Horizons for the Future :

Strategic Plan for CIAT for the 1990s and Beyond

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CHAPTER ONE

CIAT IN PERSPECTIVE

The CIAT Experiment

Founded in 1967, CIAT was an experiment in developing a new type of international agricultural research center.

The essentially humanitarian reasons for CIAT's creation were similar to those for its predecessors in the international agricultural research system. Food production in developing countries was failing to keep pace with population growth; unless the output of basic staples could be rapidly increased, hunger would afflict growing numbers of the world's poorest people. By the time CIAT came into being, research by the system's two earliest centers, the International Rice Research Institute (IRRI) and the International Wheat and Maize Improvement Center (CIMMYT), had already begun to show significant pay-off for two of the developing world's most important food staples, wheat and rice. These early successes inspired the hope that developing the international center concept would make a rapid and substantial contribution to solving the global food crisis. Establishing additional centers would be an effective means of extending the new technology successfully developed in Mexico and South-East Asia to new areas and new products. In addition, the adoption of a farming systems focus would ensure that new technology would reach smaller farmers, and that appropriate production systems for less fertile areas would be developed.

The model for CIAT, like that of its sister center the International Institute for Tropical Agriculture (IITA) founded in the same year, was therefore markedly different to that of IRRI and CIMMYT. Whereas the two earlier centers had been given global mandates for one or two specific basic commodities about which much was already known, the mandates of the two new centers were more regional in character and embraced a wider range of comparatively neglected products which, at foundation, were less clearly specified. In addition, there was a new emphasis on ecosystems. CIAT's task was to develop technologies and production systems to exploit the potential of the humid lowland tropics of Latin America, while IITA fulfilled a similar function in West and Central Africa. Both centers were to adopt a farming systems approach, developing new systems to suit fragile environments. IITA's aim was to stabilize the shifting cultivation systems of the African humid and subhumid zones; CIAT's to open up the underexploited acid-soil savannahs of Latin America. The far-sightedness of these original aims is borne out by their continuing relevance today.

An Evolving Program

With its wide variety of ecologies and production systems, Colombia offered the necessary research locations for a center serving tropical Latin America and the Caribbean. Besides having strong national institutions, Colombia also had a history of close working relationships with the Ford and Rockefeller Foundations, the two agencies responsible for the establishment and initial funding of CIAT. Choosing Colombia as the Center's host country was therefore logical on both scientific and institutional grounds.

The original proposal for the Center had suggested a wide array of initial activities, including research on at least one food legume, on forage legumes and grasses, and on beef cattle production, as well as limited work on rice and maize in collaboration with CIMMYT and IRRI. Root crops, vegetables and tropical fruit crops were suggested for possible inclusion at a later stage.

Reflecting the difficulty of selecting priorities from this list on the basis of the information then available, CIAT's first Board of Trustees designed the Center's initial program around disciplinary groups rather than commodities. Four groups were formed, consisting of plant sciences, animal sciences, service disciplines (economics, engineering, biometrics), and training and communications.

This initial structure was retained for only a short time. By the early 1970s, CIAT had begun to move towards a multidisciplinary commodity-based approach, with programs taking shape as the understanding of research priorities improved. Programs on rice, swine and beef were the first to emerge, followed shortly by cassava and beans. The aim was to develop a set of commodities that gave adequate emphasis to both urban and rural equity. All programs were to adopt a farming systems approach, but a small farm systems program was also launched, giving added emphasis to the need to reach small-scale producers.

The major evolution during the 1970s was the redefinition of the multi-faceted beef program, whose ambitious agenda in animal health, husbandry and nutrition was discarded once it was realized that feed quality, rather than disease, was the major constraint to the increased production of milk as well as beef, and that the infertile acid-soil savannahs offered a major opportunity to solve the problem, provided appropriate soil-enhancing technology could be generated. The result was a much streamlined tropical pastures program, sharply focussed on the development of improved, legume-based pastures. Two further changes during the decade were the phasing out of the swine program, following the realization that the returns to further research on this species would not be as high as for other commodities, and the reabsorption of the functions of the small farms systems program within commodity programs adopting a farming systems perspective. A systems-oriented program had been useful during the diagnostic phase of the early years, but the main priority now was to aim for maximum impact by developing improved system components. All three changes thus demonstrated the vigor of a young Center learning rapidly from experience.

Thus, by the late 1970s, CIAT's current set of four commodity programs had evolved. The commodities had been selected on the basis of their contribution to the diets and incomes of resource-poor farmers and consumers in tropical America. Beans and cassava had been chosen because they were grown almost entirely by small-scale producers, but also because both commodities were important in the diets of poor urban consumers. Rice, found on somewhat larger farms, was the preferred convenience food of city dwellers; lowering its price on the urban market was seen as a powerful means of benefitting low-income consumers. Beef and milk, produced from cattle raised on medium- to large-scale ranches, were staples across social classes, but had been found to be especially important for low-income urban consumers. In order to target technology toward resource-poor farmers, a low-input approach to research was adopted and applied across programs.

For beans and cassava, CIAT now has global responsibility. In the case of cassava, the Center supports IITA in meeting the regional mandate for Africa. For rice, CIAT's responsibility is restricted to Latin America and the Caribbean, since IRRI has overall global responsibility for this commodity. For tropical pastures, CIAT has primary responsibility for Latin America and the Caribbean, and global responsibility for selected species of pasture germplasm.

CIAT is thus a Center with a dual nature. Global responsibilities for specific commodities have been acquired over the years, and are now superimposed on the regional and ecosystems focus implicit at foundation. This evolution, which runs counter to that in the CGIAR system as a whole, is reflected in the formal mandate statement agreed by the Board of Trustees in 1983, according to which the Center's task is 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 emphasizes the food production (growth) and poverty alleviation (equity) objectives typical of an early 'Green Revolution' center, omitting explicit reference to the resource conservation (sustainability) objectives characteristic of the system's second generation centers.

The 1980s saw the consolidation and expansion of CIAT's program as the Center responded to both its regional and its global commodity responsibilities. The number of professional core staff rose by one third during the decade to reach its current level of 82. These are complemented by a further 12 special project staff. Overall, CIAT is now a relatively decentralized center, with about one third of its professional staff posted away from headquarters. Some 15% of professional staff are outposted in Latin America and the Caribbean, representing a considerable advance over the limited presence outside Colombia of a decade ago. A further 17% are outposted in Africa and Asia. The 13 scientists in Africa represent a substantial commitment to the problems of resource-poor farmers in that continent.

Besides outposting its own staff, CIAT is host to a number of initiatives of other institutions in the international research system. The staff of CIMMYT's Andean maize program are based at CIAT headquarters, providing important opportunities for collaboration with CIAT's beans and cassava programs, these two crops being the ones with which maize is most frequently intercropped. An IRRI scientist is a member of CIAT's rice program, ensuring the flow of information and germplasm between the two institutes. Work by the International Sorghum and Millet (INTSORMIL) program, whose regional initiative is based at CIAT, has provided a strong basis for the development of acid-tolerant sorghum varieties for the savannahs. The regional office of the International Board for Plant Genetic Resources (IBPGR) is also located on the CIAT compound, ensuring effective collaboration in germplasm collection and storage. Lastly, the Andean regional team of the Centro Internacional de la Papa (CIP) has its offices in Bogota, under the CIAT agreement with the Colombian government.

CIAT's core budget in 1990 amounted to US$ 28.1 million, with a further US$ 4 million of special project funding. In budgetary terms CIAT is the fourth largest center in the CGIAR system, after IRRI, CIMMYT and ICRISAT. The system has approved 89 professional staff positions regarded as necessary to conduct the Center's essential program, and a further 17 positions regarded as desirable for complementary activities.

Taking Stock

Has the CIAT experiment been a successful one? As the Center looks forward into the 1990s and beyond, it is important to assess the degree to which its current programs have fulfilled the dual nature of the Center's mandate. Combined with an analysis of future trends in CIAT's external environment (See Chapter 2), this assessment will provide a basis for identifying those areas to which CIAT will be able to devote fewer resources in future, and those in which it must seek to build an additional capacity in order to meet evolving needs.

