientists and then feed it forward to extension personnel. A strong training component is essential in this work, as well as a methodology development research program, initially based in Colombia, to be expanded later during the decade into Central America and Africa in collaboration with the cropping systems agronomists located at the decentralized regional programs.

Agronomy/Soil Science

This position, which was transferred to Brazil in 1979, continues to be needed as a CIAT-Brazil and Southern Cone liaison scientist. With the advent of the recent expansion into Africa, where soil fertility is more limiting, the Bean Program plans to reinstate this position at headquarters in 1987 in order to develop and improve the screening methodology for tolerance to low soil phosphorus and to low soil fertility in general. Additionally, the role of phosphorus and mycorrhiza in fertilizer use efficiency and nitrogen fixation will require the support of this scientist. In the second part of this decade, this research will become increasingly important as better nitrogen-fixation capacity becomes available in bean germplasm.

International Trials Agronomist

Since the formation of the IBYAN in 1976, this agronomist has been in charge of these trials. Up to 1981 the IBYAN was the main mechanism of distribution of new germplasm. With increasing decentralization and expansion into Africa and West Asia, the international trial scheme continues to diversify to meet specific needs of national programs. Nursery design, execution and analyses, and documentation of results as well as seed production and distribution for such trials, will continue to be the responsibilities of this scientist. The IBYAN will continue to be a mechanism to test elite germplasm worldwide. The bulk of germplasm, however, will be distributed through adaptation nurseries (VA), bean program nurseries (VEF), preliminary nurseries (EP) and segregating populations. The VEF-EP-IBYAN scheme will evaluate locally selected lines to integrate the decentralized breeding efforts.The management of this entire scheme is charged to this position.

Soil Microbiology

Past genetic improvement activities for increased nitrogen fixation have led to the development of excellent lines. The relative roles of soil-versus biologically fixed nitrogen are under study and will orient this breeding program. Research on the development of improved screening methodologies for nitrogen fixation, and the selection of efficient strain mixtures will be continued. With the expansion into Africa, the interaction of soil phosphorus and mycorrhiza with the Rhizobium symbiosis will require special attention in order to increase nitrogen fixation in traditional low-input production systems on infertile soils.

Program Leader

The size of the Bean Program and its administrative load requires a full-time leader, and this position became effective in 1985.

Regional Staffing Requirements

The composition of the program at headquarters is seen as the central research and training core to support and strengthen national programs worldwide that are involved in bean research. Through increased decentralization and networking, such a team can fully support a bean research network in which national programs will develop increasing self-sufficiency in research.

The Bean Program's policy of evaluating newly developed germplasm thoroughly, along with similarities in production conditions and constraints within the various bean-growing regions, has ensured that CIAT-derived materials are generally adapted to other production regions. For this reason, the deployment of current headquarters-based research staff to regional programs is not contemplated. Headquarters staff are considered necessary to develop solutions to difficult research problems through the strength of a multidisciplinary team.

Specific regional problems—such as BGMV in Central America and Brazil, the *Apion* pod weevil in Central America, and the bean fly, BCMV, bean scab and halo blight in Africa—will be studied in collaboration with national programs in the regions concerned. Decentralized regional projects are designed to unite and strengthen these national programs.The support of the Title XII Bean/Cowpea Collaborative Research Support Program within US universities and of other institutions in the developing and developed world will further strengthen the bean research network.

The Bean Program projects that four important bean production regions will justify decentralized regional projects in the eighties. The similarity of ecological conditions within each region (and therefore similar production constraints and varietal requirements) and the presence of many small national programs warrant such projects. Such projects seek to locate well-trained CIAT scientists within each of these regions to work within national programs. These scientists have a basic role as training officers who assist national programs to improve and focus their research programs; improve nursery management and the evaluation and use of new materials. They are not there to execute CIAT nurseries in the region per se. Through the division of research responsibilities among participating countries, each national program can concentrate on fewer areas of research, share results with and profit from other national programs participating in such networks. The Central American regional project has shown the viability of such a strategy in a region where national research needs to be strengthened and where regional-specific problems exist.

The four decentralized regional programs that have been identified are Central America and the Caribbean; Brazil and the Southern Cone; Eastern and Southern Africa, and West Asia-North Africa.

Central America and the Caribbean

This region, with numerous small national bean programs often serving similar ecological zones, in countries with high per capita bean consumption, will continue to rely on the CIAT program during this decade. Transfer of germplasm and technology from CIAT and among national programs is carried out by three scientists stationed in the region. The SDC-funded project is composed of a regional coordinator-pathologist, an agronomist and a breeder. In the coming years the project will concentrate on those countries where progress has been lacking because of staff instability and/or difficult varietal requirements. Special emphasis will be placed on the Caribbean. At the end of the current phase of restricted core funding (transferred special project) in 1986, the breeder position will be discontinued. This position is projected for placement in Brazil as the regional liaison scientist for Brazil and the Southern Cone.

Brazil and the Southern Cone

Brazil, with 55 percent of the Latin American bean production, has large national and state programs. Close collaboration between the research programs of Brazil and CIAT has been developed to ensure a two-way technology flow. Collaborative development of technology that will overcome soil aluminum toxicity and low phosphorus availability for 85 important bean production zones in Brazil will continue to be emphasized in this decade.

The one outposted research scientist in Brazil works with Brazilian scientists as part of a national bean research effort and also acts as a liaison scientist with CIAT. At present this position is provided on a temporary basis from headquarters staff. However, the importance of Brazilian bean production and the importance of tolerance to infertile soils warrant the stationing of a staff member in the country. The technology developed on these soils is expected to be relevant for many areas in Africa with similar soil conditions. Expansion of these liaison activities to other Southern Cone countries is projected during the decade with the establishment of a core-funded liaison position in 1987.

Eastern and Southern Africa

Africa, the second largest tropical bean production region, has a much higher per capita legume consumption (over 50 kg per year in some countries) than Latin America. CIAT materials in the IBYAN are frequently well adapted to African conditions, but have been shown to lack tolerance or resistance to specific African production problems. It is expected that major gains can be made with CIAT assistance in bean research despite the distance involved and quarantine restrictions.

CIAT's strategy for Africa has been the subject of three workshops involving representations of national research agencies from bean-growing countries. The first held in Malawi in 1980[40] provided the baseline data and recommendations of national representatives upon which CIAT began to build a regional effort in Sub-Saharan Africa. The second workshop[41], held at CIAT in 1983, was mainly concerned with the design of a regional project for Eastern Africa. The third meeting was a regional research conference of national representatives from the SADCC countries which met at Gaborone, Botswana, in early 1984.[42]

Based on the different ecological zones in which beans are produced in Africa, and the parallel nature of donor support to these zones, CIAT has developed an integrated Sub-Saharan regional strategy, based on three separately funded long-term corelike projects as follows:

Eastern Africa. This project will develop a collaborative research network with Kenya, Uganda, Ethiopia, Somalia and northern Tanzania. Much of the major bean-producing areas in this vast region is concentrated in a few similar ecological zones. This project will be composed of a regional coordinator/pathologist, breeder, cropping systems agronomist and an economist. The first funding commitment through the CDA mechanism is for five years, starting in 1985 and a second five-year funding period is expected.

Great Lakes Region. The regional coordinator/breeder, pathologist, cropping systems specialist, nutritionist (associated staff) and agrono-

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[40] **Potential for field beans in Eastern Africa: Proceedings of a Regional Workshop held in Lilongwe, Malawi, March 1980,** CIAT, Cali, Colombia, 1981.

[41] **Workshop on integration of research efforts of Bean/Cowpea CRSP, CIAT and national programs in Eastern and Southern Africa,** November 1983, CIAT, Cali, Colombia (mimeo).

[42] D. R. Laing, D. J. Allen, A. van Schoonhoven, and J. H. C. Davis, 1985. CIAT's strategy of improvement of bean production systems in Africa, in **Proceedings SADCC Regional Research Conference,** Botswana, 1984. SADCC, Botswana, 1985.

mist (associated staff) of this SDC-funded project serve the Francophone countries of the Great Lakes—Rwanda, Burundi, Zaire (mainly the Kivu region), and with a possible extension into western Tanzania. The initial funding is for three years starting in 1984, but long-term funding is expected.

Southern Africa. An Africa-wide coordinator, breeder, entomologist and a cropping system agronomist are projected to serve the SADCC countries; i.e., Malawi, Zimbabwe, Zambia, Swaziland, Lesotho, Botswana, Angola, Monzambique and Tanzania, with collaborative linkages to Mauritius and Madagascar. Bean flies, which do not occur in Latin America, and aphids are also more important in Africa; thus an entomologist is projected to serve all the three African subregional projects. Prospects for long- term funding for this project are good, and the base location will probably be in Malawi.

The three projects, expected to be largely operational by the end of 1985, will interact and complement each other to form an integrated African regional program. Intercountry cooperation in bean research is critical as a project strategy in each case. Self-sufficiency in research, regional cooperation and increased bean production are the primary aims of these projects.

West Asia and North Africa

In this bean-production area of North Africa and West Asia, beans are important as a warm season legume crop, often produced under irrigation. Turkey, Iran, the Yemen Arabic Republic and Pakistan are among the largest producers. Mediterranean bean-producing countries are expected to contribute new technology to this project, which was developed following the recommendations from a regional bean workshop, jointly organized by CIAT and ICARDA in 1983.[43] The one regional liaison scientist/breeder projected for this project would to be stationed within the legume program (FLIP) of ICARDA, but would be responsible to CIAT for technical matters. This project is projected to begin in the second half of this decade.

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[43] **Potential for Field Beans (*Phaseolus vulgaris* L.) in West Asia and North Africa: Proceedings of a Regional Workshop in Aleppo, Syria, May 1983.** CIAT, Cali, Colombia.

Bilateral Arrangements

The Bean Program will continue to use special bilateral funding to cooperate closely with individual national programs where these projects fit a set of defined criteria for CIAT involvement. At present one such scientist is working in Peru under World Bank funding to INIPA. Other similar projects may develop and are useful in those countries where accelerated progress is necessary to meet urgent national goals. However, the program plans to limit involvement in such activities so that ongoing core responsibilities are not affected.

Collaborative Research with Basic Research Institutions

The Bean Program will continue to seek collaborative basic research projects with research institutions in both the developed and developing world. Such research often involves expertise, equipment etc. that CIAT lacks; or it must be done elsewhere because of quarantine barriers for intercontinental germplasm movement. CIAT, as a more applied research institute, has less comparative advantage in basic research compared to the well-trained and equipped university research potential that exists in many countries. Active projects are under way with the Netherlands (on virus research), England (halo blight, N-fixation, storage insects and specific physiological traits), the USA (angular leaf spot), and Belgium (interspecific hybridization). Additional collaborative research is being sought on temperature adaptation, bean viruses, and bean tissue and anther culture. In the USA, such research is mostly concentrated in universities participating in the Bean Cowpea CRSP-Title XII project. In these collaborative projects, CIAT limits its role to applied issues, while the more basic research institutions carry out the more basic research on special project funds from interested donor agencies.

CASSAVA PROGRAM

Introduction

Cassava is grown throughout the tropical areas of the world. In terms of production measured in grain equivalents, it is one of the most important crops in South America, Asia and Africa. In tropical South America it is of almost equal importance to rice and maize. In Asia cassava is—after rice, which is the dominant crop—among the most important crops grown in the tropical areas. In tropical Africa, cassava is the dominant food crop (Fig. 8).

Despite its importance in the developing world, cassava has received scant attention from national research agencies. Within the CGIAR system, however, cassava receives funding at a level commensurate with its importance in the developing world. It should be noted, however, that while many other crops have considerable backup research carried out by research organizations in developed countries, this does not occur in the case of cassava.

Characteristics of the Crop

Cassava is grown in a wide range of tropical environments, ranging from savanna and rain forest ecosystems through the highland tropics up to altitudes of about 2000 meters above sea level, and in subtropical areas with cool winters.

The cassava plant has certain inherent characteristics that make it well adapted for low-input agricultural systems under the more marginal conditions of the tropics. Research at CIAT has shown that the plant's direct stomatal response to air humidity leads to very high efficiency in the use of water and also allows it to conserve water during the dry season. This mechanism also allows the plant to survive under conditions of uncertain rainfall. Furthermore, under stress conditions, top growth is greatly reduced while the harvest index is increased. This characteristic leads to efficient use of limited resources such as nutrients and water. Mycorrhizal associations, which occur naturally, greatly increase phosphorus absorption on soils extremely low in this essential

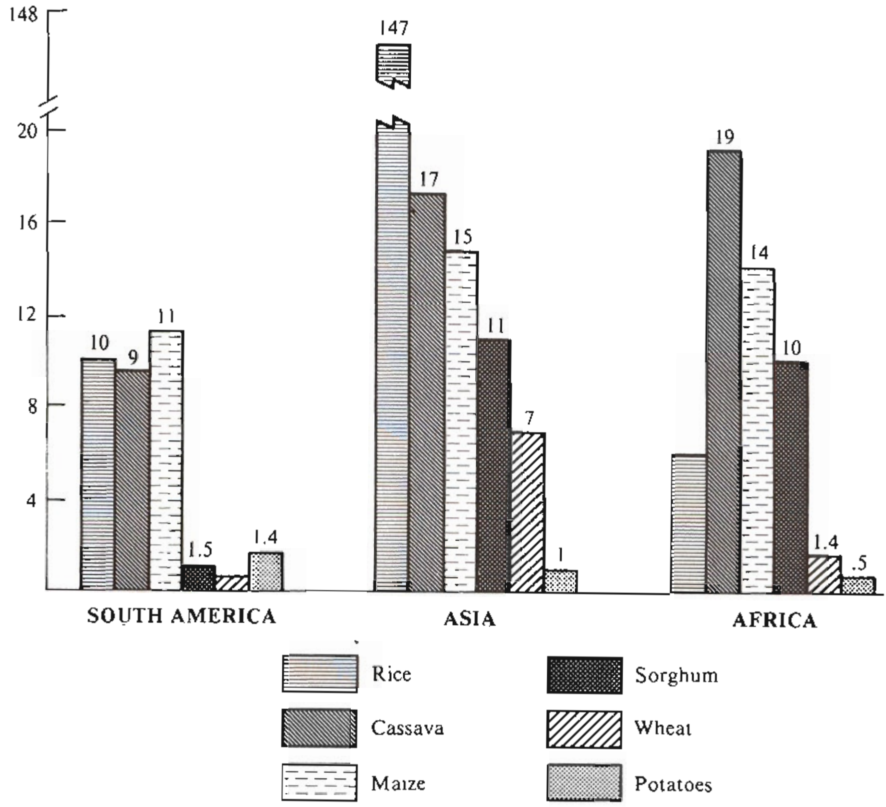

Figure 8. *Importance of various food crops in the tropics. (Data presented as millions of tons of grain equivalents).*

nutrient. In these soils, low pH and its associated high levels of aluminum are common. Cassava is naturally tolerant of such conditions. The continuous simultaneous growth of leaves and roots in the plant results in no critical periods, thereby giving the plant high levels of tolerance to sporadic pest attacks. This physiological tolerance to disease and pest attack is reinforced by high levels of stable resistance to diseases and pests in some clones. Where host plant resistance to pests has not been found, the long growth cycle of the crop has allowed effective use of biological control agents.

Another important characteristic of the plant is that the economically useful part—i.e., the roots—is not used as planting material for the subsequent crops. Thus when yields are low, farmers do not have to reduce their harvest further by keeping a large portion of the economic yield for planting material.

All these characteristics have made cassava an excellent crop for traditional agricultural systems where cassava is often associated with other crops, often under marginal agricultural conditions.The Brazilian situation is representative of most cassava-growing countries in terms of farm-size distribution.Data show that average farm size is highly skewed toward a small number of large farmers possessing most of the land. Rice and soybeans are produced mostly by the large-farm sector; whereas cassava is mostly produced by small farmers.

End Uses

In both Latin America and Asia, most cassava is used for human consumption, either as traditional dry cassava products or as fresh cassava. In Asia considerable amounts of cassava are processed for the production of starch; however, much of this starch is later used for making specialized foods. Of the cassava destined for human consumption, by far the greatest amount is for the lower income groups. Even in tropical Asia, where rice is the dominant crop, cassava makes a substantial contribution to the diets of the lowest income groups.

The final objective of any effort to increase crop production must be to ensure that this production is effectively utilized. In the case of a perishable root crop such as cassava, this factor is of paramount importance. In defining cassava research strategies, particular attention is given to a very important characteristic of the crop—its multiple end uses. The more important end uses are discussed briefly as each has implications for developing the overall research strategy.

Fresh Cassava for Foodstuffs

Fresh cassava is consumed throughout the lowland tropics. The basic premise of most commodity programs in the IARCs is that by improving yields, unit production costs can be decreased, not only allowing farmers to increase their income through the increase in total production but also giving consumers access to cheaper food supplies. In the case of dried cassava or cassava starch, this policy has a good chance of working because production costs are the major component of the total consumer price (Fig. 9). In the case of fresh cassava, however, production costs are only a small part of the total consumer price; hence the major constraint on achieving increased farmer incomes and lower consumer prices with fresh cassava is its high marketing margin. Nevertheless, a major question is whether consumers

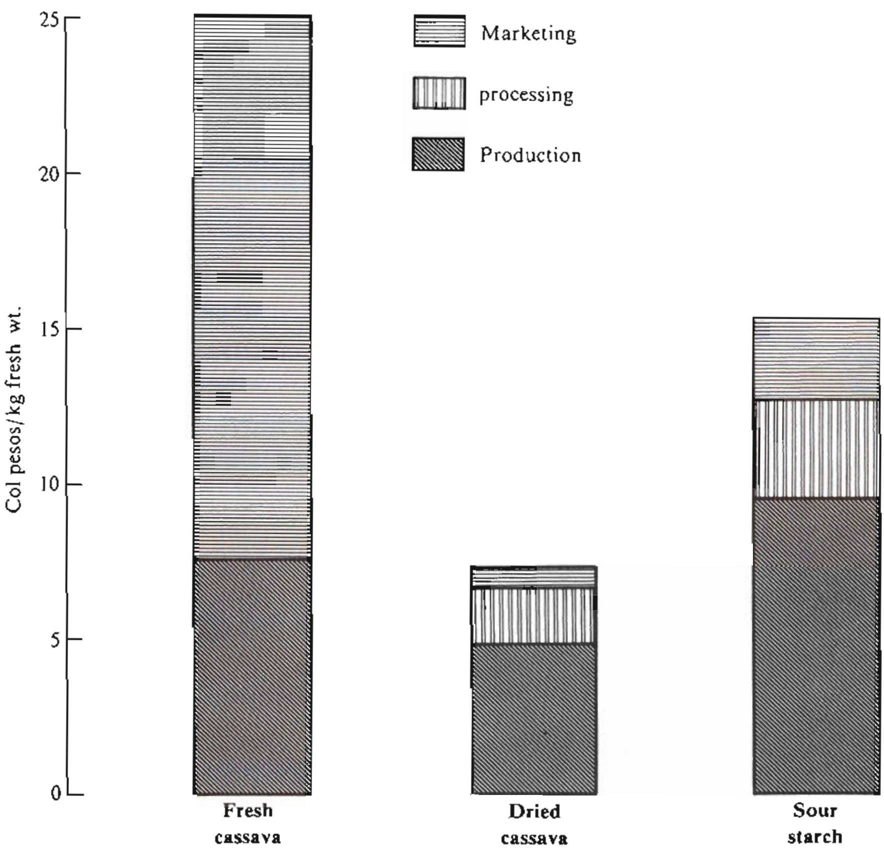

Figure 9. *Breakdown of consumer costs of cassava for different end markets.*

will purchase more cassava if marketing costs decrease and hence prices to the consumer decline. This question has been analyzed, and the data suggest that at least in urban areas, fresh cassava is reasonably elastic in its demand.