CIAT's main strength undoubtedly lies in its four commodity programs, whose continuity of funding and stability of objectives over the last decade have enabled each to make an outstanding contribution both to the stock of knowledge and to the generation of seed-embodied technology to increase output.

The rice program has successfully developed genetic materials to overcome the production constraints specific to tropical America and to meet the preferences of the region's consumers. An estimated 80% of the region's irrigated rice area is now planted with varieties developed through joint research by CIAT and national institutions. These new plants have led to additional annual production with an estimated value of US$ 1.7 billion, with substantial rises in average yields. Recently, the program has developed semi-dwarf upland rice materials with tremendous potential for rice-based ley farming in the savannahs (see 1.). Significant contributions have also been made in understanding the rice pests and diseases prevalent in tropical America, and in developing components for integrated pest management to tackle the overuse of pesticides in irrigated systems.

Collaborative research by the bean program has led to the release of over 50 new bean varieties by national programs in tropical America and Africa, resulting in increased yields worth approximately US$ 50 million annually. Most beans are grown by resource-poor farmers, with the result that this group has been the main beneficiary. The chief constraint of bean production is the crop's extreme susceptibility to pests and diseases, over 200 of which have been identified. Sources of resistance to the most economically important of these have been found and combined. The I-gene, which confers resistance to bean common mosaic virus in exotic material, has been bred into all new varieties released in tropical America. The discovery of arcelin, a protein conferring resistance to bruchids, has led to significant progress in research to overcome bean storage problems. The program has contributed to a better understanding of the dynamics of nitrogen fixation in beans, identifying significant genetic differences in the ability to nodulate. High-yielding climbing beans specifically selected for intercropping with maize have been introduced in Andean countries, leading to higher total system productivity and the spread of maize-beans intercropping to areas where maize was previously grown as a monocrop. Similar materials have also been introduced in Africa, where several new varieties are now being released.

The cassava program has contributed to the development of some 28 new cassava varieties in tropical America and Asia, and to the establishment of small-scale processing industries in seven tropical American countries. Again, resource-poor producers have been the main beneficiaries. When combined with improved management, some of the new materials yield 100% more than traditional varieties. Systems incorporating these materials are being widely adopted by farmers in Colombia, Cuba and Brazil. Research in support of IITA's biological pest control project has led to the identification and release in Africa of an effective natural enemy against cassava mealy bug, an important pest responsible for heavy crop losses. The discovery of the intermediate photosynthetic pathway of cassava, which shares characteristics of both C-3 and C-4 plants, has important implications for improving the crop's tolerance of drought and poor soil conditions.

Research by the pastures program has resulted in the rapid development of legume-based pastures adapted for acid, infertile soils. More than 23 000 accessions of grass and legume species, many of them undomesticated, have been acquired. Approximately half of these have now been characterized and tested, leading to the release of several new cultivars by national programs. The most promising pasture associations allow a tenfold increase in livestock carrying capacity, with the liveweight gains of cattle rising from 70-90 kg per year to 180-200 kg per year. On-farm research in Colombia and elsewhere has shown that farmers are willing to adopt the technology provided seeds are available. Now established on more than 750 000 ha, this technology is poised for take-off.

Strong performers both individually and in collaboration with national programs, CIAT's commodity programs have had somewhat less interaction with each other. A notable exception has been the recent collaboration between the rice and tropical pastures programs, which are developing a highly promising ley farming system for the acid-soil savannahs. In this system, the profitability of new semi-dwarf upland rice varieties grown as an initial cash crop allows farmers to purchase the seeds needed for the improved pasture phase of the rotation, which can be established without using additional fertilizer. Rice planted after the pasture phase yields 50% more than it would following native grassland, using the same fertilizer treatment.

The work of the commodity programs has been supported by a number of specialized units whose expertise has been critical to success. The Genetic Resources Unit assists in assembling, maintaining and characterizing CIAT's global collections of cassava, beans, grasses and forage legumes, which now represent an invaluable resource for current and future germplasm development. The Virology Unit ensures that materials received and distributed by CIAT are free of diseases, develops improved seed health tests, and helps to identify sources of disease resistance. The Biotechnology Research Unit acts as a bridge for the introduction to CIAT and its national research partners of advanced breeding techniques developed in specialized laboratories. The Agro-Ecological Studies Unit analyzes climate, soils and other data relevant to the targeting of improved germplasm and to the biological control of pests and diseases. The Seed Unit produces and distributes basic seed of new varieties, develops seed production techniques and helps strengthen national seed supply systems. Lastly, the Data Services Unit provides advice and assistance in experimental design, the analysis of results, and the development of databases.

Networking, training and communications activities have been fundamental to CIAT's approach to commodity research, allowing a catalytic impact on the growth and productivity of national research teams.

CIAT has been instrumental in the creation and/or coordination of some 15 subregional networks devoted to applied and adaptive research on its four mandate commodities (See Figure 1). Through the division of labor and the sharing of research results, these networks are an important mechanism for enhancing the cost-effectiveness of national research. In addition, three advanced research networks have been created. Through these, CIAT plays a key role in bringing specialized techniques to bear on the most important biological constraints associated with its mandate commodities.

Training and information activities in support of the research program are well developed at CIAT. By 1990, over 4000 people had participated in group or individual training activities at CIAT headquarters or in collaborating countries. As a result of these efforts several countries now have strong teams conducting research on commodities on which virtually no research was conducted previously. The Center has built a comprehensive library collection, and developed specialized library services. Training materials (audio-tutorials and manuals) and other publications are also produced and disseminated.

In sum, the strength of CIAT's commodity research over the last 15 years has led to many achievements. For all four commodities, the knowledge base has expanded tremendously, particularly with regard to the sources of resistance/tolerance to a wide range of biotic and abiotic stresses. In the case of rice, which was a comparatively well researched crop when CIAT was founded, the rapid and dramatic gains achieved in output constitute an impressive response to the challenge of meeting regional growth and urban equity needs. With regard to beans, cassava and tropical pastures, where the knowledge base was virtually non-existent before CIAT began work, the impact on output has been slower to materialize but still significant, with many exciting developments now in the pipeline.

Specifically designed to meet the needs of resource-poor farmers, CIAT's low-input approach to research has constituted an effective response to sustainability and rural equity considerations, without entailing sacrifices in yields. Plants selected under low fertility conditions tend to be highly efficient users of scarce nutrients, and therefore highly responsive to added inputs. Genetically induced resistance to major pests and diseases minimizes the need for agro-chemicals, saving scarce foreign exchange and reducing pollution.

CIAT has therefore responded well to one of the tasks entrusted to it at foundation, namely that of defining priorities among a set of relatively underresearched set of commodities and generating knowledge and technology to increase their productivity. But what of the other task - that of designing sustainable production systems for tropical America's fragile environments?

The main thrust of CIAT's research in this area has been the development of legume-based pastures adapted to acid soils, a technology that is widely applicable across the several ecosystems in which such soils are prevalent. Throughout most of the 1980s efforts were devoted mainly to the component research required to generate new grass and legume lines and test these in association under different management regimes. Only recently has research progressed to the systems level, testing the use of improved pastures to sustain a new rice-based ley farming system for the savannahs. The highly promising results obtained suggest that the pasture technology should now be adapted for other ecosystems and rotated with other crops. Both in hillside and cleared forest areas, improved pastures may have a vital role to play in improving the resource base through the organic recycling of nutrients, and hence in regenerating degraded land. Improved cereal ano grain legume materials developed by CIAT, CIMMYT and national programs are now available for use as the food crop components of the rotation.

In conclusion, now that improved system components are available, it is time for CIAT to give greater emphasis to the regional ecosystems aspect of its mandate implicit at foundation. Yet if the Center is to adopt this course, it must do so without sacrificing the special advantages acquired over 15 years of commodity research. The Center's future program must balance change and continuity.