Cassava consumption tends to be lower in urban areas than in the rural areas. It could be hypothesized that as the developing countries urbanize, demand for fresh cassava might decrease. Consequently, aggregate demand might not be quite so elastic as it appears from consumer budget surveys. Why does consumption decrease in the cities? One reasonable hypothesis would be that as incomes increase, people prefer to purchase food other than fresh cassava. Nevertheless, recent data from Colombia indicate that this is not normally the case. A survey of consumer attitudes toward cassava and other crops on the North Coast of Colombia indicates that consumers find cassava equally as desirable or tasty as potatoes and rice (Table 8). In addition, the same proportion of consumers said they would buy more cassava if it were cheaper, as in the case of potatoes and rice. The large difference in preference is due to factors related to the convenience of cassava as a food. Cassava is highly perishable and therefore risky to buy.

Analysis of the data from the North Coast survey suggests that if the convenience factor score of cassava were increased to 50% of a crop such as yams, for example, then urban consumption would increase by 50%. Hence there is excellent potential for increased consumption if

Table 8. **Consumer attitudes to cassava and other starchy staples on the North Coast of Colombia (data presented as present positive responses).**

Question	Crop		
	Potato	Rice	Cassava
Is quality a risk?	13	3	76
Is it difficult to store?	17	1	95
Is product tasty?	66	55	67
If cheaper, would you buy more?	42	31	38

cassava were to become a more convenient food. CIAT has developed a simple technique that involves dipping cassava into a fungicide (Mertect) solution, followed by packing it in polyethylene bags. With this technique, the roots can be stored for periods of up to two weeks; and the quality of the stored cassava is virtually identical to that of the fresh roots directly after harvest. Moreover, fungicide residues are well below the accepted limits of the US Food and Drug Administration (FDA); and thiabendazole, the active ingredient of Mertect, is approved as a medicine. Thus a technology now exists which can easily change the convenience of cassava as a food.

Not only will this storage technology make it possible to increase the convenience of cassava as a food, thereby shifting the demand curve to the right, but it also has the potential to decrease marketing margins significantly. Marketing margins in cassava are high, partly because of the extreme risk involved in handling such a perishable crop and partly because of oligopolistic market structures for such a high-risk, low-volume commodity. If perishability is reduced and a storage element introduced, then the marketing margin can be decreased, which can be represented as a shift to the right of the supply curve. As a result, savings to the consumer and an increase in the farmers' gross income as a result of a more competitive market structure can be expected.[44] If this technology were adopted in Latin America, there could be very significant savings for consumers on the one hand and increased income to farmers on the other (Table 9). Similar benefits could be expected if this technology were adopted in Asia and Africa.

Table 9. **Expected benefits of adopting new cassava storage technology for consumers, producers and marketing intermediaries in Latin America and the Caribbean.**

	Million US$/year
Consumer savings	120
Farmers and intermediaries' income	80

[44] W. Janssen and C. Wheatly, 1985, Urban cassava markets:The impact of fresh root storage, Food Policy, August 1985.

Traditional Dry Cassava Products

The processing technology for these traditional products is generally rather effective. Demand is, however, inelastic and is expected to increase at about the same rate as population increases. As these are the products that are consumed mostly by the abjectly poor in the tropics, any decrease in price of fresh roots leading to a decrease in the price of the final product could have significant social benefits for the lowest income strata of the population.In this case, therefore, the research strategy is to concentrate on reducing the costs of the raw material—the fresh roots.

Innovative Dry Cassava Products

Dry cassava products can partially replace cereal flours (especially wheat) for human consumption. The demand for wheat products is highly elastic in most tropical areas. The major constraints on meeting this demand are the cost of the fresh roots, the cost of the drying systems, and the development of effective linkages between production and processing. The drying process is expensive because most of the systems that were developed for producing high-quality cassava flour for foodstuffs were developed at a time when fuel costs were relatively low. Increased fuel costs has meant that these systems are no longer economical. Even if new, more efficient drying systems were developed, it is still essential to have a cheap source of the raw material; i.e., the fresh roots.

The primary strategy for removing these constraints is once again to develop low-cost production technology systems and more cost-effective drying systems. Another major constraint to increased cassava use as a substitute for cereal flours is that many of the competing products are heavily subsidized. Research is required to give government policy makers the basis from which they can make decisions on subsidies and to inform them of the advantages, in terms of foreign exchange, that would result from the increased use of cassava as a cereal substitute.

The potential for cassava to enter these new markets is much greater now than a few years ago. This is due to the foreign exchange problems most of the countries of the developing world are encountering. The foreign exchange problem has, in fact, already had a major impact on certain government policies. For example, cassava production in Brazil increased rapidly during the sixties, during which time the relative price of cassava flour was about 60 percent of that for wheat flour. With plentiful foreign exchange because of easy international credit, the government of Brazil heavily subsidized wheat; subsidies are estimated to have reached levels of about 1 billion dollars in 1979.[45] As a result, wheat became only half as expensive to the consumer as cassava flour, which led to a dramatic decline in cassava production. More than 200 cassava flour plants in the state of Sao Paulo alone were closed because they could no longer compete. Brazil has now started to remove the subsidies on imported and locally produced wheats; similar situations are occurring in countries such as Ecuador and Peru. Thus the time has never been better to implement a program to produce cassava flour that partially substitutes for imported cereal flour.

Animal Feed. The demand for animal feed is highly elastic. The major constraints to cassava's playing a significant role in this market are the availability of roots at a competitive price and the integration of production, processing and marketing technology by small farmers so that they can enter into this growing market.

In the past much has been said about the potential for cassava to enter the animal feed market in the form of dried chips or pellets. The Thai cassava industry, for example, has grown on the basis of exports of pellets to the protected European Common Market; however, doubts have been expressed about cassava's ability to compete with grain crops on an equal basis in the tropics. The recent development of a viable commercial cassava drying industry that produces animal feed from cassava produced by small farmers in Colombia at highly competitive prices indicates that the potential to enter this market is a reality.

Program History and Accomplishments

Over the years the Cassava Program has contributed to the organized body of knowledge on cassava—its biology and behavior under different conditions, its role in production systems, and its different end uses. A summary of the major achievements follows:

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[45] **A Review of Agricultural Policies in Brazil.** Report No. 3305, World Bank, 1981.

1. A file on production and consumption has been assembled from disparate sources; and after consistency checks, a systematic set of estimates of cassava production and utilization in Latin America and Asia was developed.

2. The principal characteristics of Latin American cassava production systems have been defined. Cassava is generally grown on small farms (10 ha or less) under some type of soil/climatic stress. Almost half the area planted to cassava is intercropped, primarily with maize. Few purchased inputs are used. Although much of rural consumption is based on subsistence production, about 70 percent of the production is marketed.

3. Identification of economic, biotic, soil, physiological and agronomic constraints to production and utilization have been identified.

4. The germplasm collection, which is the world's most extensive, has increased from 2500 to 3400 accessions. In vitro techniques have made it possible to incorporate Brazilian germplasm, previously prohibited from entry into Colombia by quarantine regulations. CIAT collaborates with the IBPGR and national programs to continue collections of both wild and cultivated species. The collection, traditionally maintained as a field collection that had to be continually regenerated, is now being transferred to in vitro culture for medium-term storage in the Genetic Resources Unit. In vitro techniques have also been developed to clean clonal material of pathogens such as frogskin disease.

5. More than 2500 clones from the germplasm bank have been evaluated for quality, agronomic characteristics, and disease and pest resistance in edapho-climatic zones (ECZ) 1, 2 and 4; as well as some 700 accessions for highland sites (ECZ 5) and germplasm for rain forest areas (ECZ 3). Arrangements have been made for Cuba to evaluate the entire collection in ECZ 6 over the rest of the decade. More than 40 hybrids and germplasm accessions, considered as elite materials adapted to the different ECZs are maintained in vitro for shipment to cooperating countries.

   These evaluations have shown that (a) there is extensive variability for all important agronomic traits; (b) yield potential of most accessions is low, manifested principally in the form of a low harvest index; (c) most individual clones are narrowly adapted to the conditions of the region where they evolved, although as a species cassava is adapted to a wide range of environmental conditions; and (d) levels of resistance to diseases and pests are generally inadequate for the intensive production systems envisioned for cassava in the future.

6. Prior to 1978 resistance to all major diseases was identified, and controlled screening methods were developed for several of them (cassava bacterial blight, superelongation disease, phoma leaf spot and anthracnosis). Since then the program has focused on the development of systems for screening for multiple-type resistance in the different ECZs where the program is working. Clones with this type of resistance have proven very stable (both in yield and resistance) during more than seven years of continuous field evaluations.

   Resistance to major pests such as mites (3 species), thrips, whiteflies, mealybugs and lacebugs is being sought. A pool of about 70 varieties with resistance to one or more pests has been formed.

7. Cassava is normally propagated through stem cuttings, limiting the rate of plants that can be multiplied yearly. Early in the history of the Program, a rapid propagation technique based on short top rooting in water was developed and has been used in Brazil, Cuba, Colombia, Mexico and the Philippines. Later the use of micropropagation techniques based on meristem culture have made it possible to increase the multiplication rate 40- to 80-fold per month. Another technique requiring less-sophisticated equipment is leafbud propagation.

8. A great deal of work has been done on cultural practices as well. The use of improved, low-input technology increased yields of local clones in Colombia to 20 t/ha (national average, 8.0 t/ha), illustrating the potential for CIAT technology to double yields at selected locations. On-farm validation trials have shown that small farmers can readily increase yields by 70 percent. The use of selected clones and hybrids in regional trials boosted yields as high as 30 t/ha.

Analysis of Production and Potential Demand

As a result of the ERP recommendations, CIAT has recently accelerated its studies of the potential demand for cassava in Latin America and the Caribbean in order to determine the future role of cassava in the agricultural economies of selected countries in Meso-America, the Andean countries, Brazil, Paraguay and the Caribbean. In addition to the direct economic factors, particular attention is being paid to social aspects including equity and creation of employment opportunities. These studies are based on the considerable body of information that has already been obtained. The Asian cassava situation has already been reviewed by CIAT, and the production and demand situation, analyzed.

Latin America

Cassava has always been a traditional caloric source in tropical Latin America. As the region urbanizes, the importance of cassava for direct human consumption depends on its market-ability and competitiveness with other caloric staples.

In contrast to the rural areas, fresh cassava is more expensive in most urban areas than the principal grain staples, primarily because marketing margins are as much as 300 percent 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 cassava is a major caloric source in national diets in Brazil, where most of the cassava is eaten in processed form; and in Paraguay, where most of the population is still rural. At the subnational level, cassava is important in regions such as the North Coast and Santander in Colombia, the jungle region of Peru, and many regions of the Caribbean. Contrary to the commonly held view in developed countries, cassava is not viewed by Latin American consumers as a nonpreferred food, only to be eaten in the absence of other alternatives.

A strategy to increase the incomes of small-scale farmers through the development of new cassava technology has been constrained by the limited demand for cassava as an urban food, except in Brazil, where other constraints have existed. As previously indicated, cassava, as a carbohydrate source with a low unit production cost, has the potential to enter alternative markets, as a wheat 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. Government policies aimed at cheap cereals for the urban population through subsidies on grain crops have had an adverse effect on cassava expansion. Because of the prevailing financial crisis throughout Latin America, these subsidies are being reduced; and this should have a significant positive effect on the future demand for cassava. Although there are a number of complex factors affecting cassava's ability to compete in industrial markets, the price of cassava must be reduced if it is to be competitive in industrial markets in most Latin American countries.

Lower unit production costs and thus cheaper prices for cassava can best be achieved by applying new technology. In Latin America and the Caribbean, cassava is mainly grown as a small farm crop. Major production zones include the poorer more acid soil areas, and irrigation is not normally available. About 40 percent of total production occurs in mixed cropping systems with maize, beans, cowpeas and a multitude of other crops. The technology used is generally labor intensive with very little use of inputs such as fertilizers, herbicides and pesticides. Yields average 12 t/ha (equivalent to approximately 3.5 t/ha of cereals in energy terms). Historically, there has been little research on the crop; thus there is great potential for increasing yields from their present low levels. On the other hand, introducing improved cassava production technology without complementary pro-cessing technology could saturate traditional markets, resulting in decreased farmer incomes. Introduction of cassava production technology in Latin America must definitely be linked to improved processing technology.

Southern and Eastern Asia

In 1984 CIAT and the United Nations ESCAP Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in Humid Tropics of Asia and the Pacific (ESCAP-CGPRT) organized a regional workshop to review the status of cassava in Asia and requirements for future development. The following discussion is based on that workshop.

Beyond the central role that rice plays in the food economies of tropical Asian countries, the agricultural sectors of these countries are very diverse. Cassava production and utilization systems have been adapted to this diversity. It is the differences rather than the similarities that are most striking when comparing utilization across countries. Cassava has developed within different types of land constraints, and multiple markets have evolved around the crop, with the particular market structure reflecting the overall development of the economy. The rate of development of most of these economies has accelerated over the past two decades, creating a potential demand for broadening both cassava production and utilization. The demand for cassava-based products in Asia is quite different from that in Latin America, being more buoyant. The crop has moved from being a basic traditional staple to fulfilling its role as an important basic source of energy in the form of carbohydrates.

Rapid development of the crop will depend, in most cases, on increases in yields, either to relieve land constraints or to be competitive in the emerging markets. Within the Asian context, where expansion of crop area is frequently constrained, it is natural that there should be a bias toward crops with high yield potential. Very high cassava productivity is already being achieved in certain areas; but average yields remain well below the known potential of the crop. What still remains to be determined is the means of achieving high yields across tropical Asia. Obviously, the type of technology will vary from country to country. This requires an increased commitment of national resources to develop the level of cassava research that is required in the region if these objectives are to be realized.

Given its adaptation to a wide range of upland conditions and its multiple use characteristics, cassava can provide substantial flexibility in developing appropriate agricultural policies. As has been stressed, the role of cassava in each country's economy will differ; but in each case, cassava can be the basis for meeting multiple-policy objectives. Increased cassava production with lowered costs will first be used for human consumption in fresh or dried form. In India and Indonesia, for example, cassava can play a clear role in nutrition policy. As this demand is satisfied, dried cassava may readily move into both local and international animal feed markets; the former are increasing so rapidly at present that they can only be satisfied by increased imports of cereal grains.

Because of its multiple-market potential, cassava can play a major role as a source of income generation for small-scale farmers in upland areas in all countries in the region, including India and Indonesia. Increased production will also bring socioeconomic benefits to rural areas. The level of labor used in cassava cultivation varies widely, with very intensive labor use in southern India and Indonesia. For every two hectares of cassava planted, one more person gains the equivalent of full employment for one year. Moreover, cassava processing is highly labor intensive and uses equipment that can readily be manufactured by local craftsmen; thus processing will create employment and stimulate local industry. In Thailand, for example, it has been estimated that 8 to 10 million people are receiving direct or indirect benefits from the rapid expansion of the Thai cassava industry. A further advantage in satisfying growing domestic markets by increased domestic production is the positive impact on a country's balance of payments. Further market diversification of cassava will, however, require both improved production and appropriate processing technologies, together with better integrated markets.

The Green Revolution that swept Asia in the late sixties and seventies was limited to irrigated areas. Expansion of irrigated areas is costly and, in many cases, difficult to accomplish in the near future. The next major challenge is to raise crop productivity and farmer incomes in the upland areas. With probably limited prospects for further major growth in the world demand for rubber, palm oil and coconut oil; with growing domestic markets that could absorb cassava products; and with a growing regional market for carbohydrate sources for livestock, cassava is a major, if not **the** major crop in a position to foster income growth in the upland areas of tropical Asia.

Sub-Saharan Africa

Although Africa has slightly more than half the world's area planted to cassava, it produces only 37 percent of the world crop. Yields tend to be low, ranging from 5 to 9 t/ha in the four major producing countries—Zaire, Nigeria, Tanzania and Mozambique. However, as there are more than 7 million hectares planted to cassava, total production is close to 50 million tons.

In Africa the only important end use of cassava is for human consumption. Cassava provides an average of 230 calories per person per day. Levels of consumption in Zaire and the Congo are much higher—more than 1000 calories per day; i.e., about 55 percent of total caloric intake. In areas where rainfall is uncertain and/or locust attacks are common, cassava is extremely important as a famine relief crop. Of the cassava destined for human consumption, a little more than half is consumed after processing into such products as gari and fufu; the rest is consumed in fresh form.

The importance of cassava in Africa as a basic food staple is unquestionable, but the future demand situation as the continent develops has yet to be studied carefully. Although normally considered a subsistence crop, cassava can be found in both rural and urban markets throughout tropical Africa. Although it is impossible to make an accurate estimate of how much cassava is traded and how much is consumed by the growers themselves, it is certain that a significant proportion of African production enters the market economy; and this amount will likely increase as Africa urbanizes. Because of the very high rates of population increase, demand will surely increase over the coming years.

At present, production technology is largely based on traditional low-input agricultural systems. As bush fallow periods are shortened, cassava has become more popular because of its ability to fit into these systems. However, recent problems with cassava bacterial blight, mealybugs and green spidermites in Africa suggest that a substantial research effort is required just to maintain present low levels of production, let alone increase them.

Program Objectives and Strategies in the Eighties

At the beginning of the sixties, the role of the IARCs was considered to be that of providing technology based on improved varieties for almost direct application to farmers' fields. This strategy was highly successful in the case of irrigated wheat (CIMMYT) and rice (IRRI), grown under relatively homogeneous conditions with heavy use of inputs to overcome specific local constraints. In the case of small farmer crops grown under marginal conditions with a wide range of different ecologies, this strategy is unlikely to succeed because much of the technology requires adaptation for location-specific conditions, and varieties must be selected with tolerance to these constraints. As a result, the IARCs involved with small farm crops grown under difficult conditions have evolved a strategy in which they form an essential integral part of a global network dedicated to crop improvement.

Program Objectives

> The overall goal of the cassava network is to increase small farmers' food supplies and income, as well as to improve food availability for the overall population. This can be achieved by converting cassava from being mainly a traditional rural staple to a major multiuse carbohydrate source.

In order to accomplish these goals, it is necessary to look at the overall research and development network and the roles of its various components based on the comparative advantages of the centers forming the network vis-a-vis the different fields of research. CIAT is the international center with global responsibility for cassava and has comparative advantages in the following areas: (a) documentation and information, (b) germplasm, (c) establishment of basic principles of improved production/ utilization systems, (d) research directed toward a better understanding of the crop, (e) analyses of the future role of cassava, and (f) training and conferences. CIAT as the regional center for cassava in Latin America and Asia has a comparative advantage in (a) coordination of the regional network, (b) training on a regional basis, (c) resolution of problems related to the peculiar socioeconomic context of the regions, and (d) development and distribution of germplasm with the characteristics appropriate to the region. The national centers in turn have comparative advantages in the following areas: (a) identification of location-specific problems; (b) establishing and recommending production practices and utilization technology; (c) testing, selection, multiplication and release of varieties suitable for local conditions; (d) implementation of development projects; and (e) transfer of technology to users.