CHAPTER TWO

CIAT'S FUTURE ENVIRONMENT

The environment external to CIAT is changing fast and will continue to do so. Four spheres in which change is taking place are of special importance to CIAT, forming the backdrop against which the Center must develop its strategy for the 1990s and beyond. Advances in global agricultural science and technology determine the opportunities for CIAT and its research partners to apply new methods and approaches to the agricultural problems of developing countries. Trends in tropical America's economic and agricultural development form the setting in which research topics must be selected and the results of research applied. The evolution of the international agricultural research system influences the objectives of CIAT's research and the roles the Center is likely to perform. Lastly, the changing roles of CIAT's major research partners, the national and regional research systems of tropical America and the specialized institutions of the developed world, also affect the research agenda.

Advances in Agricultural Science and Technology

Strategic research

The gains in yield potential achievement through crop improvement research over the last decade have been limited by the comparatively underresearched species, more heterogeneous production systems and marginal environments on which post-Green Revolution research has had to focus. Recent advances in strategic research suggest that progress in the 1990's will be somewhat more rapid.

Research to modify the genetic make-up of crops follows one of two avenues: either it seeks to increase yield potential directly, by incorporating traits associated with high agronomic performance, as the Green Revolution technology did; or it seeks to defend the plant against yield losses, by incorporating resistance to biotic and physical stresses, and so to increase yield potential indirectly.

Strategic research along the first of these avenues is likely to allow moderate gains in yields over the short to medium term. Biotechniques are creating new opportunities for the transgenic transfer of yield-increasing genes. Quantitative trait loci analysis using restriction fragment length polimorphisms has already begun to raise the current ceilings on yield potential.

The really big gains lie in the distant future, however. Cereals that could fix their own nitrogen, as legumes do, would be of immense value to farmers in developing countries, where chemical fertilizers are little used, but the process of transferring the multiple genes responsible for this trait is complex and its outcome unpredictable. Even if this research were successful, natural limits to photosynthesis might prevent the new technology from raising yields substantially. It is not yet clear what foreign genes would need to be inserted to alter the photosynthetic rate of plants. The current efficiency of solar energy conversion through photosynthesis is estimated at 3%; raising this theoretical ceiling to around 8% could take another 20 to 30 years of basic research.

Research along the second avenue - defensive breeding - still has considerable potential, particularly with regard to physical stresses. Indeed, as the environmental costs of development become apparent and as cultivation moves into increasingly marginal areas, the main challenge to plant breeders over the next 25 years will be to develop plants able to produce stable yield gains under difficult edaphic conditions. Attention will turn increasingly to areas with poor soils and/or susceptible to drought stress. Competition for scarce water will become a major topic of research.

Defensive breeding by conventional methods confronts several limitations. Research to develop resistance or tolerance to a given stress normally produces only a relatively small gain in yields. Resistance to diseases and pests sometimes breaks down after a few years, as new strains or races develop. The enemies of plants are many, such that costly research must be pursued simultaneously across a wide range of topics.

Biothecnology offers opportunities for overcoming some of these problems. Once identified, the same gene for resistance to a given pest or disease can now be transferred to many different crop species. New techniques that allow the introduction of a second, artificial source of resistance to complement natural sources can outwit the organisms causing diseases, preventing them from developing new mechanisms to overcome the host's defences. Understanding of the basic mechanisms underlying resistance/tolerance is growing rapidly.

More important still, biotechniques can radically improve the efficiency of research, allowing significant advances in both the direct and the indirect approaches to increasing yield potential. Techniques such as genetic probes, anther culture and restriction fragment length polymorhism (RFLP) analysis can cut breeding times in half, sharply reducing the amount of field work needed to evaluate germplasm. Such techniques will be especially useful in tapping the genetic variability of land races and wild relatives - important sources of drought tolerance and other traits needed for stable production in marginal environments.

The single biggest influence on the global agricultural research agenda over the next 25 years will be the concept of sustainability. Biotechnology has important contributions to make to sustainable agricultural production, notably through the development of technologies that reduce pollution. Naturally occurring microbes can be used to produce non-toxic pesticides for crop protection and inoculums to promote more efficient nutrient cycling. The symbiosis of micorrhizae and legumes can be expanded and enhanced by broadening the genetic base of micorrhizal populations. The artificial creation of new metabolic hybrids through the introduction of C4 genes into C3 plants - mimicking the intermediate forms found in nature - would enhance carbon fixation and increase plant survival in difficult environments.

Some of the most promising applications of biotechnology lie in the field of crop protection. The conventional control of pests and diseases through agrochemicals is expensive, and frequently leads to problems of abuse. Improving pest resistance or control by genetic means brings substantial savings in farmers' labor and recurrent costs, as well as reduced risks to human health and the environment. The recent development of protozoa-based locust control methods, and the incorporation of herbicide resistance in cereal crops for use in conjunction with non-toxic sprays illustrate the potential of biotechnology to make crop protection a cleaner and cheaper process. Technology that reduces the use of pesticides will be especially welcome in Latin America and the Caribbean, where overuse is a growing problem at present.

In sum, the gains made possible through advanced techniques over the next decade are likely to be substantial, though less dramatic than those of the Green Revolution. A recently discovered gene expressing drought tolerance in pearl millet, for instance, is expected to lead to a 25% increase in yields, compared with gains of 100% or more achieved in wheat and rice during the late 1960s. Nevertheless, the many new applications of biotechnology - the field is making startling advances almost daily - hold out significant hope that its cumulative impact will eventually be high. National research systems in developing countries stand to benefit increasingly from these applications, as their research interests gradually converge with those of public-sector research institutions in the developed world (see 2.).

Applied research

As part of the new quest for sustainable development, research on land use and crop/livestock management is likely to become increasingly important in developing countries over the next 25 years. As the competition for soil and water resources becomes more intense, selecting the right combinations of crops and animals for given systems and knowing how to make the most efficient use of limited resources will be crucial. Special attention will need to be paid to the prevention of negative externalities resulting from agriculture.

Resource degradation in developing countries is often caused by the underuse rather than the overuse of inputs. Declining soil fertility is widespread, and an acute problem in slash-and-burn production systems. In these circumstances production is unsustainable largely because farmers cannot afford commercial fertilizers, often lacking even the resources to develop and apply organic approaches. The judicious use of commercial fertilizers to supplement organic approaches must increase in developing countries. Needed will be technologies which efficiently combine both types of input, keeping both investment and environmental costs low.

Increasing the productivity of labor will continue to be a major objective of applied research in developing countries. As we have seen (2.), the advanced technology currently being developed in specialized institutions will have some useful spin-off for these countries, especially in Latin America and the Caribbean. Technologies such as the incorporation of herbicide resistance into food and feed crops will help to reduce the currently very high allocations of labor to weeding necessary in most small-scale farming systems. Plant breeding still offers the best overall prospects for increasing labor productivity in developing countries, but there may also be more research in areas such as small-scale mechanization, the labor requirements of different management practices, and the efficiency of post-harvest technology.

The complexity of agricultural research and development will increasingly require the efficient handling of large amounts of data and information. The use of microcomputers for this purpose will increase. Areas of application relevant to developing countries will include constraint diagnosis and the assessment of land use patterns, the characterization and evaluation of germplasm, expert systems for integrated pest managment, and the modelling of nutrient recycling in multi-species production systems. Information technology will be slow to reach small-scale farmers in developing countries, but eventually - perhaps within 50 years - it may constitute a powerful tool for improving their day-to-day farm management. Some of the packages developed for herd management may already be applicable on larger-scale ranches. As the knowledge of genotypes and environments increases, it may prove possible to develop similar packages for cropping systems

New approaches in the social sciences will have important implications for the conduct of research at farm level. Partipatory research will enable farmers to play a more active part in technology design, as well as bringing significant savings in researcher time through involving groups of farmers, rather than individuals, in the research process. The inclusion of gender analysis as a variable in data collection will improve the targeting of research and the delivery of its results. Research in general will continue to involve an increasingly broad range of actors - including policy makers, extensionists and the staff of non-governmental organizations, as well as scientists and farmers - in the planning and implementation of projects on the basis of a jointly agreed agenda.