It should be noted that new approaches to development, new scientific discoveries, and other innovations of potential importance on a global scale may be developed by national, regional or international centers. The national centers will oftentimes be the most important sources of such information; thus the comparative advantage of disseminating it on a national scale will lie within the national programs. On a global scale, however, dissemination can be more effectively carried out by international centers.

The CIAT cassava program has two main components or functions: firstly that of an international center with global responsibilities and secondly that of a center with regional responsibilities in Asia and Latin America and the Caribbean. In Asia the regional activities are closely interwoven with the CGPRT Centre, which has a comparative advantage in the socioeconomic aspects specific to Asian agriculture. IITA is also an international center, but its function in the case of cassava is that of a regional center, serving the vastly important needs of Africa. CIAT's objectives and strategies, first as a global center and secondly as a regional center, are outlined below.

Global Strategies

In its global capacity, the Cassava Program will provide the following major inputs into the overall research and development efforts of the network:

1. Maintenance of the world cassava germplasm collection, and from this base, the provision of elite gene pools with known characteristics to regional and national programs; coupled with this effort will be the development of improved breeding methodology.

2. Development of the basic principles for establishing improved production and utilization systems, together with the research methodology required to adapt such systems to local conditions.

3. Carrying out of basic research directed to understanding the crop and its interaction with environmental stresses better.

4. Analysis of the future potential role of cassava in the economy of the developing world.

5. Provision of services based on the world's cassava documentation and information center.

6. Organization of training opportunities and meetings for cassava workers from national and regional programs.

The following basic activities outline the program's projected plans to fulfill its global mandate.

The Role of Cassava in the Economies of the Developing World

The economics section has carefully analyzed the status quo of cassava production and utilization in the Americas and Asia. From this base the future role of cassava is and will continue to be analyzed in the light of new production and utilization technology. Careful attention will be paid to how cassava can contribute to countries' meeting social goals such as increased employment and equity, as well as economic goals such as foreign exchange savings.

In order to achieve these goals, the economics section will collect, collate and analyze secondary data on cassava production and utilization at a global level. Where data are lacking or totally deficient, primary data will be collected on a limited scale. The main constraints to cassava productivity will also be studied in order to understand the economic factors affecting the viability of integrated production, processing and marketing programs utilizing dried cassava for the feed industry and composite flours and fresh root storage systems.

In addition the economics section will make both an **ex ante** and **ex post** analysis of the socioeconomic benefits of investment in cassava research. The former will include the development and use of simulation models, and the latter will be based on monitoring the diffusion of cassava production and utilization technologies.

Basic Understanding of the Crop

In order to improve production, a basic understanding of the plant and its reaction to various stress factors is required. Because of budgetary restrictions, however, the plant physiology section was suspended for two reasons: (a) Great advances have already been made in the field of cassava physiology, and (b) it is an activity in which continuity of effort is not essential. It is proposed that this section be reinstated in 1988 in order to continue research to define the optimal varietal characteristics for different water regimes, screen for tolerance to long days (photoperiod response), define plant types for differing soil fertility levels, and develop techniques for synchronous flowering in crossing blocks. It should be noted that although this type of research will not give immediate payoff, over the long term it is essential for the program.

Germplasm Development

The ultimate objective of germplasm efforts is the adoption of new varieties by farmers as part of the technology package to increase productivity and improve the quality of cassava. The fundamental base for germplasm improvement is the world cassava germplasm bank, which now contains 3,700 accessions and should reach a level of approximately 5,000 by 1990. The germplasm bank is evaluated, catalogued and maintained by CIAT. The information on the bank is available to national programs, which can request and receive clones directly from the bank or sexual seed from specified crosses (national quarantine regulations permitting and when it is considered safe to transfer material).

The new production technology for cassava exploits the crop's productivity under marginal conditions with low inputs. This precludes using high levels of expensive, energy-consuming inputs such as pesticides, soil amendments and irrigation. Rather, new technology is based on improved germplasm, which by itself overcomes many of the production constraints. Germplasm improvement is directed toward obtaining elite gene pools for each of the major ecosystems in which cassava is grown (Table 10). These gene pools form the basic materials the national programs can use for direct selection of new varieties or for their own crossing programs.

At present major emphasis is placed on ECZs 1 and 2; in coming years, however, more effort will be devoted to ECZs 3, 5 and 6, and to providing elite germplasm to African programs through IITA. The breeding scheme involves observation of genetic material in each of the ecosystems, selection of parental materials with desirable characteristics, hybridization at headquarters, and evaluation of the progeny in the particular ecosystems to which the crosses are directed. As national programs have developed, emphasis has moved away from providing them with a small number of superior clones toward sending large numbers of sexual seeds from crosses directed toward combining the characteristics desired by the individual programs.

The germplasm development section will continue cooperating with the IBPGR in the selective collection and introduction of new germplasm.

Table 10. **Ecosystems for cassava production and their main characteristics.**

General description	Mean temperature (°C)	Dry season duration (months)	Annual rainfall (mm)
Lowland tropics with long dry season; low to moderate rainfall; high year-round temperature	above 22	3-6	700-2000 (unimodal distribution[a])
Lowland tropics with moderate to high rainfall; savanna vegetation on infertile, acid soils; moderate to long dry season; low relative humidity during dry season	above 22	3-6	2000 (unimodal distribution)
Lowland tropics with no pronounced dry seasons; high rainfall; constant high relative humidity.	above 22	absent or very short	2500 (unimodal distribution)
Medium altitude tropics; moderate dry season and temperature	20-24	3-4	1000-2000 (bimodal distribution[b])
Cool highland areas; moderate to high rainfall	17-20	variable	2000
Subtropical areas; cool winters; fluctuating day lengths	min. 0	variable	variable (unimodal distribution)

a Unimodal distribution: one wet season and one dry season each year.

b Bimodal: two wet and two dry seasons.

Special emphasis will be placed on collection in ecosystems poorly represented in the germplasm bank. Evaluation of the germplasm will be expanded to the hot humid lowland tropics and the subtropical regions. Clones with desirable characteristics for each ecosystem will be crossed, the progeny tested in each of the major ecosystems, and elite germplasm pools developed. Selection of clones for ECZs 1 through 5 will continue in Colombia, and these clones will be distributed as advanced lines to the national programs. In the case of ECZ 6, crosses will be made at CIAT; however, the breeder in charge of this ecosystem will be specifically responsible for ensuring adequate testing of progeny and feedback on performance in testing sites such as southern Brazil. Local junior support staff will be hired to maintain the trials. The results of this work will be used to improve the germplasm sent to similar regions in other countries.

In Asia the breeder in the regional program will continue to assist national programs in selection and ensure that they receive appropriate materials from the germplasm development section at CIAT.

The introduction of AMD-resistant materials from IITA will make it possible for CIAT to provide elite germplasm for Africa. Particular attention will be paid to combining AMD resistance with mite and mealybug resistance.

Germplasm development at headquarters will comprise one senior staff position, pending the results of the demand studies. During this period breeding efforts will be largely limited to ECZs 1 and 2, with reduced efforts in ECZs 3 and 5. If the results of the demand studies are positive, the section will be increased to two senior staff positions in order to cover the full range of conditions under which cassava is grown. One scientist will be responsible for germplasm collection, maintenance and materials for ECZs 4, 5 and 6, as well as materials suitable for AMD areas (Africa and India); the other for ECZs 1, 2 and 3 and provision of crosses for the Southern and Eastern Asian region.

Major problems in a vegetatively propagated crop such as cassava are associated with germplasm storage and production of disease-free stock. The tissue culture section of the Germplasm Resources Unit has developed methods for cheap storage of germplasm as plantlets in test tubes and for producing planting stocks from meristems. These procedures will be used on a routine basis. Attention will be given to using tissue culture techniques for haploid production, protoplast fusion and, eventually, genetic engineering in support of varietal improvement, with special emphasis on production of HCN-free clones.

Production Systems

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. Moreover, some 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 also be developed.

Past emphasis on development of management practices has concentrated on a single crop of cassava. In the future, emphasis will be placed on how cassava fits into longer term agricultural production systems. Special attention will be paid to the long-term effects of cropping patterns and fertilizer use on productivity and on methods of erosion control and soil conservation.

Research on soil/plant nutrition in cassava will emphasize areas such as the screening of clones for adaptation to low soil fertility, elucidation of mechanisms for this adaptation, and the maintenance of soil fertility including the problem of erosion and its control. Particular attention will be paid to developing an overall understanding of how fertility can be maintained by modifying cropping systems. Mycorrhizal research will continue to be integrated into all these activities with support from extracore sources when appropriate. The overall objective of the section is to develop principles that can be extrapolated to other ecosystems, rather than to concentrate on more site-specific research.

Entomological research on pest control in the crop has concentrated on mechanisms of host plant resistance and biological control. The serious pest problem in cassava worldwide, the difficulties related to chemical control in a long-season crop, and the fact that Latin America is the center of origin of many of the pests are all factors that determine that CIAT must continue to show leadership in this area. Work of the section will concentrate on developing integrated control of major pest complexes (particularly mites and mealybugs, which are very serious pests in Africa); assessment of new pest problems that could be faced in new areas where cassava production may expand; collection and evaluation of natural enemies, and development of rearing techniques; and the evaluation of host-plant resistance. A collaborative project with IITA is under way to advance aspects of identifying and collecting natural enemies in the Latin American region.

Plant pathology research has concentrated on fungal and bacterial diseases. More recently, work on virus diseases is being emphasized. Pathological research will concentrate on the development of new cultivars (in collaboration with the breeders) and cultural practices that prevent the commonly observed degeneration of cassava varieties under high disease pressure when grown over a series of years at the same location. Specifically, activities in the pathology section will continue to describe the diseases of cassava, the pathogens and their vectors; to study climatic and edaphic factors influencing disease development; to identify genetic sources of stable resistance; to develop techniques for the production and testing of pathogen-free planting materials; and to develop methods for providing high-quality vegetative and seed material for international germplasm exchange.

Recent CIAT studies indicate that yield losses from viruses are significant in some production zones. One of the new diseases, tentatively identified as being of viral origin, is capable of causing complete crop failure. In addition, Latin American material is generally not resistant to AMD, which has not yet appeared in the Americas. Thus additional support for virology within the Biotechnology Research Unit has been projected for 1986 in order to deal with viral problems, which are relatively unresearched in cassava. It is likely that viral pathogens are transmitted continuously through cassava planting material. Research on viruses at CIAT is necessary to detect, identify and isolate 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. Resistance to viral diseases through breeding will also be emphasized if other control methods prove unsatisfactory.

Utilization Technologies

A large market exists for low-cost carbohydrate sources.CIAT will concentrate on utilization research contributing to expanded demand for cassava products destined for human consumption, either directly or indirectly. Several other institutes or private agencies are involved in processing research for starch or ethanol production and the use of cassava as a substrate for single-cell protein production; thus CIAT will not duplicate their efforts. CIAT will, however, produce state-of-the-art bulletins on a wide range of utilization technologies through its utilization and documentation sections even though it is not engaged in active research in these areas.

Cassava's high perishability and lack of alternative outlets unless it is processed can 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. Consequently, farmers are often unwilling to increase productivity or area planted. Improved technology that permits arbitrage or the entry of cassava into more stable markets will produce a more stable floor price, thereby breaking the vicious circle. The objective of the utilization section is to develop such technology for the following products:

1. **Fresh cassava.** Initial work has shown that simple techniques for fresh storage can be developed. Efforts will concentrate on developing this technology for commercial use, which will allow expansion of the urban market through reduced prices and improved quality and convenience of the fresh roots at the consumer level. Studies on factors affecting root quality parameters will be initiated.

2. **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,

there is a great demand for cassava flour as a partial substitute for wheat flour in bakery products across all income groups. High-quality flours can be produced at present; however, the drying processes are capital intensive and tend to consume large amounts of energy. The program will develop solar-assisted and other drying systems that will ensure a high-quality product at a lower cost more suitable to the supply and socioeconomic conditions prevailing in the cassava-producing regions. The program will also collaborate with other agencies on the development of new products based upon high-quality cassava flour.

3. **Animal feed.** Potential demand for cassava in animal feed concentrates is great; however, there are several important limitations that make it difficult to enter this market: (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. The program's production research continues to concentrate on reducing unit production cost, and the utilization section will emphasize research to remove the remaining constraints through collaborative projects with national or other agencies.

Documentation and Information

The successful establishment of a complex network involving a large number of different entities requires an effective means of information exchange among the diverse agencies comprising the network. This allows effective transfer of new technology and methodologies and greatly reduces duplication of effort. The fundamental keystone of the network is the documentation center, which is the information bank. Its role can perhaps be compared to that of the germplasm bank in varietal improvement.

The Cassava Documentation Center at present has more than 7,000 documents related to cassava. Abstracts of this material are distributed to cassava workers, either free or at cost, depending upon the users' ability to pay for the service. In addition literature searches are provided upon request to users of the service. The center is also involved in the packaging of information. Recently a comprehensive practical book on the use of cassava in animal feed was commissioned; in those cases where the expertise exists within the Cassava Program, the staff produces monographs and bulletins that synthesize the knowledge available on themes such as intercropping or field problems of cassava. Not all the information produced by the program or other agencies is published by CIAT; for example, CIAT staff contributes articles to scientific journals, books and magazines.

For effective dissemination of information, it is not only necessary to package the information but also to ensure that it reaches those who can use it effectively. The recently established computerized profile of individual cassava workers makes it possible to distribute the information on an individualized basis, so that they receive information tailored to their own specific interests and requirements.

It is crucial to maintain cassava workers informed of the latest advances and concepts if a research and development network is to be effective. Although the aforementioned publications and services can partially achieve this objective, there is always considerable delay in information exchange. Through the cassava newsletter, which describes ongoing research and development projects as well as providing a forum for new ideas, delays are kept to a minimum.

The Cassava Program, through the Communication and Information Support Unit, will continue to provide the services outlined above.

CIAT's Regional Responsibilities

Latin America and the Caribbean

When the CIAT Cassava Program initiated activities, national cassava programs in the region were essentially nonexistent; at the most they were comprised of one or two professionals within the root and tuber program. In subsequent years several strong national programs have been established, and close links with CIAT have been formed. Most of these programs have a strong bias towards agronomy and varietal improvement and are weak in the areas of marketing and utilization. Nevertheless, as has clearly been pointed out, cassava production technology must be linked to improved processing and marketing.

CIAT will continue to assist national programs in the development of production technology through provision of appropriate germplasm, training, dissemination of research findings and advisory visits. Particular attention will be paid to assisting national programs in the selection of improved varieties by accompanying national program scientists in the selection process. This will not only facilitate the breeding process but will also provide valuable feedback for the CIAT breeding program.

The proposal to define a research group that would work within the Cassava Program on the integration of research in production, utilization, and marketing in cassava is based on the recognition that any approach without all three elements will not be functional, at least in the Latin American context. The group would work with national programs in the development of pilot projects, which requires a close linkage between research and development activities if such projects are to be viable. Failures in the past in several cassava projects have been associated with lack of attention to one or more of the above facets.

In collaboration with the national programs, this group would concentrate on the following overall activities: (a) macroeconomic analysis of cassava's potential in the particular country/project; (b) planning and organization of project structure; (c) establishment of projects and development of local adaptative research; (d) economic analysis of the pilot projects, and (e) policy recommendations on commercialization when requested by governments. The activities of each specialist in the proposed group can be summarized as follows:

The economics section will continue to evaluate potential demand for cassava products and the price at which they could enter the market, and estimate the costs of production and processing in each project. From the results of the pilot project, the economist will estimate the feasibility of moving to a commercial phase and in developing generalized methodologies for the implementation of integrated production-processing-marketing projects in cassava. The economist will also be responsible for coordinating the demand studies in Latin America, which will be carried out by postdoctoral fellows over a two-year period (1985-1986).

The agronomy section will evaluate the production potential of different regions, recommend and evaluate (with the national program scientists) cultural practices and cultivars, and integrate new production technology for cassava into local cropping systems. The agronomist will be heavily involved in training of national program staff.

The two headquarters breeders will also devote approximately one third of their time to assisting national programs in the selection of new varieties.

The utilization section will collaborate with the pilot projects in the establishment of processing plants and in on-site research to improve processing systems in the pilot projects, and work with the economist in the evaluation of the economic viability of different processing systems in each situation.

Meso-America and the Caribbean at present are not important cassava-producing areas although many of the countries are classified as calorie deficient. National 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 1987 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.

Sub-Saharan Africa

Approximately 40 percent of the world's cassava is produced in Africa. Because of the great importance of cassava in tropical Africa, IITA has a strong root crops program which devotes most of its resources to improving cassava production on that continent. Recently, IITA and CIAT signed an agreement on cooperation so as to fulfill the needs of Africa better. This agreement recognizes CIAT's global mandate and responsibility for collecting and maintaining germplasm, the world cassava documentation and information service, and the cassava newsletter. Furthermore, IITA's regional responsibility in Africa and CIAT's in the Americas, Southern and Eastern Asia, and Oceania are clearly defined.

The exchange of germplasm has in the past been entirely from CIAT to IITA and almost entirely in the form of sexual seed. More than 70,000 distinct genotypes have been sent in this form and incorporated into the IITA breeding program. Most of this material was open-pollinated seed sent in order to enlarge the germplasm base of the IITA program. More recently, IITA has requested specific crosses with characteristics such as green spidermite resistance. A major problem with these crosses is their susceptibility to AMD. After a special meeting of an expert committee on quarantine, a methodology including testing of the phytosanitary status of clones in the United Kingdom, was established to transfer elite clones with AMD resistance to CIAT so that these can be crossed with mite-tolerant or highland materials and returned to IITA for testing.

Apart from the direct tangible exchange of germplasm, there is much information generated at both centers that can be useful outside their respective areas of direct responsibility. In the case of CIAT, much of the work on the basic physiology of the plant with particular emphasis on drought tolerance, propagation techniques, the new plastic bag storage technology, the epidemiology and etiology of pathogens, techniques for safe movement of sexual seed, and numerous agronomic practices can be applied in Africa. On the other hand, IITA's expertise on cropping systems and soil conservation can be applied to other continents.

Cooperation in the future will be particularly strong in the area of biological control of green spidermites and the cassava mealybug. The two institutes have already cooperated on the identification of collecting sites, development of mass rearing techniques and methods of transferring beneficial insects across national borders. Many beneficial agents collected by CIAT are now being actively tested by IITA in Africa.

IITA has also agreed to assist CIAT in improving documentation services by both collecting and distributing materials within Africa, as well as by contributing to the newsletter and taking charge of the version to be published in French.

IITA's regional efforts in Africa could be greatly enhanced through greater liaison with CIAT. This is especially true with respect to genetic resources. It is tentatively proposed to station one CIAT scientist at

IITA, starting in 1987, to be responsible for germplasm movement from the Americas to Africa and for more rapid interchange of information on research and development between the two institutes.