Economic and Agricultural Development in Latin America and the Caribbean

The crisis of the 1980s

For many countries in Latin America and the Caribbean, the 1980s were a 'lost decade'. The region's debts took on unmanageable proportions, reaching US$ 415 billion in 1987/89. The capital inflow of the 1970s went into reverse, with more than US$ 30 billion a year leaving the region during the second half of the decade. In addition, terms of trade deteriorated, and loose monetary policies led to rampant inflation. At a regional level economic growth came to a complete standstill, and in many countries the economy actually shrank. The share of agriculture in GDP - which had been falling since the 1960s - began to rise again as industrial development faltered.

The crisis of the 1980s led to a decline in both real wages and employment opportunities, aggravating poverty and malnutrition in many countries. In the course of the decade per caput income fell by 1% a year, so that by 1990 people were on average some 10% poorer than in 1980. By 1986, poverty affected an estimated 44% of the region's population, 3% more than at the start of the decade. Having increased throughout the 1970s, per caput food consumption started to fall again during the mid-1980s. In 1986, more than 55 million people in the region were suffering from malnutrition, with urban households being particularly severely affected. Restrictions on food imports reduced food security for the urban poor still further. The three countries in which malnutrition was most prevalent were Haiti, Honduras and Peru, where the daily per caput supply of calories was 1902, 2078 and 2192 respectively, compared with 3100 in Argentina.

Agriculture weathered the crisis years surprisingly well, maintaining a growth rate of 2.2% compared with 1.0% for industry. However, the increase in food production still failed to keep pace with the population growth rate, which averaged 2.4% during the decade.

Most of the growth in production came from medium-sized farms. The conventional view of tropical American agriculture as highly polarized is gradually becoming out of date. A medium-sized commercially oriented sector has emerged, using modern inputs and specializing in a few products for market. This sector may be expected to contribute substantially to development in the coming decades.

The small farm sector as a whole fared less well, largely failing to participate in production increases. Poor access to inputs and services meant that small-scale farmers had little incentive either to produce more or to invest in improving the land they cultivated. In many areas, insecurity of tenure was an added disincentive to invest. Under these circumstances resource endowment was critical to survival. In areas of medium to high potential the sector proved remarkably resilient, with farmers generally able to ride out the crisis, particularly if they specialized in high-value cash crops for export. In more marginal areas, continuing impoverishment and, in some cases, utter destitution drove growing numbers of families off their land. Some migrated to cities; others to forest areas; many became landless rural laborers.

The recovery of the 1990s

The general context of economic development in tropical America over the next 10 years will be one of increasing belief in market forces and the private sector as the keys to growth. The need to reduce the role of the state in national economies has been generally accepted, and important policy changes have been implemented in many countries. Price and import controls are being gradually reduced; overvalued exchange rates, which particularly damage the agricultural sector, are being revised.

These policy changes should bring about a gradual economic recovery during the 1990s, as the debt crisis slowly recedes. Except in Colombia and Chile, slow growth is a constant throughout the region at present. But the conditions for faster growth should emerge by about the middle of the decade, with a period of relatively rapid growth possible toward the year 2000. Per caput income is expected to grow at a modest 1.5% over the decade as a whole.

Throughout the 1990s and beyond, governments will continue to rely heavily on agricultural exports to generate foreign currency earnings and stimulate renewed growth. Tropical America's abundant land and relatively cheap rural labor give it a comparative advantage in exports. The region's most promising export market in the long term is probably Asia, many of whose densely populated countries will eventually be unable to sustain their current production surpluses. High-income developed countries will also represent a potentially lucrative export market, provided the current barriers to trade are removed. These two very different markets imply demand for two distinct types of product - high-quality staple food grains and animal feeds for the former, and high-value speciality products, such as flowers, fruit and vegetables, for the latter. It is mainly with the staple food products, for which there will also be high domestic demand, that the major opportunities for stimulating rural growth through the development of yield-increasing technology lie.

The population of Latin America and the Caribbean is currently growing at 1.9% a year, and is expected to rise to some 760 million by the year 2025. Assuming current trends persist, this growth will be largely urban (135% increase), while the number of people in rural areas will probably remain about the same. This means that, simply in order to maintain today's levels of per caput food availability, the productivity of labor in rural areas must more than double if increased food imports are to be avoided. And if real incomes in the agricultural sector are to rise and food prices to fall, a threefold increase in labor productivity will be necessary. What are the region's prospects for meeting this challenge?

Attitudes to agriculture in the region have changed in recent years. The sector is now widely regarded as a key contributor to future growth, and is being gradually released from the inequitable tax burdens imposed on it during the 1970s. Government support to agriculture has traditionally been oriented more towards the commercial sector and to export crops than it has toward the needs of the resource-poor farmer. However, there is now increasing recognition of the productive potential of small-scale farms, and of the value added through linkage effects and expenditure multipliers.

Despite the change of heart towards agriculture, the increasingly limited funds available for public investment will curb the contribution of agriculture to economic recovery in two major ways during the 1990s. First, support to national agricultural research, already severely curtailed following the debt crisis, is unlikely to increase. Second, governments will lack the resources to build roads or provide services in frontier areas. This will limit the incentives for frontier expansion, a major traditional source of agricultural growth.

Nevertheless, having performed relatively well even when disadvantaged in comparison to industry, agriculture may be considered well placed to contribute relatively strongly to renewed economic growth in the 1990s. The challenge will be to ensure that the hitherto severely handicapped small farm sector is able to participate.

There are three interrelated factors which critically determine the points at which agricultural research can have maximum impact in stimulating regional recovery and ensuring the equitable distribution of its benefits. First continuing urban migration will increase the demand for food which must be met by a static and ageing (though largely underemployed) rural population. Second, unless food production can be increased, the rapidly rising populations of cities will deepen the region's already severe urban equity crisis. Third, there are a number of staple food commodities for which both domestic and export demand should prove relatively strong in the medium to longer term. Maximum impact will thus be achieved by generating technology that enhances crop and labor productivity for a set of commodities giving maximum synergy between the need to provide cheap food for urban dwellers, ensure the welfare of resource-poor farmers, and increase export earnings. A major aim of both research and development should be to link the small-scale farmer to expanding commodity markets, both domestic and international.

As economic recovery gathers pace, further pressures will be placed on tropical America's already threatened ecosystems. These pressures are of two kinds, market and social. Market pressures arise as private enterprise responds to domestic and export demand for raw materials and other commodities. Social pressures arise as the region's marginalized resource-poor farmers are forced either to mine the natural resource base in the areas they have already farmed or to migrate in search of new land to bring into cultivation.

To sum up, the current food surpluses of tropical America are largely a market rather than a social phenomenon. If the region's poor had more cash, they would spend a high proportion of it on more food. Technology to reduce production costs and so lower the price of food is urgently needed, to expand domestic markets and increase competitiveness in international markets. At the same time as increasing productivity, this technology must help to preserve tropical America's fragile ecosystems. And it must also allow scope for the resource-poor farmer to participate in development. Given the links between resource conservation and rural equity (see 3.), these two requirements are not necessarily incompatible.

Role of the International Agricultural Research System

CIAT's future program will reflect changes in the role of the international agricultural research system of which it forms a part. The objectives of the Consultative Group on International Agricultural Research, to which CIAT belongs, have already evolved considerably since the group was founded in the early 1970s, and are currently being redefined. The programs and structure of the group will continue to change to accommodate these new objectives.

Founded in response to the food crisis of the 1960s, the initial objective of the group's earlier centers was to increase food self-sufficiency in developing countries. However, with the experience of the Green Revolution came the recognition that poverty is as important a cause of malnutrition as insufficient food availability. Increasing the supply of food is a necessary but not a sufficient condition for the alleviation of hunger. Accordingly, the emphasis today is increasingly on food self-reliance rather than food self-sufficiency, at both household and national levels. The inclusion of income generation as an explicit objective of the group has broadened the scope of its research, leading to increased emphasis on a wider range of crops and other commodities to meet the cash rather than merely the subsistence needs of small-scale producers. This trend may be expected to continue through the 1990s, with a possible expansion of the group to cover aspects of forestry and fishery research in addition to agriculture.

Reflecting international concern, environmental issues have risen to the top of the agenda for international agricultural research in recent years. The CGIAR proposed in 19 to double its allocations to resource management research ( ). The concept of sustainability, first defined by the World Commission on Environment and Development in 1986 ( ), has become central to the work of the CGIAR and will undoubtedly remain so. Less subject to political pressures to achieve short-term production gains than are national research systems, the international research community is well placed to undertake research on sustainability issues, which is necessarily long-term in nature and has a less easily identifiable pay-off. To allow sustainability issues to be more fully addressed, the traditional commodity focus of the CGIAR's research is likely to be complemented in the future by a growing number of programs focussing on resource management research at the ecosystems level. Possible scenarios for such an evolution of the CGIAR system have been depicted recently ( ). The new emphasis on environmental concerns also implies increased research on land use and related policy issues.

Within commodity research the traditional role of the CGIAR centers has been to provide promising lines and populations for testing and release as new varieties by national programs. This too is changing. Stronger national programs will increasingly enable the centers to conduct more strategic research, applying advanced techniques to the development of improved germplasm. The centers are ideally placed to collaborate with advanced laboratories in the developed countries in bringing the benefits of biotechnology to developing countries.

Stronger national programs will eventually allow the centers to relinquish a number of the support activities they perform at present. These include the provision of production courses, assistance in problem identification and priority setting, involvement in technical assistance projects, and the ongoing coordination of networks. However, the rate at which the centers are able to devolve these and other responsibilities to national institutions will be highly variable, depending on the extent to which these institutions are able to secure adequate financial support from governments. As we shall see, the continuity of funding at present gives cause for concern in this respect.

Roles of CIAT's Research Partners

National research

CIAT's main institutional partners in its task are the public-sector national agricultural research institutions of tropical America. How will these institutions develop in the coming years?

In the short term at least, their ability to collaborate with CIAT will be severely constrained by the funding limitations they face. Tropical America is somewhat better off in this respect than Africa, but probably worse off than Asia. Cutbacks in public spending in response to the debt crisis have hit public-sector research particularly hard in recent years.

In the longer term the prospects are somewhat brighter. The number of trained professional staff in national institutions has risen substantially over the last decade. This 'human capital' provides a firm basis for collaboration once the current financial crisis is over.

Latin America and the Caribbean are characterized by extreme variability in the size and strength of their national agricultural research systems. This variability is highly correlated with size of country, larger countries such as Brazil and Mexico tending to have stronger systems (though even these are subject to drastic fluctuations in their budgets). Smaller countries, especially those of Central America and the Caribbean, tend to have less well developed systems in which the critical mass for research is frequently lacking for important food staples.

Two different trends in national institutional development may therefore be identified for the longer term. Larger, stronger systems will increasingly demand a more sophisticated range of services from CIAT. On the germplasm development side these services will include gene mapping and transfer, which will complement current germplasm characterization and crossing methods. Smaller systems, on the other hand, will increasingly focus on adapting technology developed from elsewhere rather than on generating technology themselves. These countries will need to capitalize fully on the economies of scale made possible through regional projects and networks.

One outcome of the recent cutbacks in government spending on public-sector research is increasing involvement of the private sector in commodity research. In return for injections of cash to meet running costs, private companies and producers' associations are able to use public-sector staff and facilities to conduct research on a jointly agreed agenda. Such joint research ventures seem likely to become a permanent feature of national research in the future. However, they will be firmly oriented toward profitablity; other kinds of partnership will be required to cater for environmental concerns and for the needs of resource-poor farmers.

Research in the national systems of tropical America is thus likely to become more complex in the coming years. While plant breeding and input distribution are increasingly privatized, research on sustainability and equity issues will require increased support from international centers, donor agencies and non-government organizations. In addition, natural resources departments and institutions that have hitherto remained outside the national agricultural research system (sensu stricto) will increasingly be required to integrate their activities with it.

Regional research

In contrast with national research, regional research in Latin America and the Caribbean is currently undergoing a revival. In response to the debt crisis, many countries are seeking horizontal cooperation at regional level as a means of achieving public-sector cost reductions through the more rational division of labor. This pooling of resources reflects Latin America's growing sense of regional identity.

In the agricultural sector, a number of new subregional, multi-commodity network initiatives have been launched in recent years, sponsored by IICA and IDB. We expect regional networking to grow in strength in the years to come, as the trend towards regional integration gathers momentum.

These new networks will be vital to the success of CIAT's future program, playing an important part in ecosystems and land use research as well as in germplasm development. They represent an exciting opportunity to involve research leaders and policy makers in the setting of research priorities on a regional basis. They will also serve as a mechanism for attracting funds to more cost-effective public-sector research. Lastly, strong programs at regional level will enable CIAT to devolve some of its support activities, allowing the Center to pursue more strategic research.

Specialized institutions

Following the food surpluses of the past decade, plant breeding in developed countries is rapidly being privatized. The private sector is prepared to conduct much of the research for which the public sector was previously responsible, provided its profitability can be assured through breeders' rights and other forms of patent legislation. In response to these altered circumstances, public-sector research is moving upstream and looking for new roles. The currently limited interest of advanced research institutions in the food production problems of developing countries is therefore likely to increase in future.

During the coming decades, a significant proportion of biotechnology research is likely to remain in the public sector. The private sector is investing heavily in the 'near market' applications of biotechnology, but public-sector research will still be needed to address long-term, basic research problems.
Partly in response to public pressure, research to develop environmentally friendly agricultural technologies will gain ground in many developed-country public-sector research institutions in the coming years. The pollution caused by agrochemicals is already causing increasing concern in both the developed and the developing countries. Biotechnology is seen as an important tool for addressing this and other sustainability issues. Research on such issues is often long-term in nature, and can therefore be expected to remain largely the domain of the public sector.

During the 1990s and beyond, developing countries will thus be presented with increasing opportunities to benefit from the biotechnology revolution, especially when this addresses issues of common concern to both developed and developing countries, as in the case of environmental pollution. However, as we have seen, national institutions in developing countries will be handicapped by funding and administrative constraints. In addition, lack of contact with their colleagues in advanced laboratories reduces the effectiveness of many developing country scientists in applying advanced techniques at present.

The international agricultural research centers will have an important role to play in overcoming these problems. Advanced research networks will increasingly be used to stimulate collaborative research in biotechnology, linking specialized laboratories with national and international institutions in developing countries.

CHAPTER THREE

THE WAY AHEAD

A New Focus: Natural Resource Management Research

As we have seen, the commodity focus adopted by CIAT over the last 15 years has served the Center well. It has allowed the institute to assemble interdisciplinary research teams with a strong commitment to the development of seed-embodied technology to increase production (1. - 1.). It has enabled CIAT to carve out a clearly defined niche in the eyes of its research partners and donors, helping to build stronger national programs and link them with the global research community (1.). And because certain commodities are strongly associated with certain classes of producer and consumer, the process of choosing the commodities on which to work and allocating resources among them has been instrumental in helping the Center define the impact it seeks in terms of equity and growth (1.).

To a certain extent the commodity focus has also allowed the pursuit of sustainability objectives, for example through the the development of plants able to produce stable yields under difficult and highly variable natural conditions. These lines of research have been vigorously pursued by CIAT's commodity programs.

However, neither at CIAT nor elsewhere in the international agricultural research community has the commodity focus enabled the full range of factors affecting sustainability to be taken into account. Plant scientists, however systems-oriented their work, tend to view systems with a bias toward the production of the crop in which they specialize. The organization of programs around single crops mitigates against the objective analysis of land use strategies and related policy issues.