Southern and Eastern Asia

The overall strategy in Asia is to strengthen national cassava research and development programs through a research network of technical collaboration with CIAT and ESCAP-CGPRT, particularly with respect to the determination of overall government policies towards cassava, development of improved varieties and agronomic practices, and training of national program personnel.

The advantages of such a regional research network include (a) effective horizontal cooperation and rapid communication of new methodologies and technological advances; (b) identification and assessment of macrolevel problems that need to be solved through coordinated efforts; and (c) development of young scientists as a result of opportunities for mutual exchange of information, consultation and training.

This project envisages the placement of three senior cassava research scientists in Asia with regional responsibilities: an agronomist, a breeder and an economist.

There is a great need for a regional agronomist for the Asian cassava research network, who would be located in Thailand. In collaboration with the breeder and economist, as well as the national personnel in each country, the agronomist would be involved in the assessment of production problems; agronomic research at the national level; crop protection; and general consulting and technical assistance. A cassava breeder is already based in Thailand at the Rayong Experiment Station and is working closely with the Field Crops Division of the Thai Department of Agriculture on developing new clones suitable for Asian conditions. He is responsible for (a) seeing that national programs with established breeding programs, such as those in China, Philippines, Malaysia, India and Indonesia, obtain sexual seed from suitable crosses from both CIAT and the Thai-based regional program; (b) advising national program researchers on selection and testing procedures; and (c) assisting in the evaluation of hybrids through the process of selection and the final naming or release of new varieties. One of the Thailand-based regional staff will be designated as coordinator. In addition to his disciplinary duties, he will also be responsible for organizing regional workshops and conferences; coordinating training programs; and facilitating information exchange.

Economic research activities on cassava will be centered at the CGPRT Centre in Bogor, Indonesia, a country in which cassava is an important crop. A series of country-by-country coordinated studies on the economics of cassava production, utilization and future potential have already been conducted. With respect to production, the cassava economist will collaborate with the agronomist and national program personnel in identifying the key constraints to increased production in the region including competition with other crops for scarce resources such as land, labor and capital. As new production technology is developed, the economist will assist in onfarm evaluations, focusing on how readily the new varieties and management practices fit into different farming systems and affect production costs.

Research in the area of utilization and demand will provide input into the broader planning of cassava development. Of particular importance is the development of an accurate, consistent set of statistics on cassava production, area planted and utilization.

Evaluation according to end use (i.e., human food, animal feed, starch) will also be undertaken to determine priorities for research in these areas. The economist will undertake a macroanalysis of (a) prices cassava will have to compete at in alternative markets, and (b) the effect of processing costs on farm-level prices, production costs and yield targets, thereby bringing together production and demand research. The economist will also assist the national programs in determining how cassava may contribute to government policy objectives based on an evaluation of the socioeconomic cost/benefit accounting of the crop's potential.

Staffing Projections

Of the projected senior staff positions, approximately 6.4 person-years will be devoted to the global functions of the Cassava Program (Table 11), all of which will be core funded. As the Latin American and

Caribbean regional center, CIAT will have a core-funded total of approximately 3 person-years senior staff time. In addition there will be 1 person-year of special project-funded time for the Meso-American and Caribbean liaison officer.

The regional center for Asia will comprise one person-year of full-time core-funded staff in the breeder position plus the two full-time special project-funded positions of the economist and agronomist. In Africa IITA is the regional center; however, CIAT projects the placement of a liaison officer in 1987 subject to further negotiations with IITA.

The program will also receive support from the CISU in terms of documentation; the GRU, in terms of germplasm maintenance and tissue culture; the Biotechnology Research Unit (BRU), for virus and basic mycorrhizal work and training services.

Table 11. **Estimated allocation of senior staff time, by person-years, to regional and global responsibilities in 1987 when program is projected to be at full strength.**

	Global	Caribbean & Latin America	Asia	Africa
Leader	0.7	0.1	0.1	0.1
Physiologist	1	0	0	0
Breeder (HQ)	1	0	0	0
Breeder (HQ 1987)	0.7	0.3	0	0
Breeder (Asia)	0	0	1	0
Entomologist	1	0	0	0
Pathologist	1	0	0	0
Agronomist (Asia)	0	0	1	0
Agronomist (HQ)	0	1	0	0
Agronomist (Caribbean)	0	1	0	0
Economist	0.5	0.5	0	0
Utilization Specialist	0.5	0.5	0	0
Liaison Officer (Africa)	0	0	0	1
Total	6.4	3.4	2.1	1.1
(% Total)	(49%)	(26%)	(16%)	(9%)

Table 12. **Approved senior staff positions in the CIAT Cassava Program for 1980-85 and projected positions fo projects (CL), special projects (SP).**

Position	Funding source	80	81	82	83	84	85
Headquarters based							
Leader	CF	0	0	0	0	0	1[a]
Physiologist	CF	1	1	1	1	1[b]	b
Breeder	CF	1	1	1	c	c	c
Breeder	CF	1	1	1	1	1	1
Pathologist	CF	1	1	1	1	1	1
Entomologist	CF	1	1	1	1	1	1
Soil Scientist/Plant Nutritionist	CF	1	1	1	1	1	1
Economist	CF	1	1	1	1	1	1
Utilization Specialist	CF	1	1	1	d	d	1
Cultural Practices/Agronomist	CF	1	1	1	1	1	1
Regional Trials/Agronomist	CF	1	1	1	0[e]	0	0
Outreach Agronomist	SP	1[f]	0	0	0	0	0
Decentralized Regional Programs							
Asia							
Agronomist	SP	1	0	0	0	0	0
Breeder	CF	0	0	0	1	1	1
Sub-Saharan Africa							
IITA-CIAT Liaison Scientist	CF	0	0	0	0	0	0
Caribbean & Central America							
Agronomist	CL	0	0	0	0	0	0
Total headquarters		11	10	10	7	7	8
Total decentralized		1	0	0	1	1	1
GRAND TOTAL		12	10	10	8	8	9

a **Leader:** The full-time leader position was created in 1985 following the EPR recommendations in 1984.

b **Physiologist:** This position will be temporarily discontinued in 1985 as a major body of work has been achieved, and CIAT has opted for increased activity in the area of cassava utilization. The position is projected for reinstatement in 1988 in response to the need for further upstream research in cassava.

c **Breeders:** One breeder position was moved to the Asian Regional Program in 1983; a second breeder is projected to be reinstated at headquarters in 1987. This will allow expansion of breeding efforts in ECZs 3, 5 and 6, as well as closer collaboration with national programs in the final stages of selection.

d **Utilization Specialist:** Discontinued in 1982 as a result of center-wide budget cuts, this position was reinstated in 1985.

e **Regional Trials Agronomist:** This
center-wide budget cuts.

f **International Agronomist:** This
termination of the IDRC special pr
Latin America.

g **Agronomist (Asia):** This position
of the IDRC-funded special proje
reinstate the position in 1985-86

h **Agronomist (Caribbean):** A co-pr
IITA and CIAT as participants i
Caribbean. This corelike project

This plan is written at a time when, in accordance with the EPR's recommendation, a major study of demand for cassava in Latin America is under way. CIAT's currently projected global responsibilities are in line with the EPR's recommendations—i.e., assuming that the demand studies show little hope for a growing demand for cassava in Latin America—that "CIAT should consider tailoring its program to meeting its responsibilities as a major germplasm center for the world. Such a program would take full advantage of the excellent team of scientists currently working at CIAT and would provide a major resource for training." If, on the other hand, the demand studies predict an increasing demand for cassava, particularly in Latin America, then CIAT projects the full team shown in Table 12.

Research Support Units

AGROECOLOGICAL STUDIES UNIT

The report of the first TAC Quinquennial Review of CIAT (1977) recommended support for CIAT proposals for work designed to collect ecological, land use and farming systems information. It especially recommended that CIAT undertake the integration and classification of 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 important or have the potential for becoming so. 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; however, as resources were limited, it was not possible to mount a concerted effort that would cover the needs of all programs adequately through core funding. Given its strong ecosystem emphasis, the Tropical Pastures Program was considered the highest priority. Accordingly, a modest effort was begun in 1978 by utilizing provisions for visiting scientists in the core budget to provide for the agroecological characterization and analysis of areas of interest to the program. More recently, work has focused on the needs of the other commodity programs.

The section began functioning formally as a core activity in 1983 with the appointment of an agrometeorologist working within the Data Services Unit. Upon the recommendation of the EPR in 1984, the Agroecological Studies Unit became a separate unit serving the needs of CIAT's commodity programs.

One of the most important underlying reasons for agroecological analysis is that crop and pasture improvement for less-favored areas with highly diverse production constraints imposes severe problems on new technology design, development and transfer. The main targets of CIAT research are the less favored production zones—i.e., most nonirrigated areas in the tropics with a wide range of soil constraints and insect and disease pressures. The rate of progress in genetic improvement of any species is generally inversely proportionate to the number of constraints to be overcome through new genetic variability. It is clear that accurate information on the relevant constraints in each zone is essential at all stages of increasing production and productivity of basic food commodities in the tropics. This need is even more critical for small farm research as 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 great diversity of prevailing climates, soils, cropping systems and socioeconomic conditions, there is a pressing need for an inventory of production conditions in the small farm sector.

Objectives for Agroecosystems Analysis

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

1. To develop a system for environmental and socioeconomic assessment of introduction constraints 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 that can be integrated with the germplasm development process, thereby providing 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 imposed on national institutions of having to test all germplasm at all locations.
3. To develop a data system that 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; e.g., crop/weather relations in international nurseries and in other experiments.

4. To develop a data system that will provide a firm base for comparative socioeconomic studies on the highly diverse 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 make it possible 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 sufficiently flexible in order to provide the appropriate degree of detail and scale in each case. In addition, the collection of data, 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 cost-effective methodology that relies on prior surveys, census information, and local knowledge of the situation in each zone was developed. Information is acquired 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. The data acquired appear sufficiently adequate; in any event, attempts at a more detailed approach would probably be frustrated by lack of accurate local data.

The following components of the data system were developed to provide the necessary flexibility and coverage:

Land System Data

The concept of the **land system**[46] has been redefined as an "area or groups of areas throughout which there is a recurring pattern of climate,

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[46] C. S. Christian and S. A. Stewart, **Survey of the Katherine-Darwin Region, 1946**, CSIRO, Australia, 1953.

landscape and soils." Each land system is a regionally based reference unit with a strict geographic boundary to the basic data element. This analysis relies on satellite and radar imagery, and occasionally on aerial photography to provide a geographical base. 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 of 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 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 4900 meteorological stations in the western hemisphere, and work is in progress on a similar data base for Africa. Daily historic observations are being collected at selected stations in order to provide a flexible system for climatic definition of microregions, which will be useful in defining appropriate locations for regional trials and in evaluating 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, distributions of farm size, etc. will be managed on a microregion basis the same as the cropping systems data. These data will make it possible to determine the socioeconomic constraints faced in each zone as an important input into research design projects. Commodity program economists work closely with the Agroecosystems Analysis Section in this portion of the study.

Status of Agroecosystem Analysis for Commodity Programs

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

Tropical Pastures

The study of the South American lowlands[47] has enabled a classification of the major ecosystems making up the program's area of interest. Quantitative assessment of the natural resources available in each ecosystem has made it possible to aggregate the land system units within each major 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 evaluation 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 advantages of different zones with respect to future development will facilitate national policymaking. The studies (in the form of computer files at EMBRAPA) are already in use at CIAT and in Brazil.

Beans

Early agroecosystem studies have considerably aided in defining the program's research priorities and strategies and in locating its primary sites for the first two stages of the germplasm evaluation program. Climatic analysis of the 110 bean microregions permitted an assessment of crop/temperature conditions. It also verified that growing season

[47] T. T. Cochrane et al., in press, op. cit.

temperature conditions at CIAT-Palmira and CIAT-Popayán are clearly representative of and encompass the major proportion of production zone temperatures in Latin America.

With the Bean Program's increasing interest in Eastern Africa, the unit's work has been extended. Crop distribution, soils and climatic data are being compiled. In the meantime a preliminary agroecological zonation of African bean regions has been produced to aid the new efforts in the region.

Rice

Initial studies have begun to define, locate and classify the microregions of upland rice production in South and Central America including Mexico. Census data have defined municipal-level information on which to aggregate data into definable and relatively homogenous microregions. This information is vital in the more precise definition of the research strategy for the upland sector.

Cassava

The cassava production zone or ecosystem classification provided in this plan is a preliminary one.Detailed analysis of cassava distribution is now under way. An inventory of Latin American cassava production at a scale of 1:5,000,000 has been produced, whereby valuable insights have been gained into the range of environments encountered. Present projects are microregion definition and data base design. As these projects are completed and the data base becomes operational, a reevaluation of the cassava agroecozone classification will be feasible.

Projections for Agroecosystems Research

The creation of the Agroecological Studies Unit as a formal core-funded activity was based upon a thorough trial of the potential value of this work. This activity will constitute a centralized service function to the four commodity programs as the basic natural resources inventory and methodologies are common to all. Research will continue to be done in collaboration with program scientists.

The unit currently consists of one senior staff position; i.e., an agro-meteorologist. In line with CIAT's previously stated plans and with the

1984 EPR recommendations, CIAT has projected a second position of Land Resources Specialist, who will take over the responsibility for all land systems and soils-related work of the unit in 1987.

The unit's work depends heavily on the existence of sufficient computer capacity to handle large data bases within the Integrated Data Management Systems (IDMS) installed at CIAT. The recent upgrading of the CIAT computer facilities and the acquisition of digital mapping capacity will greatly expedite work over the next few years.

BIOTECHNOLOGY RESEARCH UNIT

The involvement of CIAT in monitoring and applying some of the most promising biotechnologies was anticipated in the Long Range Plan in 1981. The panel of CIAT's second EPR recommended the establishment of an interdisciplinary research unit comprising those related disciplines that would interact increasingly with all commodity programs in the future. In its response to this EPR recommendation, CIAT agreed upon the concept of a cross-commodity effort in the form of a research unit devoted to the emerging field of biotechnology and related disciplines such as virology. Consequently, the Biotechnology Research Unit (BRU) was established in 1985.

Initial efforts in biotechnology within the GRU at CIAT concentrated on developing a tissue culture technique to facilitate germplasm-related activities in cassava. The methodologies developed have served to build up an *in vitro* gene bank of cassava clones, which includes at present 60% of the 3,800 accessions of CIAT's *Manihot* collection. All cassava clonal materials including recently added accessions have been exchanged with national programs in Latin America and Southeast Asia, using *in vitro* techniques.

Once these techniques were developed and utilized, new research approaches more closely related to CIAT breeding efforts were tackled. Thus the subsequent development of anther culture methods has made possible the production of homozygous rice lines from F_1 hybrids in a 7-to 8-month period. Current work in collaboration with the Rice Program breeders has demonstrated the potential of using anther culture in the production of improved rice varieties. Although cassava has resisted regeneration from unorganized tissue cultures, recent research resulted in the differentiation of somatic embryos in six cultivars using foliar segments, and the isolation and culture of leaf mesophyll protoplasts has been standardized. Using leaf mesophyll protoplasts and cell cultures, *Stylosanthes* spp. plants have been regenerated in large numbers. These more recent results should permit the application of new genetic manipulations in the future.

In those cases where other institutions are in a better position to conduct specialized research, collaborative research projects have been established; e.g., development of cryopreservation of cassava; eletrophoretic characterization of beans, cassava, and pasture legume genotypes; and improving the recovery efficiency of hybrid plants from interspecific crosses of *Phaseolus.*

Objectives

As a center largely dedicated to producing new genetic variability, CIAT is aware of the advances being made in those areas of cell and genetic manipulation that are likely to affect present breeding systems, particularly with respect to the time and cost needed to produce such new variability. CIAT has the potential to become an important user of new biotechnologies and has the mechanisms for transferring these technologies to national research programs in developing countries. Thus the BRU has the following broad objectives:

a. The unit will be charged with center-wide responsibility for all research in the general area of plant biotechnology.

b. The unit will act as an interface between advanced research institutions, where new methodologies are becoming available, and CIAT commodity program and national programs where the new technologies will be tested.

c. The unit's work will deal primarily with those biotechnological applications that can significantly increase the efficiency of traditional plant breeding methods or help resolve problems that escape solutions through these traditional procedures.

Research Strategies

To achieve its objectives, research at the BRU will be carried out in accordance with the following general strategies:

1. **Technology selection:** In collaboration with CIAT scientists, the unit will monitor and choose the most promising technologies available for application to relevant problems in each of CIAT's commodities.

2. **Technology development:** To be carried out through collaborative research projects with specialized institutions aimed at advancing knowledge in critical areas, or through work aimed at adapting more developed technologies.

3. **Technology application:** The application of a proven technology to breeding strategies will be carried out with the support and collaboration of the respective CIAT commodity program.

4. **Technology transfer:** Selected national programs will be encouraged to adapt those technologies that have been successfully applied at CIAT.

In the development of these activities, CIAT will seek special projects to speed up the development and application of emerging technologies with the collaboration of advanced institutes and national program scientists. This strategy has been relatively functional in recent years. For instance, cassava shoot-tip culture methods have been rapidly adopted by several national programs in Latin America and Southeast Asia as a means of producing clean planting material and for germplasm exchange. Other technologies such as rice anther culture have progressed significantly and now form an integral part of CIAT Rice Program operations. It is envisaged that this technology will move out to national programs in the near future. On the other hand, other technologies (e.g., cryogenic preservation of cassava clones) are still in the development stage, while other more advanced technologies, e.g., recombinant DNA and gene transfer, are being evaluated for collaborative research with other institutions.

Projections

Currently the major activity in the BRU involves research in cell and tissue culture for clonal propagation and for the generation and selection of useful variability. Laboratories were completed (1984-85) to carry out this work with cassava, rice, legume pastures, and beans. Given the large volume of plant material generated in these laboratories, more greenhouse facilities will be needed.

The BRU staff comprises at present one senior staff and support staff. The senior scientist is the cell physiologist transferred from the GRU to the BRU as head of this unit.

As a discipline closely related to biotechnology, virological research at CIAT will become integrated as a section of the BRU in 1986. The existing virology position in the Bean Program will be transferred to the BRU staff; and in 1987 another virologist is projected for the unit to handle the increasing work load across all commodities. The virologists will have center-wide responsibility, and interaction with the commodity programs will mainly take place through support staff. This association will also allow the sharing of specialized facilities such as the electron microscope, ultracentrifuges and autoradioagraphy. The inclusion of all cross-commodity research on mycorrhizal associations in the BRU, as suggested in the Cassava Program section, is being evaluated at this time.

Further adaptation of laboratory facilities for the virology section has been planned for 1985-86. The unit has also projected for 1986 two additional small support laboratories for radioactive and biochemical work.

Through the CIAT postdoctoral fellowship program and special project funding, extra support for specific biotechnological research will be sought.

SEED UNIT

The Seed Unit initiated activities in 1979 with special project funding from the Swiss Development Cooperation (SDC) for the first five years. This initiative was the first direct effort by an international center to help strengthen national seed-related activities in a region. The unit also provided CIAT with the capacity to produce, condition and distribute basic seed, especially of CIAT commodities, to national programs to help accelerate the use of new germplasm at the farm level. The second phase (1984-86) of the Seed Unit's activities is being carried forward as a restricted core activity with continued support by the SDC.

Objectives

The rationale for creating the Seed Unit was the recognition that a series of factors were limiting progress in the development of national seed programs and industry in Latin America and the Caribbean: the lack of trained personnel; unclear and inconsistent government policies; limited supplies of breeder and basic seed for transfer to the seed industry; problems in producing, conditioning and storing of good-quality seed; weak marketing systems and lack of effective mechanisms for transferring improved seed to small farmers. Obviously the problems in Latin America are manifold, and the role of seed-related activities at an international center must be defined clearly as these problems cannot be solved only at that level.

The unit was thus created with five specific objectives:

1. To increase the number and competence of seed technologists in both the public and private sectors of the seed industry in the region.

2. To strengthen seed programs and seed enterprises in the region through technical collaboration.

3. To stimulate seed production and accelerate use of the most promising varieties and hybrids.

4. To assist in the solution of problems limiting seed production and distribution through appropriate research.

5. To disseminate information on seed activities, advances in seed technology and the availability of promising materials in the region.

Accomplishments of the Unit

From the start the Seed Unit has placed a strong emphasis on training and has conducted 13 courses of different levels and specialization over the past six years involving 374 participants. In addition, seed technology and production training held at the subregional and in-country level has involved a further 440 seed technology and production specialists. The intense training effort has been backed up by technical cooperation at the subregional and national level to (a) help clarify seed production goals and strategies for meeting them; (b) improve links between research and seed programs; and (c) encourage the formation of basic seed and commercial seed production units. Over 250 tons of basic seed of rice, beans and tropical grasses and legumes have been produced and processed by the Seed and Station Operation units, and made available to collaborating national programs upon request.

Six workshops have been held with the purpose of strengthening seed improvement and network development, the proceedings of which have been published. Two books and several audiotutorials on seed production and technology have been developed, and a newsletter is circulated quarterly to 1500 readers.

Though a relatively minor component, research conducted by scholars has yielded valuable contributions, primarily on methodology for improved variety descriptions and on seed quality of beans and tropical grasses and legumes.

The initial impact of the unit can be seen in the improved technical capability and motivation of course participants and the increased quantities of seed of improved varieties. National programs have given the unit strong support; simultaneously, national program goals are being clarified. The network of seed technologists, seed associations and universities with seed technology and production courses is growing. Subregional activities and networks are developing, primarily in Central America and among the Andean Pact countries. This extremely positive response has resulted in the Seed Unit becoming a

CIAT restricted core activity with a clear long-range role to play within Latin America and the Caribbean.

Strategies for the Future

As can be seen from the foregoing discussion, progress during the first six years of the Seed Unit's activities has increased the human capital base and started a series of collaborative networks. The challenge during the next ten years is to capitalize on the advances made and develop this base into efficient, fully operational seed programs and industries in each country of the region.

In order to develop first-rate seed programs and industries, there is a need for the following: (a) a continuous supply of improved varieties and hybrids from both public and private research efforts; (b) the existence of basic, certified and commercial seed production units; (c) the means to assure that only good-quality seed is supplied; (d) the capability to educate seed users and to market seed to them at acceptable price levels; and (e) national-level planning on how to improve the seed sector. Thus during the coming years, the Seed Unit, working from its regional headquarters at CIAT, will collaborate with the national programs in executing a program at the regional, subregional and national levels in order to achieve the desired objectives within national programs.

Tables 13 through 16 outline the Seed Unit's primary objectives to be accomplished within each country and the strategies for meeting them. The complementary nature of the work at the national, subregional and regional level is also shown.

As has been true over the past six years, the unit will continue to focus on CIAT's commodities, but will not limit its effort to them because national-level basic seed units, seed enterprises and quality-control programs must include several crops. First priority will be given to the crops in the international center system. The discussion that follows is divided into sections in accordance with the unit's specific strategies for fulfilling the aforementioned objectives.

Training and Conferences

The availability of trained personnel is not the same in each country, and some attrition occurs in all countries. Thus broad training at the introductory level consisting of a nine-week course and in-service specialization will continue to be offered at CIAT to help keep the most advanced national programs moving and to expand the numbers of trained people especially in the less-developed national programs (see Section II).

The Seed Unit's greatest comparative advantage is its capability in conducting advanced, specialized courses to upgrade the present pool of seed production and technology people. Because of the facilities available and the nature of courses, these are best offered at CIAT headquarters. Courses planned include: seed enterprise management and marketing, breeder and basic seed production, seed quality control, tropical pasture seed production, cassava propagation, seed conditioning, and improved seed testing methodology.

A more sharply defined in-service program will provide national programs with the chance to train staff in the specific areas covered in Tables 13 through 16; i.e., national seed program development, breeder and basic seed production, commercial seed production and processing, and seed quality control. Training at the subregional and national level will complement the CIAT effort by greatly expanding the numbers and kinds of people reached with shorter term, location-specific courses. Specialized workshops would be offered on subjects identified as high priority at the regional, subregional and in-country level. Each workshop would support strategies as they evolve to meet the objectives given in Tables 13 through 16.

Throughout the training effort and the follow-up of trainees, special attention will be focused on the multiple-network development that was initiated during the first six years. Opportunities will exist for strengthening national capabilities through visiting researchers, thesis candidates, postdoctoral and research fellow appointments with the Seed Unit.

A seed training plan will be developed in conjunction with national seed improvement plans as part of the overall strategy of helping national programs achieve their objectives in seed program and industry development. Priority will be given to those countries showing the greatest interest in the accelerated development of their seed sector.

Table 13. **Strategies for a National Seed Improvement Plan that contributes effectively to the long-term development of the seed sector within each country.**

	Strategies	
National	Subregional	Regional (CIAT)
Working through national seed program leadership, seed associations, the commercial seed sector, research programs and former course participants, assist countries in formulating and implementing a National Seed Improvement Plan. Workshops, seminars and special seed study teams will be encouraged to achieve this objective. Guidelines and assistance will be provided on request to National Seed Boards, where they exist. Support from donor and technical assistance agencies will be sought wherever possible.	Workshops and seminars at the subregional level will be used to provide national leaders with common geographic interests a chance to share experiences, identify successful policies and strategies, and develop outlines of plans for possible use in individual countries and in subregional collaborative programs. In a similar manner, follow-up activities on effective implementation of plans will be carried out.	Using the newsletter, training letter, training courses and workshops, develop broad regional interest and a consensus on the value of a National Seed Improvement Plan, the content of such a plan, the steps for developing it, and the importance of effective implementation of the plan in cooperation with research and extension personnel. Offer opportunities to seed program leaders to develop plans in consultation with CIAT staff.

Table 14. **Strategies for increasing breeder and basic seed supplies.**

	Strategies	
National	Subregional	Regional (CIAT)
Increase breeder seed multiplied and maintained by national research programs in cooperation with CIAT commodity programs. Strengthen basic seed units through technical and structural improvements, increased links with research programs and improved seed-allocation policies to seed enterprises and seed growers.	Enhance opportunities for the exchange of breeder and basic seed among national programs, through workshops, training courses, improved communication to increase an awareness of opportunities and benefits for cooperation, especially at the subregional level.	Through links with the commodity programs help identify and overcome weaknesses in breeder seed supplies. Train personnel to improve technical and organizational aspects of basic seed seed units. Produce, process and sell basic seed to national programs as needed. Provide technical assistance on how to improve programs at the national level.

Table 15. **Strategies for increasing farmers' certified and commercial seed supplies, irrespective of operational scale.**

	Strategies	
National	Subregional	Regional (CIAT)
Increase the number and capacity of seed enterprises and small grower/sellers to produce and market seed through an emphasis on clear policies, incentives, easy access to basic seed, and strong training efforts including in-country courses. Cooperate closely with donor and technical assistance agencies in support of these developments.	Work to facilitate the movement of seed across national boundaries. Concentrate on seed enterprise management and marketing courses and workshops geared to subregional needs.	Through regional workshops and courses, assist national leaders and seed industry leaders in clarifying policy objectives, share experiences of incentive programs and projects to stimulate increased seed production. Improve supplies of basic seed and information available on technical aspects, production costs, seed pricing and marketing methods. Research on methods for increasing good-quality seed yields per hectare. Keep donor and technical assistance agencies abreast of opportunities for strategic assistance.

Table 16. **Strategies for improving the quality of seed produced, distributed and used.**

Strategies: National	Strategies: Subregional	Strategies: Regional (CIAT)
Encourage national seed programs to improve and enforce seed legislation, develop effective seed-certifying agencies, and realistic quality standards. Focus more attention on need for strong internal quality control systems within seed enterprises and the need to increase seed testing—both official and unofficial. Improve user awareness of quality factors and methods to improve quality of seed saved for planting. Stimulate more in-country training on seed quality.	Focus on realistic quality norms and increased uniformity of seed standards and procedures to facilitate movement of good-quality seed among countries through workshops, training and subregional mechanisms and institutional structures.	Use workshops and courses to achieve greater understanding of requirements to improve seed quality through legislation, seed certification and internal quality-control systems. Focus attention on achieving realistic quality norms and more uniformity of seed standards and procedures among countries. Research on priority of seed-quality problems. Develop model legislation. Help donors and technical assistance agencies become aware of regional needs.

Technical Collaboration

Increased effort will be given to improving national seed program goals, strategies and policies to achieve the objectives in Tables 13 through 16. The preparation of a national seed improvement plan will help clarify goals, strategies and policies; contribute to improvements in the seed program and industry; and make more purposeful seed technology and production training. Improved linkages among research, extension and seed activities at the national level should result from this effort. The follow-up with former course participants, work with national program leaders, the commercial seed industry and seed associations can provide the means of achieving these objectives.

Of special concern in the development of national seed improvement plans will be a stronger orientation toward improving the quality of seed planted by small farmers. Thus emphasis will be placed on measures that (a) will help farmers (or their wives) do a better job of saving their own planting seed and (b) improve the supply of good-quality seed of improved varieties available to the small farmer.

In support of subregional strategies, technical collaboration will concentrate on working through key groups in specific areas. The institutional structures developed in Central America during the past six years will be used there. In the Andean area and the Southern Cone, it is expected that present agreements with the Andean Pact and the Centro de Estudos e Treinamento em Tecnologia de Sementes e Mudas (CETREISEM) in Brazil will provide mechanisms for effective subregional activities in those areas.

The country profiles (the national seed program status files) that have been developed up to 1984 will be improved, refined and updated. Each national seed improvement plan will contribute to information in the country profiles. This information is of value not only to the Seed Unit but also to groups interested in the identification and development of seed projects to strengthen specific seed activities at the national level. Throughout the technical collaboration activities, links with donor and technical assistance agencies and other international centers are to be maintained and strengthened. The potential for achieving maximum impact at the national level through the synergistic effect of combined efforts is great, and the Seed Unit will always be alert to these possibilities.

Seed Production and Use

The ultimate objective of the Seed Unit is to increase production and the use of improved varieties. Existing weaknesses in breeder and basic seed supplies make improvement of this component essential in most national programs. The development of operational basic seed production units at the national level is one of the best ways to overcome this weakness and will therefore be given even greater attention than in the past. Equally important is the encouragement of activities that stimulate local seed production and use of certified and commercial seed.

Of top priority in the immediate future is the development and improvement of seed enterprises and new seed producers/sellers to meet the region's needs. Training, technical collaboration and actual seed production by the unit will support these developments.

The unit will also continue its support to CIAT's commodity programs by multiplying breeder and basic seed of the most promising materials and making it available to national programs and other interested organizations. Commercial seed will not be distributed directly to farmers as this is clearly a national activity.

To strengthen the unit's seed production capability and simultaneously assist national production of basic seed, more attention will be given to contracting seed production in the most suitable areas, especially for bean, grass and legume seed. Improved support to sister centers will be provided by multiplying and selling basic seed of promising lines and varieties from their collaborative research programs in the region. These production activites are expected to be self-financing.

To accelerate the development of basic seed units and commercial seed production and marketing, the unit expects to explore various collaborative and funding mechanisms with donor agencies. If this proves successful, the unit would work with others in pioneering the most promising opportunities. Linked with and in support of this initiative is the need to improve the data base on the most suitable seed production areas; amounts of seed produced, especially of improved varieties; costs of production; seed pricing; and variety usage. In cooperation with national programs and seed associations and with improved economic and computer capabilities, the Seed Unit plans to provide the region with a more solid data base upon which to make decisions for future seed development.

Research and Development in Seed Production and Technology

In research the Seed Unit has a comparative advantage on several high-priority projects of special interest to the CIAT commodity programs and sister centers. Work on these projects will be done in collaboration with the commodity programs, primarily through graduate students doing their thesis research, as well as research fellows associated with the unit. The main research effort, however, will continue to be done by others; i.e., primarily scientists associated with graduate programs in a few Latin American universities. The unit will work to develop a collaborative research network by playing a catalytic role in linking researchers, in providing information, and in offering opportunities for short-term research work within the unit. A list of seed technology researchers, research underway and research highlights in the region will be developed and updated periodically.

The Seed Unit will help to identify priority areas for research in seed technology. 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. Cooperation with the Tropical Pastures Program will be strengthened further as they work to solve these problems. For beans, cassava and rice, the unit expects to participate in research to facilitate improved seed production and distribution.

Efforts will be increased to identify research and development results from outside Latin America and the Caribbean that are of value to the region. Leaders from outside the region who can assist seed research and development in the region will be offered Visiting Scientist appointments to complement the Seed Unit staff and achieve specific short-term objectives that are of high priority.

Communications and Documentation

The seed programs in the region have no mechanism for continued communication among themselves except for the CIAT Seed Unit. It is in the interest of CIAT, its sister centers and the seed activities in the region for the unit to continue to fulfill this communication role. The unit can also keep the window open to seed technology development internationally through its links with universities, associations and program activities outside of Latin America.

Thus communications and documentation are an integral component of the Seed Unit's activities in support of training and conferences, technical collaboration, seed production and use, and research and development. Although some differences exist in the modus operandi, these activities have application at the national, subregional and regional level. Training materials, handbooks and manuals which cannot easily be prepared and updated at the national level will be prepared. Included among the proposed publications are materials on breeder and basic seed production, seed certification and law enforcement, internal quality control, operation of seed-conditioning facilities, training material for teachers and trainees at the national level, and guidelines for improving the supplies of seed for small farmers. A special publication on seed production and technology written by seed specialists in the region is to be completed for use at the university level and in national training activities. In a few cases work on a subregional basis can result in publications of value at all levels. Complementary audiotutorial and laboratory training material will continue to be prepared in both Spanish and English. The quarterly newsletter in Spanish will concentrate increasingly on successful achievements in the region. The growing collection of references in the Seed Unit and the CIAT library will be systematized to develop a stronger documentation base to serve researchers, seed technologists, the seed industry and the more general group of specialists interested in seed improvement.

Resource and Staffing Projections

Two senior staff positions are essential to deal with the work outlined: A specialist with experience in seed-quality control, seed development and training will fill one position. The other position will be covered by a seed specialist familiar with breeder and basic seed production, certified and commercial seed production, seed enterprise operation, management and seed marketing. These two positions are projected for the remainder of the decade of the eighties.

The stage of development, the recognized need and the interest expressed by national programs now justifies an outposted staff position in the two subregions that have the greatest need for accelerated development in the region, based upon country profiles—Central America and the Andean Zone. The desire for increased cooperation with the Seed Unit through the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), IICA, CATIE and the Asociación Regional de Tecnólogos de Semillas (ARTES) in Central America, and the Junta del Acuerdo de Cartagena (JUNAC) in the Andean Zone provides opportunities for catalytic mechanisms that go far beyond the present staff resources. To achieve the rate of development required, the two outposted positions, to be linked with existing institutional structures and backed up by the Seed Unit, are needed for a minimum of 3 to 5 years. These positions would be funded as special projects in collaboration with other institutions in the region and are not proposed for support under CIAT's core budget.

The responsibilities of the Seed Unit staff working at the subregional and national levels focus on achieving objectives and strategies summarized in Tables 13 through 16. These activities include cooperating with national and subregional leadership in organizing courses and workshops at both levels; working with subregional technical committees and associations; assisting countries in the subregion to clarify goals and strategies, developing national seed plans and seed training plans; helping to strengthen breeder, basic, certified and commercial seed production operations; and guiding the development of more effective official and internal quality control systems. In seed production special emphasis would be placed on the development of small seed grower/sellers to cater to local seed needs such as is required for beans, upland rice, maize and sorghum.

To strengthen or accelerate specific areas of research and development, the full-time staff of the unit will be complemented with one twelve-month postdoctoral or research fellow appointment per year and the equivalent of six months per year of a CIAT fellow, visiting scientist or consultant. The areas of specialization will relate to the country objectives in Tables 13 through 16 and the backup required by the Seed Unit to carry out the strategies involved. Priorities will be established as work progresses during the period and the specific tasks undertaken based upon the availability of specialists. For example, specialists in seed enterprise management, seed marketing, and seed drying and storage could assist in achieving the objectives of seed production and supply. Specialists on seed legislation, pasture seed testing and seed pathology would contribute to the seed quality-control objectives. To assist the development of the data base and conduct research on costs of production and seed pricing might utilize an agricultural economist with a seed interest. The assistance of these short-term seed specialists will help the Seed Unit staff and the region will benefit from the best of the international seed community.

Close links will also be maintained with all the commodity programs and the GRU as their work relates to the Seed Unit objectives. In the case of the GRU, it is expected that joint research and development activities would relate to seed storage, seed pathology and cultivar identification, especially by means of electrophoresis. Some improvements in facilities are planned to include more air-conditioned space for seed storage, and increased training space is planned for the immediate future.

Links with Other Organizations

Donor and technical assistance agencies will need to continue assisting seed programs in the region in their development for at least another decade. The Seed Unit is in an excellent position to work closely with these agencies in developing projects and in supporting their implementation. As agencies request help, it is in the interest of the countries and CIAT for the Seed Unit to provide some assistance to assure better projects and to integrate the project development process with the technical, training and seed-supply capabilities of the unit. One aspect of technical collaboration would include providing assistance to national programs in identifying suitable sources of financial and technical support.

It is expected that links with CIAT's sister centers and other agencies with program interests in the region will be strengthened. It is conceivable that some of them might choose to locate a breeder/seed production specialist at CIAT to work with national research programs, basic seed units and seed enterprises in support of their particular crop interest. This kind of cooperation will be encouraged.

GENETIC RESOURCES UNIT

The Genetic Resources Unit (GRU) was established in 1977 to provide centralized conservation and documentation for species covered by CIAT's mandate. The need for genetic conservation had become increasingly apparent as the spread of improved varieties and changes in land use lead to increasing genetic erosion of landraces. The establishment of the unit was a clear indication that CIAT was prepared to give a high priority to the conservation of genetic resources, both for use in its own research and as a future service to world agriculture.

The unit was formed to avoid duplication of effort in handling germplasm, to provide an efficient service in supplying germplasm to CIAT and other crop improvement programs and to enable problem-oriented research to be conducted on aspects of genetic resource maintenance.

In planning for the remainder of the decade, the increasing international concern over the future of plant genetic resources on a global scale will provide a stimulus to theGRU to demonstrate the effectiveness of the CIAT approach, both in the conservation and utilization of genetic resources.

The following statement outlines the objectives and operational plan for the GRU for the remainder of the decade.