Since CIAT was founded, the concept of what is required to conduct effective ecosystems research has changed considerably, moving beyond the objective of developing new production systems. The links between poverty and resource degradation are better understood, as also are the negative externalities that may result from agriculture. As world markets become increasingly open, there is increasing pressure to apply the principles of comparative advantage. These and other factors mean that, to be effective, ecosystems research must integrate the generation of technology with the development of more rational land use strategies and policies.

The need for more rational land use is acute in tropical America, where powerful social and economic forces drive agricultural development. The region as a whole has abundant land, with an overall rural population density far lower than that of Asia or Europe. Yet it also has rural areas of extreme overcrowding and poverty, where the natural resource base is already severely degraded. The results are land hunger, social conflict - and a natural landscape undergoing rapid, sometimes catastrophic, change.

Tropical America is home to the world's largest surviving tropical forest, a resource under immense and increasing pressure from the landless poor as well as from commercial exploitation. Forest clearance and expansion of the area cultivated have been traditional sources of economic growth in the region. While impressive gains in productivity have taken place during the 1980s, around 20 to 30% of production increases are still occurring as a result of expansion, mostly into primary semi-evergreen forest areas. Both within the region and outside it, there is growing concern about the environmental consequences.

Many of the forest zone's immigrants are resource-poor farmers from the Andean hillsides, forced to abandon their holdings because of soil erosion, loss of soil fertility or lack of an adequate water supply. Others have chosen to leave overcrowded, poverty-stricken areas in north-east and coastal Brazil, joining voluntary resettlement schemes in search of a better life. While both politicians and the general public in tropical America are aware that environmental protection is vital to the region's future, the drive to develop economically has frequently relegated environmental considerations to second place.

An attractive alternative to clearing more forest for commercial exploitation is to develop the acid soil savannas, which cover vast, currently underexploited areas of tropical South America. However, in most areas the right policy incentives and infrastructure, as well as the right technologies, have yet to be put in place to encourage this.

Natural vegetation is inevitably replaced by managed ecosystems as the area used for agriculture expands. Yet the rapid clearance of tropical America's natural forest in recent years has often brought only ephemeral gains in food production, cleared areas frequently reverting to bush only a few years later. The futility of this onslaught on the natural resource base is the region's most potent symbol of the need to create more viable land use alternatives.

Natural resource management research in tropical America has several requirements that make it appropriate for the involvement of an international center such as CIAT. It is complex and long-term in nature, involves issues that cross national boundaries, requires political impartiality, and demands sophisticated facilities and services. Most important, it requires a strategic input to identify the principles that determine the successful planning and implementation of rational land use. CIAT, with its knowledge of Latin America and the Caribbean and its access to the many protagonists involved in determining land use, has a central role to play.

In the light of these considerations, CIAT proposes to complement its existing research focus on major food commodities with an additional focus, on the management of natural resources. This proposal is in line both with the spirit of CIAT's original mandate (see 1.) and with the more recent decision of TAC and the CGIAR to give greater emphasis to resource management through 'ecoregional' research (see 2.).

To meet the needs of resource management research, CIAT proposes to create a new Natural Resources Management Division. The new division will exist alongside CIAT's existing commodity programs, which will be regrouped to form a Germplasm Development Division. The work of the programs within each division is described in Chapters 4 and 5.

Moving Upstream: Commodity Research

As we have seen (2. - 2.), advanced techniques allow new opportunities for contributing to sustainable agricultural production through the exploration and utilization of germplasm resources. During the coming years, CIAT's commodity programs will move gradually upstream to take advantage of these opportunities.

Germplasm development objectives are now more complex than during the Green Revolution era. Increasingly, they must be set within the context of overall land use strategies that take into account conservation and equity considerations, as well as growth objectives. Breeding for niches in multiple-species systems that allow sustainable land use, avoiding negative externalities, will become increasingly important. In addition, plants will increasingly be designed for use in conjunction with specific inputs and management practices, and for more specialized end uses.

The growing integration of the plant sciences with other discplines, particularly those associated with advanced research techniques, will constitute a powerful critical mass for meeting these more complex objectives. New biological approaches will play a key role in creating new breeding opportunities, as well as responding to existing needs. Increasingly, CIAT's commodity research will be concerned with understanding the basic genetic structure of plants and enhancing the mechanisms determining plant responses to the environment. Knowledge derived from these studies will serve to develop environmentally sound approaches to germplasm development and management.

CIAT will have a special responsibility for the application of new technology to sustainability concerns in developing countries. Often subject to short-term pressures to achieve production gains, national institutions may find it difficult to respond to these concerns. However, as we have seen, advanced technology offers exciting opportunities for tackling environmental issues at the same time as increasing productivity (2.). CIAT must ensure that developing countries benefit from these opportunities.

As CIAT's commodity research moves upstream, stronger national institutions will enable the Center's programs to relinquish some of the tasks they currently perform. By the end of the 1990s, CIAT will be conducting less research on agronomy, the applied aspects of crop management, and the post-harvest processing of commodities. Responsibility for the strategic aspects of crop management will pass gradually to the Natural Resources Management Division.

During the coming years the process of setting breeding objectives will become increasingly participatory. Farmers will have more say, but policy makers and land use experts will also need to be involved. Responsibility for the process will lie increasingly with national institutions, with CIAT providing an important input from a land use perspective. Within CIAT, responsibility for providing this input will be shared jointly between the Germplasm Development Division and the Natural Resource Management Division.

A New Portfolio

Priority Setting Criteria

In selecting a portfolio of commodities and agro-ecozones on which to focus its future research programs, CIAT has sought maximum synergy between three interrelated objectives: growth, equity and conservation.

Economic growth is the sine qua non of development. Since agriculture serves as an engine of growth in developing countries, agricultural research can make a major contribution to development, notably through the generation of technology that increases production, lowers costs and raises the productivity of labor. Growth is not an end in itself, but because it raises incomes it is an important tool for meeting CIAT's mandate to improve human welfare.

Economic growth raises the incomes of the poor, but it often does so in absolute rather than relative terms, such that the poor benefit from development less than do other, more privileged groups. For this reason, the pursuit of growth as the objective of CIAT's research must be tempered by equity considerations if the Center's goal of alleviating hunger and poverty is to be met.

Growth may also have adverse environmental consequences, undermining both the quality of life in the short term, through pollution, and the prospects for human survival in the long term, through the destruction of natural resources. The world's natural resources are the 'capital' on which future growth depends. Sustainable growth means living off the earth's interest, not its capital ( ). Replenishing and enhancing the natural resource base, to ensure future dividends, is essential for sustainable growth. Hence conservation must be used as a third criteria for assessing the potential impact of CIAT's research.

Conservation and equity are often complementary objectives. To survive, marginalized people often have no option but to consume natural capital, mining the soils and vegetation on which their future livelihood - and that of their children - depends. Increasing the incomes of the rural poor makes them better custodians of natural resources. Focussing research solely on conservation, excluding the interests of the poor, would be socially divisive.

The three objectives amount to a single, superordinate goal: sustainable, equitable growth. This goal implies an appropriate balance between exploitation and conservation of the natural resource base, with the poor enjoying equitable access both to the resources that fuel growth and to the benefits that flow from it.

Three sets of criteria were derived from these objectives and used to evaluate different agro-ecological zones and commodities. A fourth set of criteria, used as a screening mechanism, concerned the degree to which research by CIAT on a given commodity or ecosystem would complement the activities of other institutions. The priority setting process used to select agro-ecozones and commodities is described in detail in Annexes and

Agro-ecozones

CIAT has elected to focus its resource management research on the needs of three major agro-ecological zones: the forest margins, the medium-altitude hillsides, and the savannahs (see Figure and Table). The three zones are linked by a common theme central to tropical American agriculture: the problems and opportunities of frontier development. Another common theme across zones is the problems of acid, infertile soils, an area of research in which CIAT has acquired a special advantage.

Each of these zones presents major opportunities to contribute to sustainable agricultural development. In the forest margins, sustainability issues are strongly linked with the objective of resource conservation, in the hillsides with equity, and in the savannahs with growth.

A number of other agro-ecological zones in Latin America and the Caribbean experience significant resource degradation problems. These include highly productive land, the semi-arid zone, and the high-altitude hillsides. The problems of these zones will not be subject to natural resource management research, but will receive some attention through CIAT's commodity research.

The forest margins. Forested or once forested areas account for about 35% of the land area of Latin America and the Caribbean. During the 1970s and 1980s, nearly 125 million hectares of the region's forests were cleared for agricultural or commercial exploitation ( ). Brazil and the Andean countries accounted for about three quarters of this total, but in relative terms deforestation was greatest in Central America and Mexico, which have now lost 31% and 22% of their forests respectively, compared to about 7% in Brazil and 19% in the Andean region.

The lands being cleared first in any given area tend to be those with a dry season. The wettest areas are in the least demand because they are the most difficult to clear, burning being far more difficult here than in drier areas. The probability of abandonment after a few years of cultivation increases with humidity, since the more humid zones tend to be more prone to rapid degradation following land clearing. This means that, for the most part, deforestation is opening up increasingly marginal land for use, and that each successive wave of forest clearing is likely to culminate in the degradation of greater amounts of land. Conversely, it means that the most vulnerable forest lands can still be protected if governments act to do so, and that the protection of remaining forest areas does not entail sacrifices of large amounts of potentially arable land.

Settlement in the forest areas occurs as a result of both social and market pressures. Venture capital and surplus labor are attracted by the opportunities presented by cheap land that could rise rapidly in value, and by short-term income streams from land use that mines the natural resource base. National policies in the region are frequently designed to stimulate rather than prevent forest clearance.

In the Amazon, ribbon development along roads typically follows a 'leapfrog' pattern. Unsustainable production systems drive small-scale farmers to clear new land, the degraded areas they leave behind them being taken over by larger-scale ranchers. Degradation in other ecosystems, notably the Andean hillsides and north-east Brazil, causes a steady influx of new settlers, accelerating the rate of slash-and-burn cultivation. In Central America, the remaining pockets and coastal strips of forest are under similar threat from the densely populated uplands that flank them.

Direct clearance for ranching is also an important cause of deforestation in both the Amazon and Central America. In Brazil, government policy has until recently provided tax shelters and other incentives to clear land for this purpose. Ranching represents a safe and profitable haven for capital.

Frontier settlement inevitably destroys natural environments. In North America and Europe, the long history of frontier settlement ended only with the exhaustion of the frontier. The issue, in tropical America, is whether this process can culminate in anything less than the complete destruction of the forest.

The social pressures on forest ecosystems must be tackled at source - in the overpopulated, poverty-stricken areas from which many of the new settlers come. The market pressures can be at least partially relieved by developing the savannah areas instead of the forests.

The main technical challenge facing research in the forest margins themselves is to settle the shifting cultivator. The aim will be to develop stable, sustainable systems that allow two to three times the current per caput income from areas a fifth of the current size. Because of the influx of immigrants from other zones, such systems would not prevent slash-and-burn cultivation, but they would sharply reduce the demand for new land originating from people already living within the forest margins. And they would allow currently degraded land to be regenerated and resettled.

By virtue of its research on pasture improvement and ley farming (see 1.), CIAT has acquired a special advantage for technology generation to stabilize production in cleared forest areas, many of which share the acid, infertile soils of the savannahs. However, little is known - either by CIAT or by other research groups - about the likely social and environmental impact of such technology. While it is imperative that degraded areas are regenerated, more sustainable and profitable production systems might act as a magnet, swelling the stream of small-scale farmers to the frontier and attracting increased capital investment in ranching. For these reasons, technology development must be accompanied by micro-economic and policy studies that will lead to the formulation and implementation of appropriate land use strategies for remaining uncleared areas.

The medium-altitude hillsides. Land degradation is particularly rapid in tropical America's 10 million hectares of densely populated medium-altitude hillsides. Many of the settlers in the forest lands are migrants from these areas, which contain a major concentration of the region's rural poor. The 30 to 50 million resource-poor farmers that live in these hillsides produce over 40% of the food consumed in urban areas, but their labor productivity is currently extremely low.
The main forms of degradation include deforestation and the cultivation of steep lands, leading to increased runoff and erosion, and continuous cropping without the use of inputs, leading to declining soil fertility. Not only is the productive potential of the hillsides steadily reduced by these practices, but there are also significant costs to water regimes downstream. The pressure on remaining areas of hillside forest - for firewood, building materials and additional

arable land - is considerable. Clearing these areas will increase erosion risks still further by bringing even steeper land into cultivation.

Production systems in the hillsides are already highly heterogeneous. Climate and soils vary widely with altitude and slope. Degradation is far from universal: high-potential land is found adjacent to, or even on the same farm as, degraded land. It is therefore difficult to specify technologies that will have broad adaptability, and to predict the effects of introducing new technology. As in the forest areas there is a danger that improved, more sustainable production systems will act as a magnet, attracting people from nearby degraded areas. Before developing new technology, CIAT will need to conduct micro-economic and policy studies to determine its likely effects on migration patterns as well as the environment.

Land degradation in the hillsides is poverty driven. To ease the pressure on these lands it will be essential to increase incomes. Needed are technologies that will prevent erosion and conserve water resources, while providing significant returns in the early years of adoption.

Legume-based pastures and multi-purpose trees may provide the basis for sustaining mixed crop-livestock farming systems, with the potential for producing high-value products for domestic, and perhaps export, markets. The major research needs in pastures will be germplasm exploration, to identify materials adapted for a wider range of temperatures and soils. Research on multi-purpose trees will need to define suitable niches in the landscape, identify fast-growing species to ensure early returns, and determine the policy measures required to promote adoption (see 4.). Fruit trees may have some potential.

If these technologies are adopted, incomes from upland farming will increase, helping to stem the rising tide of migrants to the forest areas.

The Savannahs. Acid-soil, infertile savannahs account for more than 10% of the land area of Latin America and the Caribbean. Some 76 million ha of well watered savannahs are currently accessible for more intensive cultivation and grazing. Over 200 million more could be opened up if roads were constructed.

Three distinct kinds of savannah land may be identified: lowland savannahs with extensive grazing on poor soils and with little or no other agricultural activity; lowland savannahs with extensive grazing, mechanized cropping and some manual cropping; and cerrados-type upland pastures with mechanized cropping. Several intermediate forms also exist.

Unlike the forest, savannahs require little initial investment in land clearance; nor does their development incur the high environmental costs associated with the loss of forest. Indeed, developing the savannahs implies increasing rather than reducing their biological diversity. However, the acid, infertile soils of the savannahs - just as susceptible to degradation as those in forest areas if improperly used - constitute a major barrier to development. Migrants to forest areas burn standing biomass not merely to clear the land but also to fertilize it. To achieve the same effect in savannah lands, they would have to invest heavily in chemical fertilizers - a cost they are unable to bear.

The savannahs thus offer only limited scope for directly relieving the social pressures causing land degradation in the hills and the forests. Consisting largely of extensive plains with relatively poor soils, they are unlikely to absorb large amounts of surplus labor, being more suited to mechanization. However, they could relieve much of the market pressure on the forests, presenting considerable opportunities for ranching and mixed farming. The expansion of agriculture in the savannahs would lower the prices of staple commodities - especially rice, beef and milk - bringing significant benefits to poor urban consumers. In the longer term, cheaper food would reduce the incentives to clear more forest areas, since the relative costs of production in these areas would become too high.

In areas with relatively good access to infrastructure, farming and ranching have already become established. However, current management practices in these areas are incurring rapid deterioration of the resource base: the continuous mechanized cultivation of soybean is leading to soil compaction and erosion; the buildup of weeds and pests is provoking heavy use of toxic agrochemicals; and overgrazing, combined with the use of inferior plant species, is leading to the degradation of sown grass pastures. The lessons are clear: both here and in the vast underexploited savannah areas that remain, more sustainable production systems are needed.