Objectives

1. To collect, evaluate, maintain, document and distribute the CIAT germplasm collections in *Phaseolus, Manihot* and tropical forages, thus providing support to the center's plant improvement programs while at the same time providing for the proper conservation of these resources for future generations.
2. To provide unrestricted access to those germplasm resources that can be made available at any given time, to other organizations and individuals in both the public and private sectors of developed and developing countries.
3. To conduct research on the collections related to issues of germplasm conservation in the broad sense and complementary to the work of the center's commodity programs.

Operational Strategies

The basic strategies of the GRU can best be defined in relation to the individual functions of the unit.

Germplasm Exploration

Emphasis is placed on collecting landraces (especially those thought to be in danger of being lost) and on assembling samples from commercial sources and national programs. The initial rapid buildup of CIAT collections, particularly for *Phaseolus*, depended on receiving duplicates of established collections; for example, from the U.S. Department of Agriculture (USDA) at Pullman, Washington. Continued attempts are being made to fill gaps in the collection, and collecting priorities have been established by CIAT staff in cooperation with the germplasm advisory committees of the IBPGR for *Phaseolus*, *Manihot* and tropical forages. The main sources of germplasm will continue to be:

1. Multipurpose germplasm exploration missions financed and organized by the IBPGR in which the collectors are obliged by the Board to deposit properly documented samples of the materials with CIAT.

2. Germplasm exploration missions organized by CIAT and/or national programs in collaboration with the IBPGR specifically for the purpose of collecting *Phaseolus* and its wild relatives.

3. Germplasm received from national and regional research institutions, usually representing national or regional collections from the areas of genetic diversity.

4. Germplasm received from other organizations that have been active in collecting internationally and have agreed to cooperate with CIAT by making available these collections along with appropriate documentation.

Samples for the GRU originating outside Colombia are subjected to a carefully regulated quarantine procedure under the supervision of the Colombian authorities.

Characterization

In order to provide a basic description of samples held in the unit, a process of characterization is undertaken; for example, in *Phaseolus,* a standard list of important descriptors is used. This list is revised by an IBPGR advisory committee, of which CIAT is a member, as a step towards international standardization of information. The present trend in characterization is towards a list of descriptors of stable characters that show little environmental variation. Such characters are practical to score and useful to breeders.

More extensive evaluation including disease resistance and tolerance to environmental factors is the responsibility of the commodity programs.

Conservation

The longevity of seed can be enhanced by drying the seed to a controlled low moisture content and storing under cold conditions. Plant tissue can be maintained at low temperatures in a low growth medium. By use of these long-term storage techniques the expense and possible contamination of germplasm during annual rejuvenation in the field is reduced. Balancing the requirements of convenience against long-term security, two types of storage conditions are used for seed: so-called "active" collections when frequent access is required; and "base" collections, which are intended as a resource for the future. Details of current holdings and storage conditions are given below with respect to each of the collections.

The recognition by the IBPGR of the CIAT *Phaseolus* and *Manihot* collections as world base collections places an additional responsibility on the GRU for careful conservation.

Documentation

The large number of accessions in the GRU—more than 50,000 at present—and the wide range of information available on each sample require the development of a computerized data base. The acquisition by CIAT of an Integrated Data Management Systems (IDMS) on the IBM 4331 provides a powerful facility for data management. Information about each sample is divided into different categories: (a) "passport" data on the origin of each sample and its identification; (b) characterization data (see above); and (c) evaluation data available to the GRU data base from the research programs.

The data base has been used to produce general catalogs for Tropical Forages (1983), *Phaseolus vulgaris* (1984), and Elite Cassava (1983). Because of the great number of accessions, only the most basic passport or characterization data can be included in the catalogs, which are regularly updated. It is also possible to list samples with particular required properties—for example, *Phaseolus vulgaris* with small black seed and resistance to BGMV, for use in a specified climatic zone. By cluster analysis, groups of samples with similar morphological characters and similar expected performance can be identified.

The increasing emphasis on wild relatives of *Phaseolus* and *Manihot* and the wide range of genera and species within the tropical pastures program have dictated the need for a reference herbarium, which has been included as part of routine GRU activities.

Distribution

One of the objectives of the GRU is to make germplasm readily available to anyone interested in germplasm conservation or utilization. Priority is given to returning collections to their country of origin, for further use by national programs. The GRU can advise on suitable material or refer requests for the supply of improved material to the respective commodity program. In practice, there are some restrictions on availability, particularly in tropical pasture species, where seed production is difficult. When a large number of samples are requested by commercial organizations, they are asked to pay handling charges. A full statement on CIATpolicies for the distribution of germplasm to other organizations was prepared recently.

Seed Health Monitoring

With the increasing exchange of germplasm, there are increased opportunities for the spread of seed-borne diseases and pests. An independent consultant has reviewed CIAT's phytosanitary activities and has given the center a favorable report.[48] The seed health testing

[48] R. P. Kahn, Safeguards and the international exchange of plant germplasm as seed, Seed Sci. and Technol. 11:1159-1173, 1983.

laboratory within the GRU is responsible for implementing routine tests for defined seed-borne pests and disease on seed destined for export. Research on developing the actual testing methodologies will remain a responsibility of the programs.

Research within the GRU

Research in the GRU is related to problems of maintenance and utilization of the collection. Priority is given to evaluation/characterization of all the collections, and the subsequent analysis of characterization data to indicate the potential value of each sample.

Research is in progress to determine the requirements for seed conservation for different species. Problems to be solved include choice of seed-drying techniques, appropriate packing materials, and optimum intervals for seed rejuvenation. Research towards breaking seed dormancy in wild *Manihot* species should help in conservating the potentially useful collections held at CIAT.

Research on the problems and potential of wide crosses between *Phaseolus vulgaris, P. acutifolius* and *P. lunatus* and between *P. vulgaris* and *P. coccineus* is under way in collaboration with the Faculté des Sciences Agronomiques de l'Etat in Gembloux.

As a further example of the types of cooperation possible between CIAT and other institutions, a study is now in progress on the taxonomic relations of wild *Phaseolus* species and of *Phaseolus* collection needs, by an IBPGR-financed postdoctoral fellow. Research on genotyping through protein/enzyme eletrophoresis is the basis of cooperation between the CIAT BRU and the University of Manitoba. Techniques developed in this research will be used by the GRU to provide additional data on germplasm accessions including identification of duplicates.

Status of CIAT Germplasm Collection

The status of germplasm held by the GRU is indicated in Table 17. A total of 53,700 germplasm accessions are held at CIAT, and it is expected that by the end of the decade there will be about 81,000 accessions. This figure, which is based on the estimated germplasm resource base remaining to be collected, is being used as a target for the design of new facilities. Little expansion beyond this figure is expected in the next decade.

Phaseolus Collection

The GRU is responsible for a full range of activities for *Phaseolus*—collecting, characterizing, conserving, documenting and distributing germplasm. A total of 33,968 accessions are held as seed, of which 20,000 have been processed (seed rejuvenation, characterization) and are available for distribution. In the last seven years 27,000 samples of

Table 17. **Current (1985) and projected size of CIAT's germplasm collections in 1990.**

		No. of accessions	
Genera/Species		1985	1990
Phaseolus Collections			
P. vulgaris		29,876	35,000
P. lunatus		2,590	7,000
P. coccineus		1,235	5,000
P. acutifolius		182	1,500
P. spp. (wild noncultivated)		85	1,500
	Subtotal	33,968	50,000
Manihot Collection			
M. esculenta (clones)		3,700	6,000
M. spp. (seed, wild species)		32	100
	Subtotal	3,732	6,100
Tropical Forage Collection			
Legume species		13,500	20,000
Grass species		2,500	5,000
	Subtotal	16,000	25,000
	GRAND TOTAL	53,700	81,100

germplasm have been sent to 66 countries. Bottlenecks still exist in the through-put of these materials, including problems related to facilities at CIAT for postentry phytosanitary control. At present many accessions are waiting to be processed through postentry quarantine, and the introduction of germplasm from the CIAT African projects will increase this problem. Third-country quarantine cooperation is being established in Belgium, the United Kingdom and the United States, which should relieve the situation.

Manihot Collection

The cassava germplasm collection is held as clones growing in the field (3,800 accessions) and in minimal growth storage following *in vitro* culture (1,900 accessions). The convenience of tissue culture techniques for rapid multiplication, freeing material of disease, and international exchange mean that increasing emphasis will be placed on maintenance in *in vitro* culture. The physical facilities for this already exist in the CIAT BTU. The highly successful program of collection and subsequent introduction via tissue culture will continue, but on a reduced scale as areas are collected. CIAT/IBPGR cooperation exists for collecting in the areas of diversity in Latin America.

Since 1979 germplasm has been distributed to 57 different countries in the form of (a) cuttings, 699 (this form of distribution has been discontinued); *in vitro* cultures, 1,115; and seeds, 321,611. In the next five years, the GRU will become entirely responsible for the maintenance of field collections, distribution of samples, and maintaining the data base.

Tropical Forages Collection

Collecting and evaluation/characterization is directly under the supervision of the CIAT Tropical Pasture Program. The GRU is responsible for maintenance of the collection [conserved seed, in medium-term storage (5-8^{0}C)], for the routine rejuvenation of samples, and for small-scale seed multiplication to fill requests. Prior to placing in long-term storage, 1,832 samples were rejuvenated. At present, less than 2% of the collection is in long-term storage. From January 1984 to the present, 14 different countries have received a total of 2,068 samples.

The physical diversity of the forage germplasm—two major plant families and hundreds of species—produces problems at several stages of processing within the GRU. Identification is difficult (a reference herbarium is being expanded); seed production is very labor intensive, and seed health testing techniques need to be developed more fully. In collaboration with the Tropical Pastures Program, the GRU will update the forage germplasm catalog regularly.

Projections in the Eighties

For *Phaseolus, Manihot* and tropical forages, further detailed investigation will be required on the status of germplasm in the countryside. Collecting programs will take into account the spread of improved varieties from CIAT, the effect of this on landrace germplasm, and the specific needs of CIAT programs.

The increasing interest in wild relatives of *Phaseolus* and *Manihot* and the diversity of wild pastures plants requires an increased effort to identify samples, and, even more, to indicate morphological relationships as a guide to breeding and selection. Contacts are being made with several taxonomic institutes to help with this effort.

There is strong international interest, through the recently formed FAO Plant Genetic Resources Commission, in the *in situ* conservation of germplasm. CIAT is in an excellent position to stimulate this conservation, in cooperation with national programs, by recommending specific areas needing conservation.

The present research on wide crosses with *Phaseolus vulgaris, P. acutifolius, P. coccineus* and *P. lunatus* will continue. In addition to indicating potential use in breeding programs, this research will help to identify techniques for the seed production necessary for germplasm maintenance. The techniques of electrophoresis research developed for cassava will be applied to *Phaseolus* and tropical forages to produce additional characterization data. All available information—passport, characterization and evaluation—will be collected in the data base and analyzed to provide information on the stability of characters and the potential of accessions. Cooperation with IBPGR for a multisite evaluation of *P. vulgaris* accessions is planned and should provide a model for future evaluations.

The increasing importance of wild relatives means an increased effort in investigating seed dormancy, particularly in *Manihot* species. Seed storage characteristics will also receive attention, particularly in the wide range of species in the tropical forage collection. For both seed and tissue culture, liquid nitrogen storage is being investigated as a potential low-cost, secure storage technique.

Resources and Staffing Requirements

In an effort to provide a better service to CIAT programs and to fulfill international obligations such as servicing the IBPGR designated world base collections of cultivated *Phaseolus* and *Manihot*, a continuing upgrading of GRU facilities is envisaged.

The most urgent requirement for the GRU is the provision of larger, more efficient, cold stores for medium- and long-term storage of the seed collections. A large-capacity seed-drying system has been designed and will be incorporated into the present building. These facilities will allow the urgently needed transfer of all seed collections to long-term storage.

Third-country quarantine facilities are being negotiated. This may eventually involve funding for an institute outside the region to grow and inspect samples under appropriate phytosanitary control.

Based on the IBPGR's general recommendations, projected operational procedures will include the duplication of base collections in other institutes. In the case of *Phaseolus,* this is being actively negotiated with Centro Nacional de Recursos Genéticos (CENARGEN) in Brazil.

No other positions than that of the Head of the Unit are projected (Table 18). The IBPGR Regional Coordinator for Latin America, who is based at CIAT, is a welcome advisor to the GRU on all matters related to germplasm cooperation in the hemisphere and acts as a liaison with IBPGR activities generally.

Table 18. **Research and administrative support units: Summary of actual senior staff positions for period 1980-1985, and projections for period 1986-1990 from core funding (CF) and through special projects (SP).**

Position	Funding source	80	81	82	83	84	85	86	87	88	89	90
Genetic Resources Unit	CF	2	2	1[a]	1	1	1	1	1	1	1	1
Biotechnology Research Unit	CF	-	-	-	-	-	1	2[b]	3[c]	3	3	3
Data Services	CF	1	1	1	1	1	1	1	1	1	1	1
Agroecological Studies	CF	1	1	1	1	1	1	1	2	2	2	2
Seed Unit	CF	2	2	2	2	2	2	2	2	2	2	2
Laboratory Services	CF	1	1	-	-	-	-	-	-	-	-	-
Station Operations	CF	1	1	1	1	1	1	1	1	1	1	1
Training	CF	1	1	1	1	1	1	1	1	1	1	1
Communications	CF	4	4	4	3	3	3	3	3	3	3	3
Administration	CF	6	6	6	6	6	6	6	6	6	6	6
Projects Officer	SP	-	-	-	-	1[d]	1	1	1	1	1	1
Total		19	19	17	16	17	18	19	21	21	21	21

a One position in the GRU remained unfilled during 1982-84 due to overall cuts in the center budgets in those years

b Transfer of virologist from Bean Program.

c Virologist for all CIAT programs.

d Projects Officer (paid from overhead on special projects).

INTERNATIONAL COOPERATION STRATEGIES: EMPHASES AND PROJECTIONS FOR 1986-1990

The principal goals of CIAT's international cooperation activities are to provide for collaboration in research and interinstitutional technology transfer, and to assist in the strengthening of the research capacity of national programs. Projections of cooperative activities related to commodity research priorities, exchange of germplasm, operations of regional/international research networks and collaborative research are contained in the discussions of the individual research programs in the previous sections. Emphasis and projections of center-wide aspects of international cooperation are presented in this section.

Scientific manpower dedicated to agricultural research in developing countries is significantly below that of developed countries. Expressed as a proportion of the value of agricultural production, Latin America, Africa and Asia deployed roughly one-fourth, one-half and two-thirds, respectively, of the manpower resources devoted in North America and Oceania in 1971 (Table 19). Although there is evidence that the overall situation has improved in many countries in recent years, available data shows that progress has been uneven,[49] and that there is still a considerable research manpower gap in relation to needs.

In contrast, manpower devoted to extension in developing countries is significantly greater than in developed countries. This is probably due largely to the assumption commonly made in the fifties and sixties that advanced technology from developed countries could be readily adapted to tropical farming conditions and transferred to farmers—an assumption that has not been confirmed by events. International centers have thus focused on strengthening principally the research components of the agricultural research and development systems in developing countries.

Selective Institution Building Through Training

In the second half of the eighties, training will continue to be the principal means whereby CIAT collaborates with national programs to build their capabilities to cooperatively and independently conduct

[49] Three case studies conducted in Latin America on Argentina, Colombia and Peru, document large outmigration of professionals from national research institutions (E. Trigo, M. Piñeiro and J. Ardila, **Organización de la Investigación Agropecuaria en América Latina**, IICA, 1982).

agricultural research. Virtually all training opportunities offered by CIAT are commodity based and are at 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.

Table 19. **Research and extension manpower resources relative to the value of agricultural product, 1951-1971.**

Region	"Quality-Adjusted" Scientist Person-Years/US$10 Million of Agricultural Product			
	1951	1959	1965	1971
	(In constant 1971 US dollars)			
Western Europe	0.85	0.94	0.89	0.91
Eastern Europe & USSR	0.22	0.39	0.70	0.86
North America & 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	0.56	0.69	0.84	0.92
	(Extension workers per US$10 million of agricultural product)			
Western Europe	-	7.36	7.14	7.71
Eastern Europe & USSR	-	-	-	-
North America & 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

a Excluding People's Republic of China.

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

It is expected that increasing emphasis will be given to universities during the last half of this decade, as they become more active in research. The center will train university staff conducting research and/or teaching production courses that relate to CIAT's commodities and will help develop teaching materials for such courses. Such efforts will have a significant multiplier effect on the utilization of new technology and will contribute to increased productivity and production in the respective commodities.

Agricultural research and extension are well integrated in some developing countries; in many countries, however, these activities developed separately and to a large extent continue to operate independently. Recent advances in developing new technologies have shown that the research-extension gap becomes a serious bottleneck that threatens to offset research gains and prevents their application in farmers' fields. Although CIAT's primary audience is not agricultural extension programs, 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 contribute to the bridging of the gap between those two important functions. As indicated in Section III, on-farm research will receive increasing attention from CIAT's commodity programs in order to evaluate technology. 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. Additionally, CIAT will lend technical assistance to national programs in the organization and conducting of in-country and regional courses for extension personnel working with beans, rice, cassava, tropical pastures and seeds.

Planning Approach for Developing Research Capability

Until rather recently, CIAT mostly followed a "reactive approach," trying to satisfy requests for training from national programs. A more "proactive approach," tried since the early 1980s, will be more fully implemented in the future by assisting national programs in planning their trained scientific manpower needs for the short term (2 years) and medium term (5 years). The long-range objective is the systematic development of strong national commodity teams for research and transfer of improved technologies according to a given program's stage of evolution and its particular interests and priorities.

Selection of Training Candidates

The primary purpose of training is to strengthen the ability of national organizations to carry out research on their respective commodities. Accordingly, training participants must be working actively 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. Final selection is made through mutual consultation and agreement. The type of training is always determined case by case on the basis of the national commodity program's stage of development and its particular needs and priorities (Table 3, Section II). In all cases, the training candidates are selected in order to form research teams for each CIAT commodity, or to train professionals who will contribute to the bridging of the gap between research and extension at the national level.

Regional Emphasis

Reflecting CIAT's primary concern with Latin America and its scientific manpower needs, approximately 80% of the 3,000 professionals trained at CIAT (excluding in-country training courses) between 1969 and 1985 have been selected from this region. As the activities of the center's program expand into Africa and Asia, the number of participants from these regions is expected to increase during the rest of the decade to approximately 30 percent of the total trained each year. Most of such training will be provided through regional courses.

With the expansion of outposting of regional staff, as part of CIAT's decentralized outreach strategy, an increasing part of the research will be conducted at regional, subregional and in-country locations. While some types of training can best be done at CIAT's headquarters, particularly in specialized subjects, the decentralization of research opens up an excellent opportunity for regionalizing training to focus, along with research, on specific problems of different ecologies and subregional characteristics and to maximize the cost effectiveness of CIAT's training resources.

Some experience has already been gained with regional courses on cassava in Asia, subregional courses on beans and in seeds in Central America, and in-country courses in numerous countries. CIAT plans to conduct the following regional and subregional courses on its commodities periodically during the latter half of the decade of the eighties: beans, pastures and seed technology in Central America; rice, pastures and seed technology in the Caribbean; beans in Eastern Africa; cassava in southern and eastern Asia; and possibly beans in the Middle East. These courses will be directed to young researchers, to OFR workers, to educators and to extensionists; the mix will depend on the needs of the respective region.

In-Service Research Training

Many of CIAT's current training opportunities are nondegree programs. Many Latin American and Caribbean countries request opportunities for relatively short, but intensive research training to allow young graduates to become efficient in practical agronomic research and validation/technology transfer activities. With restricted budgetary and manpower resources, these countries cannot assign their personnel for long training periods. Therefore, this type of nondegree, in-service training is expected to be in demand for some time, and CIAT plans to continue providing opportunities for this type of training.

Thesis Training

Because nondegree training does not usually result in commensurate professional and leadership opportunities for the professionals trained and because of the need of highly qualified and independent research capabilities in national programs, the Center must strive to provide increased opportunities for thesis research in conjunction with cooperating universities. Because of the shortage of scholarships for academic degrees, there are at present only a few candidates for graduate thesis work; however, numbers are expected to increase over coming years.

Assistance with In-Country Training

Certain types of training, especially for research personnel with major extension responsibilities, can best be conducted at the country level. To date CIAT has collaborated with 17 countries in planning and conducting 70 in-country courses on aspects of research and production of CIAT's commodities. Throughout the rest of the eighties, CIAT expects to continue to assist national programs in conducting courses that will strengthen their technology validation and transfer capabilities. Increased use will be made of national scientists and consultants from other countries in the region for teaching these courses, thereby minimizing the additional load for CIAT scientists. In addition to increasing cost effectiveness, this will provide for better and more permanent links between research and extension personnel in the respective countries/regions.

Relative Magnitude of Training Activities

Training is coordinated by the Training Office, comprised of one 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 the effective integration of training with research and center-wide application of uniform training standards. Each year some 230 to 300 professionals participate in training at CIAT for periods of 1 to 12 months (selected thesis students stay for longer periods); the average length of stay is approximately 4 months. The total number of participants in CIAT-sponsored training activities in the first half of the eighties increased from around 230 to 360; in the latter half of the decade, this number is expected to increase and level off at about 440. Figure 10 shows these projections through 1990.

The number of courses organized by CIAT is projected to increase from 10 in 1985 to 14 in 1988 and to remain at that level thereafter. Beginning in 1987 intensive, multidisciplinary research courses at CIAT headquarters will decrease from four to two, which means holding a course in each of CIAT's four commodities every other year. This has been done to allow an increase of regional research/production courses from 2 to 4 per year, and to allow for an increase from 4 to 8 specialized courses per year (Table 20). These changes are in line with the development of regional programs and in direct response to the needs and requests from national programs, as well as to the need for more cost-effective use of financial and manpower resources available to the center and to the national programs.

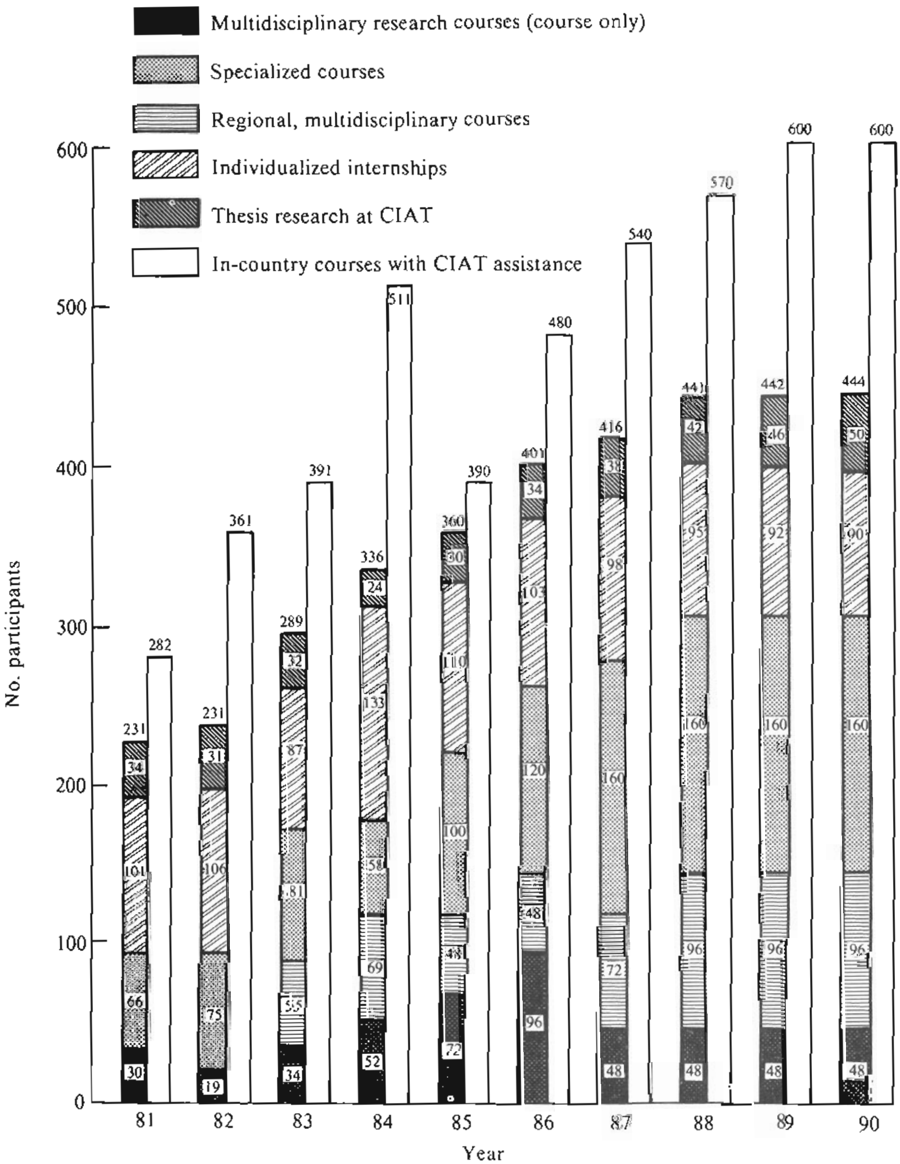

Figure 10. *Number of training participants; actual number of participants for period 1981-1985; and projected numbers for period 1986-1990.*

Table 20. **Number of courses, participants and man-months in CIAT's training activities: actual 1981-1985 and projected 1986-1990.**

TYPES OF TRAINING	81	82	83	84	85	86	87	88	89	90
Group Courses										
Multidisciplinary Research										
courses	4	4	3	4	3	4	2	2	2	2
Participants	30	19	34	52	72	96	48	48	48	48
Specialized Courses										
Courses	3	2	4	2	5	6	8	8	8	8
Participants	66	75	81	58	100	120	160	60	160	160
Regional Courses										
Courses			2	3	2	2	3	4	4	4
Participants			55	69	48	48	72	96	96	96
Total Component										
Courses	7	6	9	9	10	12	13	14	14	14
Participants	96	94	170	179	220	264	280	304	304	304
Individual Training										
Specialization	101	106	87	133	110	103	98	95	92	90
Thesis Research	34	37	32	24	30	34	38	42	46	50
Total Component	135	143	9	157	40	137	36	37	138	140
Subtotals										
Courses	7	6	9	9	10	12	13	14	14	14
Participants	231	237	289	336	360	401	416	441	442	444
Person-Months	792	786	732	945	1290	1398	1428	482	1512	1548
In-Country Courses										
Courses	11	12	13	19	13	16	18	19	20	20
Participants	282	362	391	511	390	480	540	570	600	600
GRAND TOTAL										
Courses	8	18	22	28	23	28	31	33	34	34
Participants	513	598	680	847	750	881	956	1011	1042	1044

A significant increase is projected in the number of professionals carrying out thesis research at CIAT. Although it is difficult to anticipate exact numbers, it is expected that these could increase from the current level of 30 professionals to about 50 per year by the end of the decade. The number of professionals in specialized in-service training at CIAT is expected to remain at high levels, slightly declining from the current number of 110 to about 90 per year, with an average stay of 4 to 6 months at the center.

The number of in-country courses co-organized with the national programs or assisted by CIAT during the first half of the decade has ranged from 11 to 19 per year. After the initial involvement of CIAT's staff in the first two courses, national programs are normally able to organize and carry out the courses on their own. As new countries develop the manpower to carry out in-country courses and as CIAT's regional programs in Africa and Asia consolidate, the demand for CIAT to co-organize or assist in in-country courses will continue and is expected to increase slightly over the coming years. Current projections call for CIAT's staff participating in about 20 courses per year (Table 20).

In summary, plans and projections of training activities for the rest of the decade represent significant changes in its composition. These changes are in response to the evolution of national program needs and CIAT's research activities in the different regions. They represent a movement toward more specialized and degree-related training on the one hand, and toward more decentralized training on the other. The above projections of training activities represent a significant increase in training activities of about 24% in the number of participants and 20% in terms of trainee person-months. Taking into account the projected increases in number of senior staff, the increase in training activities is manageable in terms of the manpower resources projected to be available to the center; nevertheless, it represents a slight net increase in the training load carried by CIAT research staff. At present senior staff are dedicating, on the average, some 12% of their working time to training; with the projected increase in volume and changes in its composition, this percentage load may reach 14 to 15%.

Funding of Scholarships

Approximately one-third of the scholarships for CIAT training participants are core funded; the remainder are financed from special project funds or by/through national institutions. This percentage has been showing a decreasing trend since the beginning of the decade. Because of the relative shortage of funds available to the CGIAR centers, CIAT has been and will continue to be very active in obtaining special project funding and in encouraging individual sponsorships for training scholarships among donor agencies and national institutions. The expansion of training activities for Asia and Africa are expected to be funded almost totally in these ways.

Conferences

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

All three types of conferences will be continued throughout the eighties. The first type, center-wide consultation workshops, will be held every three years, most probably on a regional basis. The second type of conference will be scheduled as needs arise; normally there are 6 to 9 of such specialized workshops every year. Regarding the third type, one world-wide network workshop in each of CIAT's commodities is expected to be held every three years, with regional workshops scheduled for the intervening years.

Because organizing and conducting conferences require considerable financial and other resource investments, conferences will be held only when they contribute to achieving the research and cooperation objectives of both CIAT and the respective commodity research networks. In general, core-financed conferences will not exceed 1% of the total core budget in any one year. Co-sponsorship with other international organizations will be sought whenever the conference subject lies within their interests or mandates.

Information Support: Strategies and Plans

From the communication/information point of view, CIAT assigns major importance to (a) the packaging and dissemination of scientific/technical information produced by the center in a form that is useful to the respective users of such information, especially direct research collaborators; (b) the establishment and maintenance of effective communication channels between researchers and research institutions in the respective commodity networks; and (c) the provision of technical information services to commodity researchers throughout the area of application of CIAT's work.

Packaging and Dissemination of Scientific/Technical Information

CIAT strives systematically to assemble and publish relevant advances in research methodology and technology generation as produced by the center. Together with genetically improved materials and trained specialists, scientific/technical information products complete the triad of tangible products generated by the center.

In defining its audience for CIAT-published scientific/technical information, CIAT places particular emphasis on collaborating research scientists in national agricultural research programs throughout the area of the center's influence. This principal audience is followed by the community of higher learning (faculty and students), particularly in tropical countries, as well as the general agricultural research community in developing and developed countries.

In designing and developing scientific/technical publication materials, CIAT distinguishes among three end purposes as follows:

1. **Network publications.** Highest priority is assigned to scientific/technical materials that feed into the respective commodity networks in which collaborating national research programs and their research personnel participate. Commodity-specific network publications are an important mechanism to keep all members abreast of new technical developments, upcoming events, and research and development results from the different parts of the network.

   Network publications include commodity-specific newsletters, manuals on technology evaluation, compendiums of results of international/regional trials, and publications geared to problems and interests shared by all members. Although network publications are not particularly visible or Olympian in nature, they constitute a most important element in the sustenance and further development of commodity networks.

For the period covered in this medium-term plan, it is projected that of the resources available for publication purposes, approximately 50 percent will be invested in network publications.

2. **Scientific/technical publications.** As an important member of the international agricultural research community and a major technology-generation institution, CIAT has the obligation to make available, through its own publications program and through publishing efforts of its research staff, its research contributions to a larger scientific community.

   To this end, the center engages in the development of various technical publications (including monographs, scientific texts, and conference proceedings) that are made available to the scientific community through distribution channels in the developing and developed world. Approximately 25 percent of the resources available for publication activities will be invested in this type of publication.

3. **Training materials.** CIAT's experience in the dissemination of technical information has confirmed that a large segment of the center's primary audience—i.e., technical personnel in collaborating national programs—can best gain access to new information emanating from the international level if the information is presented in highly structured, didactic form. While this holds especially true for the younger members of the staff of national programs who are in the process of becoming specialized in a given commodity or in a given field, even older, more experienced professionals appreciate having access to multi-media materials that systematically expose them to new information and allow them to acquire specific, well-defined competencies needed to carry out research tasks.

   At the same time, through training materials CIAT is able to reach the very important university community (faculty and students) in a most cost-effective manner. Finally, CIAT's records show that its training materials find their way into a multitude of institutions in both the public and private sector, and are thereby effective disseminators of CIAT-generated information throughout the developing and developed world.

CIAT has already developed a large set of integrated training packages which are continually updated. Additional units are constantly being added. At the same time, CIAT is in the process of diversifying its training materials efforts to add additional media (especially textbooks and video segments).

Approximately 25 percent of publication resources will be invested in training materials in the period 1986-1990. In addition, CIAT hopes to be able to attract additional, special project funds to enhance the basic training materials activity.

Information Services

CIAT maintains a strong information component whose task is to provide direct and immediate technical information services to the research community at CIAT and the members of the respective commodity research networks. Over the years, CIAT has demonstrated leadership in the provision of cost-effective information services in direct support of commodity research efforts.

Information services currently provided comprise the following:

Library Services

A specialized library with a collection of 29,000 books, 2,500 microfiches, and over 2,000 serials provides references and bibliographic research service to the staff of CIAT and to its network collaborators. The Contents Pages, a current awareness service, is published monthly and distributed to CIAT staff and subscribers throughout the tropics. Tables of contents of over 800 journals are listed, and collaborating scientists can order copies of articles in their field.

Specialized Information Centers

In line with its global and restricted global mandate for field beans, cassava, and tropical pastures, CIAT has built up three specialized information centers in support of each of these commodities. Each information center seeks to collect, abstract and file systematically scientific documents on the respective commodities, and to use this data bank to provide scientific information to researchers in these commodities. Services include retrospective searchers, reference and referral, current awareness service, and document delivery. **Volumes of Abstracts** of the scientific literature are published three times yearly and distributed to CIAT staff and subscribers from the research institutions in the tropics.

The level of resources in real terms devoted to the collection, assembly, and distribution of technical information in the period from 1980 to 1985 is projected to be continued at approximately the same levels during the period 1986-1990.

Challenges Ahead

The progressive decentralization of CIAT's work and the gradual build-up of CIAT representation in regions outside the western hemisphere are putting extreme pressure on the delivery of relevant and efficient communication and information support. Researchers in distant regions, speaking different languages, facing different production constraints, and operating in a different information context have—by definition—quite different information needs from those encountered in the relatively homogeneous setting in Latin America and the Caribbean.

In terms of languages, CIAT is responding to the new challenge by increasing its output of network and other publications, and training materials, in French. At the same time, many publication products that traditionally were produced in Spanish only (e.g., audiotutorial training materials) are being translated into English in increasing numbers. However, increased publication in languages other than Spanish and English puts heavy strains on the resources available for communication/information services, and—of course—carries with it important opportunity costs.

Another way in which CIAT is responding to the new challenge is to channel its communication/information services through regional program staff, who are increasingly assuming a communications role in the region in that they help determine the information needs of their collaborators and assist in the assembly of strategies to meet these needs. CIAT headquarters, in turn, seek to backstop the communication efforts of its regional staff to the maximum possible. To be able to count on the required resources, the center attempts systematically to build in resources for communication/ information services in its regional program activities.

Finally, increased efforts will be made to join forces with other IARCs and relevant regional institutions to be able to provide region-based communication and information support to the regional projects and the regional commodity networks in which they participate.

The users of CIAT's communication and information services have a right to expect that the information services available to them continue to increase in sophistication, immediacy, and effectiveness—regardless of the fact that the information base is expanding at an astounding rate. In the coming years, CIAT will attempt to meet these expectations and will do so with the same relative resource allocation as in the first half of the decade of the eighties. This necessarily implies adaptations in the deployment of professional information support staff, and increased emphasis on the use of electronic data systems. Throughout the period under consideration, the number of senior staff in the Communication and Information Support Unit (CISU) will remain at three.

LOOKING TO THE FUTURE: CIAT IN THE 1990s

This mid-term plan represents an updating and fine tuning of the ten-year plan **CIAT in the 1980s,** taking into account developments that have occurred since that document was written and responding to the recommendations of the External Program Review, which used the ten-year plan as a centerpiece for this review.

Towards the end of this decade a new long-range plan **CIAT in the 1990s** will be developed. This will reflect achievements made in this decade, the changing nature and role of the center in relation to stronger national agricultural research systems (NARS), and the center's response to the TAC Strategic Issues Study. The exercise in developing that plan will begin in 1988 and will be an interactive process between the CIAT Board and Management, with the goal of having a final document ready for approval by the CIAT Board of Trustees by mid-1989 for presentation to the CGIAR at Centers Week in November 1989. At an appropriate stage of this process, a consultative workshop with NARS leaders will be held to ensure a special input of these important CIAT partners in the planning process.

While it is premature to comment in detail on the anticipated content of this new long-term plan, certain observations of likely trends can be made. The trend toward greater concentration on activities that come earlier in the technology-generation process (i.e., upstream), as foreseen in the TAC Strategic Issues paper, will surely be evident. However, this transition will probably not be as rapid with crops such as beans, cassava and tropical pastures as with some other crops because of the shorter history of varietal improvement and agronomic research on these crops in the tropics. The trend will also vary considerably in relation to different regions and countries because of the uneven nature of the development of national programs working with these commodities. Nevertheless, to the extent that NARS are strengthened, the current, already advanced process of decentralizing varietal selection and other aspects of technology generation will certainly continue. In this respect less finished technology will be developed by the center; rather, components of technology such as germplasm material or custom-made crosses will be provided, and other types of strategic, backstopping research will be done at the center. As most of the finished varieties and related production technology will be developed by the NARS, the involvement of CIAT outposted staff in this decentralized process will also be reduced when NARS scientists take over this responsibility. The CIAT regional program involvement will be limited more to a liaison function.

In order to backstop these NARS efforts, more strategic research at headquarters will be required in areas such as physiological studies to understand basic plant processes better and increase yield potential; pathology and entomology research on biological relationships rather than on mass screening for resistance; and breeding studies to understand the genetics of inheritance and the fine tuning of breeding methodology. The work of the GRU will concentrate more on characterization of the germplasm, limiting collection to strategic missions to fill clearly identified gaps or to deal with identified emergencies in terms of endangered materials; the climatic and edaphic parameters of microregions in which CIAT's commodities are grown will be better understood making possible more efficient testing and extrapolation of results, and the large data base of these factors will be enhanced by incorporating more agronomic and socioeconomic information. Socioeconomic research will likely deemphasize farming systems research and focus more on impact studies and on the understanding of policy interactions. It is also likely that there will be a considerable increase in the application of biotechnology to crop improvement activities as the results of more basic work on genetic engineering and molecular biology by other institutions provide new techniques that can be practically applied to production-oriented commodity programs. Nevertheless, it is not anticipated that this will include any major element of genetic engineering at the subcelullar level, but rather the application of new techniques in areas such as tissue culture, somaclonal variation, protoplast fusion, and the application of methodology for gene transfer developed by others to meet specific needs of the CIAT commodity programs.

The upstream trend will also be reflected in CIAT's training programs. In the same way as the decade of the eighties saw less emphasis on production courses at the center in favor of expanded involvement in in-country training, the nineties will see this effort turned over largely to national programs with greater concentration of the center's efforts in specialized training, through short courses in special subjects and advanced techniques, thesis research, sabbatical opportunities for national program scientists and longer term internships in selected disciplines.

The 1990s will likely be a decade of much greater stability for the Cassava Program. By the end of the eighties, the market potential for this crop in the various regions will be much better understood. At headquarters the work will be concentrated on germplasm, prebreeding and strategic research related to the backstopping obligations of a center of excellence with a global mandate on this crop, plus such varietal improvement and production research as is appropriate for the Latin America region based on the results of the demand studies. Similarly in Asia and in collaboration with IITA in Africa, crop improvement and production research will have been developed in relation to the identified needs in these regions.

By the end of the 1980s, the size of regional programs should have reached their maximum as projected in this mid-term document. During the 1990s the size of these regional programs will be reduced as the aforementioned trend from strong, local backstopping and catalytic function to largely a liaison function progresses, based on stronger national and regional efforts. At headquarters no substantial increase in senior staff numbers is currently foreseen. While there will be an increase in the amount of upstream strategic research and, undoubtedly, some new activities demanded by yet unforeseen problems, it is anticipated that such demands will largely be offset by the concurrent phasing down of current on-farm and production agronomy research, and backstopping for development projects. The TAC and the center will, of course, need to interact on possible new CGIAR activities that could be handled efficiently and effectively through the excellent infrastructure and relationships that have been developed at CIAT, which may result in some future modification of the mandate. However, unless the CIAT mandate is changed, it is expected that the size of the center at headquarters will remain at approximately the level projected for the end of the 1980s and that the total size of the center activities will experience a modest decline.

CENTER-WIDE SENIOR STAFFING PROJECTIONS: 1986-1990

The specific projections for the rest of the decade of the eighties contained in this plan for each of the programs and units of the center include projected senior staff positions the center considers to be essential for carrying out its mandate.

The projected senior staff needs represent the highest priority activities within a range of possible options. In this sense the projections represent best estimates of the most appropriate staffing pattern of the center. As overall financial requirements can be more or less gauged by the number of senior staff, the following projections can also be used as an indication of probable future budget requests.

Definition of Sources of Funding

The detailed staff projections and explanations given throughout this document for each program show considerable expected evolution in program activities. In those projections a distinction has been made with regard to source of funding.

The CGIAR system is currently undergoing a revision of budgeting and financial procedures with a view to rationalizing the current situation in which funding for the centers is received in a variety of ways and in which there is a need for a clearer definition of system-wide procedures and funding categories. The dimensions of the final outcome of this revision are as yet undefined. As an interim measure, this revised plan for CIAT for the remainder of the decade of the eighties refers to three basic funding sources as follows:

Core Funding (CF)

Core funding refers to the CGIAR-funded budget to CIAT, including all currently "Transferred Special Projects."

Corelike Funding (CL)

Corelike funding refers to long-term activities as defined in the Long-Range Plan of the center and for which funds are presently provided through special projects negotiated directly with the donors by the center. They are similar in nature to those previously approved by TAC as Transferred Special Projects.

Special Project Funding (SP)

Special Projects cover short-term activities of the center that are clearly complementary to core and corelike activities, but for which a time frame has been established with a definite date of termination; i.e., when the projects have achieved stated short-term objectives.

Senior Staff in the Eighties

Table 21 presents global information on the actual senior staff positions at the center during the period 1980-85. Actual positions refer only to the staff positions filled over this period and do not include approved positions that remained unfilled because of budgetary constraints during these years. The figures do not include bilateral positions. During this period total senior staff funded from all sources were reduced from 68 in 1980 to 60 in 1983 as a reflection of budgetary constraints on the center, mainly in core-funded positions. In 1984 the center began to increase the number of actual senior staff; this took place in decentralized positions, as well as the restoration of the GRU position, and creation of full-time leaders' positions at headquarters in 1985 as recommended by the second EPR.

In 1985 a significant increase occurred mainly as a result of the decentralized projects in Africa under corelike funding. This trend will continue as research and development activities continue to increase on that continent.

Growth in senior staff at headquarters is projected to increase from 60 in 1985 to 65 by the end of the decade. Most of this increase is projected to occur in the research support units (Biotechnology and Agroecological Studies), as well as the restoration of some positions in the Cassava Program by the end of the decade. The grand total of 92 senior staff positions by the end of the decade is considered to be manageable with present administrative staff. In the case of Africa CIAT will move to increased decentralization of administrative functions as the Africa-wide coordinator position comes on stream.

Decentralized Regional Program											
Core funded	-	-	-	1	1	1	1	2	2	2	2
Corelike projects	-	-	-	-	-	-	-	1	1	1	1
Special projects	1	-	-	-	-	-	1	1	1	1	1
Program Total	12	10	10	8	8	9	10	13	14	14	14
B. **RESEARCH SUPPORT UNITS** (Headquarters based, core funded)											
Agroecological Studies Unit	1	1	1	1	1	1	1	2	2	2	2
Germplasm Resources Unit	2	2	1	1	1	1	1	1	1	1	1
Station Operations Unit	1	1	1	1	1	1	1	1	1	1	1
Biotechnology Research Unit	-	-	-	-	-	1	2	3	3	3	3
Seed Unit	2	2	2	2	2	2	2	2	2	2	2
Data Services Unit	1	1	1	1	1	1	1	1	1	1	1
Training Coordinator	1	1	1	1	1	1	1	1	1	1	1
Communication & Information Support Unit	4	4	4	3	3	3	3	3	3	3	3
Laboratory Services	1	1	-	-	-	-	-	-	-	-	-
Subtotal	13	13	11	10	10	11	12	14	14	14	14
C. **ADMINISTRATION**											
Directors and Administrative											
Staff (Headquarters based, core funded)	6	6	6	6	6	6	6	6	6	6	6
Projects Officer (Special Project funded)	-	-	-	-	1	1	1	1	1	1	1
Subtotal	6	6	6	6	7	7	7	7	7	7	7
TOTAL CORE FUNDED	65	66	64	58	60	65	68	72	73	74	74
TOTAL CORELIKE PROJECTS	-	-	-	1	3	8	11	12	13	13	13
TOTAL SPECIAL PROJECTS	3	1	1	1	1	2	5	5	5	5	5
TOTAL HEADQUARTERS	60	60	58	53	55	60	61	64	64	65	65
TOTAL DECENTRALIZED	8	7	7	7	9	15	23	25	27	27	27
GRAND TOTAL	68	67	65	60	64	75	84	89	91	92	92

Table 21. **Actual senior staff positions (1980-1985) and projected positions (1986-90) in CIAT research programs, research support units, and administration in core-funded positions, corelike projects and special projects.**

Senior Staff Positions	80	81	82	83	84	85	86	87	88	89	90
A. COMMODITY RESEARCH PROGRAMS											
Bean Program											
Headquarters based, core funded	9	9	9	10	11	12	11	12	12	12	12
Decentralized Regional Programs											
Core funded	4	4	4	4	4	4	5	4	4	4	4
Corelike projects	-	-	-	1	3	7	10	10	10	10	10
Special projects	-	-	-	-	-	-	1	1	1	1	1
Program Total	13	13	13	15	18	23	27	27	27	27	27
Tropical Pastures Program											
Headquarters based, core funded	17	17	17	15	15	15	15	14	13	14	14
Decentralized Regional Programs											
Core funded	3	3	3	1	1	2	3	4	5	5	5
Corelike projects	-	-	-	-	-	-	-	-	1	1	1
Program Total	20	20	20	16	16	17	18	18	19	20	20
Rice Program											
Headquarters based											
Core funded	3	4	4	4	5	6	7	7	7	7	7
Special project (IRRI)	1	1	1	1	1	1	1	1	1	1	1
Decentralized Regional Programs											
Corelike projects	-	-	-	-	-	1	1	1	1	1	1
Special projects	-	-	-	-	-	-	1	1	1	1	1
Program Total	4	5	5	5	6	8	10	10	10	10	10
Cassava Program											
Headquarters based											
Core funded	10	10	10	7	7	8	8	9	10	10	10
Special projects	1	-	-	-	-	-	-	-	-	-	-

APPENDICES

APPENDIX 1

Growth in production, area and yield of selected commodities in Tropical America[a]. Annual rates (%) for the periods 1960/69, 1969/78 and 1978/83.

PRODUCTION			
Beans	-1.8[b]	-0.6	3.0
Cassava	6.0	-1.5	-1.5
Potatoes	4.0	2.9	-0.8
Maize	4.6	2.0	5.6
Rice	3.4	4.1	2.9
Sorghum	24.2	8.2	6.2
Soybean	20.8[b]	25.8	8.3
Wheat	5.2	4.3	2.7
AREA			
Beans	-1.5[b]	1.4	3.0
Cassava	5.6	0.8	-0.2
Potatoes	4.5	0.6	-2.0
Maize	3.5	0.7	1.2
Rice	4.3	3.1	-0.1
Sorghum	18.3	6.2	2.3
Soybean	21.4[b]	23.4	0.8
Wheat	0.4	4.8	-4.6
AVERAGE YIELDS			
Beans	-0.2[b]	-2.0	0.0
Cassava	0.4	-2.3	-1.2
Potatoes	-0.5	2.2	1.2
Maize	1.1	1.4	4.4
Rice	-.08	1.0	3.0
Sorghum	5.9	1.9	4.0
Soybean	-0.7[b]	2.4	7.5
Wheat	4.9	-0.5	7.3

a All countries excluding Argentina, Chile, Uruguay, U.S. and Canada.

b Period 1966/69.

APPENDIX 2

Increases in production of animal products in Tropical America[a]; growth rates (%) for 1968/75 and 1976/83.

	1968-1975		1976-1983	
Commodities	Total production	Per capita production	Total production	Per capita production
Beef and veal	2.6	-0.2	1.6	-1.0
Milk	3.6	0.8	1.8	-0.8
Poultry meat	9.2	6.0	10.5	7.9
Swine	3.4	0.7	2.8	0.2

a All countries excluding Argentina, Chile, Uruguay, U.S. and Canada.
Source: FAO, Production tapes.

APPENDIX 3

Net imports ('000 metric tons) of selected commodities in Tropical America[a]; averages for 1960/62, 1970/72 and 1981/83.

	1960-1962	1970-1972	1981-1983
Sorghum	41	392	3,503
Maize	-74	-471	5,391
Wheat	3,953	5,665	10,403

a All countries excluding Argentina, Chile, Uruguay, U.S. and Canada.
Source: FAO, Trade Yearbook.

APPENDIX 4

Latin America: Percent of total calories by source, 1975-77.

Country	Sugar	Wheat	Maize	Rice	Cassava	Potatoes	Beans	Beef	Dairy	Oils
Mexico	16.6	11.4	36.7	2.0	0	0.6	4.8	2.1	5.4	7.8
Tropical South America										
Brazil	18.4	11.9	8.2	15.5	8.0	0.8	6.4	4.6	5.3	7.6
Bolivia	13.6	18.2	11.9	7.4	4.6	9.3	0.9	4.4	1.7	7.8
Colombia	23.8	5.6	11.7	13.1	5.1	3.8	1.3	5.9	5.2	7.7
Ecuador	19.2	11.7	9.5	9.9	2.6	5.6	0.8	3.0	7.6	7.9
Peru	15.9	17.8	9.5	11.4	2.4	6.6	1.9	1.5	4.1	9.3
Paraguay	7.3	6.3	19.4	4.8	14.9	0.07	7.6	7.5	2.8	7.0
Venezuela	18.2	13.4	15.3	5.4	1.9	0.8	2.0	5.7	7.9	8.9
Central America										
Costa Rica	24.5	11.1	7.8	15.5	0.5	0.8	3.9	4.1	8.0	11.4
El Salvador	14.9	6.5	36.8	3.1	0.4	0.6	4.1	1.3	4.8	8.6
Guatemala	16.2	8.1	47.7	1.6	0.1	0.3	4.9	1.6	3.6	6.8
Honduras	16.6	5.6	44.6	2.8	0.3	0.09	3.3	1.3	4.1	7.1
Nicaragua	18.9	6.0	28.0	6.1	0.9	0.2	7.2	4.4	5.6	9.2
Panamá	14.3	8.9	8.5	26.3	1.7	1.1	6.3	6.3	3.9	9.3
Caribbean										
Cuba	20.0	20.1	0	18.3	1.9	0.9	0.8	3.5	7.7	8.9
Dominican Republic	15.8	9.0	2.7	19.5	3.4	0.2	3.5	1.9	5.0	11.3
Haiti	13.6	7.0	15.2	9.0	2.8	0.1	4.1	1.2	1.5	3.3
Jamaica	19.1	22.0	3.2	7.7	0.9	0.3	0	2.5	4.2	11.0
Temperate South America										
Argentina	11.8	27.0	1.3	1.3	0.4	2.9	0.3	16.8	7.2	11.4
Chile	12.4	45.2	1.7	2.9	0	3.3	1.5	5.5	5.5	8.2
Uruguay	13.6	26.8	3.1	2.8	0.06	2.1	0.3	17.9	10.2	9.3

Source: FAO Food Balance Sheets.

APPENDIX 5

Protein sources in Latin American diets; percent of total protein by sources, 1975-77.

Country	Beans	Beef	Pork	Chicken	Eggs	Wheat	Rice	Maize	Dairy	Fish
Mexico	10.0	7.3	3.3	1.9	2.7	12.6	1.5	37.8	12.6	2.0
Tropical South America										
Brazil	16.9	12.8	4.6	2.8	1.6	13.1	12.6	7.5	11.8	3.3
Bolivia	0.4	12.1	3.7	0.5	1.3	20.4	5.6	12.0	3.8	0.7
Colombia	2.5	19.7	3.1	1.9	2.1	6.8	11.9	13.6	15.2	2.1
Ecuador	4.2	9.2	3.2	1.6	1.8	13.2	8.4	10.4	17.4	5.2
Paraguay	15.2	17.1	9.6	1.4	2.1	6.9	3.4	17.7	5.0	0.4
Peru	3.6	4.8	2.6	4.6	1.4	22.4	8.7	9.6	10.4	6.5
Venezuela	4.9	15.4	2.9	6.8	2.9	16.5	4.0	12.5	16.3	5.7
Central America										
Belize	9.5	12.9	5.0	2.9	2.0	14.6	9.8	7.1	24.1	2.0
Costa Rica	10.8	14.3	2.2	0.9	3.4	12.7	13.1	8.8	21.7	2.1
El Salvador	10.3	6.3	2.0	1.3	3.3	6.4	2.4	36.4	15.4	1.1
Guatemala	11.0	7.1	1.1	1.3	2.4	10.1	1.1	46.9	10.1	0.6
Honduras	8.9	6.8	1.4	1.9	2.9	6.0	2.3	47.0	12.2	0.6
Nicaragua	16.3	14.1	2.8	1.3	4.1	5.7	4.3	25.4	17.9	2.1
Panama	2.8	24.0	2.6	2.9	3.1	10.4	21.1	8.8	9.7	2.8
Caribbean										
Cuba	1.9	9.9	2.8	3.7	3.4	21.7	14.0	0.0	17.7	7.7
Dominican Republic	8.4	7.2	2.6	4.6	2.3	10.9	8.4	18.8	3.7	1.2
Haiti	11.0	3.5	3.5	0.4	0.8	9.6	7.3	16.5	3.3	1.0
Temperate South America										
Argentina	0.4	42.0	3.0	2.5	1.8	21.9	0.8	0.9	12.3	1.1
Chile	3.6	11.8	1.7	1.8	2.0	46.4	3.0	0.4	12.4	0.7
Uruguay	0.4	32.7	2.1	1.8	1.6	23.9	1.8	2.4	19.1	1.6

Source: FAO Food Balance Sheets.

APPENDIX 6

The nutritional role of beans in Sub-Saharan Africa, 1979-81.

Country	% Total protein from beans	Rank of beans among protein sources	Rank of beans among quality proteins[a]
Eastern Africa			
Kenya	18.0	2	1
Somalia	1.6	13	10
Tanzania	8.3	2	1
Uganda	21.0	1	1
Great Lakes Region			
Burundi	31.5	1	1
Rwanda	36.6	1	1
Zaire	4.8	6	3
Southern Africa			
Lesotho	3.9	5	2
Madagascar	4.1	3	2
Malawi	5.8	3	1
Rep. South Africa	2.0	7	6
Swaziland	1.4	10	5
Zimbabwe	3.0	7	2
West Africa			
Cameroons	10.5	3	1

a Quality protein is defined as protein from meat, fish, dairy, pulses and eggs.
Source: FAO Food Balance Sheets, 1984; Kenyan data adjusted by Mjunganah et al., 1980.

APPENDIX 7

Growth rates in bean production, area and yields in selected[a] African countries, 1962-70 and 1970-81.

	1962-1970			1970-1981		
	Production	Area	Yield	Production	Area	Yield
Eastern Africa						
Ethiopia	2.44	1.02	1.54	-20.21	-21.62	-1.53
Tanzania	4.25	1.24	2.50	1.43	1.61	-0.15
Uganda	7.95	9.62	-1.66	1.39	-0.53	1.92
Great Lakes Region						
Burundi	3.46	6.04	-2.58	-2.43	-2.67	-0.10
Rwanda	7.46	4.98	2.43	3.06	3.59	-0.55
Southern Africa						
Angola	2.20	8.60	-6.57	-4.34	-0.61	-3.76
Rep. South Africa	1.39	-2.43	4.29	3.87	-1.22	5.02
Zimbabwe	2.15	-0.45	2.88	-0.87	-2.41	1.55

a Countries with obvious discontinuities in data or short series of data have been eliminated.
Source: FAO Production Yearbooks.

APPENDIX 8

Bean yields in Sub-Saharan Africa; averages (kg/ha) for 1962-64, 1971-73, 1981-83.

Country	1962-64	1971-73	1981-83
Eastern Africa			
Ethiopia	705	734	757
Kenya	a	a	624[b]
Somalia	150	500	333
Tanzania	430	524	498
Uganda	650	632	958
Great Lakes Region			
Burundi	684	813	980
Rwanda	741	861	830
Zaire[c]	a	a	503
Sothern Africa			
Angola	896	592	364
Lesotho	333	231	769
Madagascar	774	838	732
Malawi	538	625	529
Rep. South Africa	517	689	1140
Swaziland	150	500	1000
Zimbabwe	396	500	750
West Africa			
Cameron	750	494	656
Total	627[d]	679[d]	704

a Data not available.

b 1974-75 estimate. See Njungunah et al., 1980.

c Zaire's bean production occurs in Kivu province in the Great Lakes region.

d Not including Kenya and Zaire.

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