CIAT has a special advantage in developing such systems (see 1.   ). Ten new cultivars of grass and legume are now available for improving natural pastures. The new grasses are well suited to more extensive livestock production systems requiring a relatively low management input. The legumes are adapted to more intensive systems in which dual-purpose (milk/beef) livestock production can be combined with crop production, as in the rice-based ley farming system developed recently. This system can be complemented by a sorgum-based system for the drier areas (see 3.). Improved soybean may also be included in these systems (see 3.)

As mixed farming expands in the savannahs, the demand for fencing and building materials will rise. The current source of such materials is remaining areas of gallery or cerrado forest, which are gradually being destroyed. To offset this trend, research on multi-purpose tree species adapted for acid soils will be required.

The challenge in the savannahs is therefore twofold. First, ways must be found of overcoming the social and economic factors that limit agricultural development at present, especially distance to markets and low public investment in infrastructure (roads). Secondly, technologies must be developed that enrich the soils of these areas, allowing them to support productive mixed farming systems. Thirdly, as cropping expands, policies and technologies to protect the zone's remaining forests will be needed.

The central issue is whether the development of the savannahs can compete with that of more humid areas. Policies and technology must be developed that make the savannahs a more attractive area for investment, diverting pressures away from the primary forests.

Highly productive land. Fertile land with a growing period of over 9 months is scarce in Latin America and the Caribbean, occupying less than 5% of the region's land area. For this reason it is all the more important to protect such land, ensuring and enhancing its vital contribution to production over the long term.

Two major environmental problems afflict highly productive land in tropical America: salinization through inadequate drainage; and the overuse of pesticides and insecticides. The first can be met partly through plant breeding and partly through improved irrigation management. The second can be tackled directly, through the development of integrated pest management, and indirectly, through expanding output in other areas (notably the savannahs), lowering the costs of production and so rendering the overuse of chemicals uneconomical.

CIAT will not undertake major resource management research for this zone. However, the pest control problems of irrigated rice systems will continue to be addressed through crop improvement and integrated pest management research by CIAT's rice program.

The semi-arid zone. Accounting for 14% of the land area of Latin America and the Caribbean and containing some of the region's poorest producers and consumers, the semi-arid zone presents substantial opportunities for addressing CIAT's equity objective. However, the zone's potential for contributing to growth is low, lying mostly in irrigation, the high capital and running costs of which will limit development throughout the next decade. In addition, the zone contains few areas of acid soils, and so lies outside CIAT's major sphere of special advantage in resource management research. Approximately 80% of the zone is found in one country, Brazil, which has a relatively strong national research system.

For these reasons this zone will be omitted from CIAT's resource management research, but its needs will continue to be met in part by CIAT's commodity research programs, especially those devoted to beans and cassava. Policy and land use issues in this zone will also receive some attention (particularly in relation to outmigration to the forest zone).

The high-altitude hillsides. A fifth zone of some importance in the region consists of the hillsides and plateaux found at over 1500 metres above sea level. Cropping systems in this zone are primarily potato-based, and are therefore covered by the mandate of the Centro Internacional de la Papa (CIP). CIAT will not conduct natural resource management research on behalf of this zone, but some research on beans, which extend into the lower parts of this zone, will be required.

Commodities

CIAT will continue to conduct research on the four commodities in which it has acquired a special advantage through the work of its existing commodity programs, namely rice, beans, cassava, and tropical pastures (beef/milk). Economic analysis (see Annex) shows that, despite some change in relative market share and consumption patterns, this set of commodities still offers CIAT the best prospects for making a balanced contribution to its goal of sustainable, equitable growth. These commodities will continue to receive the major share of the resources devoted by CIAT to crop improvement. Within the beans program, some additional attention will be paid to snap beans, which allow an additional contribution to both equity and growth.

The expansion of CIAT's horizons to include research on natural resource management implies increased attention to a broader range of crops as alternative components for improved production systems. Two additional commodities, sorgum and soybean, have been selected for a highly targeted effort to capitalize on their considerable potential to contribute to growth by adapting them for expanded cropping on acid soils in the savannah lands. In addition, to strengthen its contribution to conservation, CIAT will conduct limited research on multi-purpose trees.

Various other crops, including plantain and banana, a number of vegetables, sugar, coffee, cotton, citrus and millet, were considered for possible inclusion in CIAT's portfolio. They were rejected for a variety of reasons, including their relatively low current value of production, lack of opportunity for technological advances, and unsuitability for international public-sector research (see Annex). While no crop improvement research will be conducted on these commodities, they may nevertheless be occasionally included in production systems research.

Rice. This commodity will remain the most popular carbohydrate in Latin America, where per caput consumption has risen from 15 kg in 1920 to around 45 kg in 1990. Projections to the year 2010 suggest that production will need to double in order to keep pace with rising demand. The prospects for increasing the output of rice and lowering its price through further technological advances remain high. Continued research on rice may therefore be expected to make a substantial contribution both to economic growth and to the welfare of poor urban consumers, an important equity consideration (see 2.).

Rice production in Latin America and the Caribbean is constrained by a number of problems unique to the region. These include the considerable variability of rice blast, the crop's most prevalent disease, and the environmental and human health hazards caused by the overuse of pesticides. CIAT has acquired a special advantage for research to solve these and other constraints (see 1.). In addition, among the world's developing regions Latin America and the Caribbean has the largest potential for expanding the cultivation of non-irrigated rice. The crop shows particular promise as the key growth component of ley farming systems adapted for acid infertile soils, especially in the savannahs, an agro-ecozone already selected for research by CIAT (see 3.).

CIAT's future research on rice will, as in the past, be restricted to Latin America and the Caribbean. The Center will continue to work closely with IRRI and the Rice Biotechnology Network to ensure the application of advanced techniques to regional problems.

Common beans. Grown mostly by resource-poor farmers and widely consumed by both rural and urban low-income groups, beans are the most important food legume for over 500 million people in Latin America and the Caribbean, and in the highlands of eastern and southern Africa. Demand for beans is growing fastest in Africa, where production increases lag well behind population growth. The high protein content of beans makes them an excellent substitute for meat, especially in areas where the human pressure on land is high, precluding cattle production. Continued research on beans will contribute substantially to meeting both rural and urban equity objectives.

CIAT has acquired a special advantage in research on beans (see 1.). Located at one of the centers of origin of this species, the Center is well placed to continue exploring its genetic variability, applying biotechnology as a tool for increasing the efficiency with which useful genes can be identified and transferred. Demand for high-quality beans is expected to grow during the coming decades. Increasing the crop's yield potential and overcoming specific nutritional problems will be the main challenges facing research.

The global demand for snap beans, as for other vegetables, is growing rapidly. Like other vegetables, snap beans are an ideal income-generating crop for resource-poor farmers. The crop therefore represents an opportunity to contribute to both growth and rural equity objectives. This is especially the case in Asia, where the crop is expected to become increasingly important in the future.

A major constraint to the production of snap beans is their susceptibility to pests and diseases. At present, farmers solve this problem by overusing chemicals, leading to pest resistance, human health risks and pollution. A comparatively modest research effort is needed to develop genetic resistance to the crop's major pests and diseases, transferring the strategic research techniques already successfully applied for dry beans.

CIAT will retain its global mandate for research on common beans, concentrating its efforts on dry beans in Africa and in Latin America and the Caribbean. In the medium term, the Center will continue to devote a relatively high proportion of resources for dry bean research to Africa. CIAT's effort in snap beans will concentrate on tropical America, but will have important spill-over benefits for Asia.

Cassava. This commodity is the resource-poor farmer's crop par excellence, often growing in marginal areas where low soil fertility and water availability inhibit the production of most other important food crops. Cassava remains essential to food security for resource-poor farmers and poor consumers in Africa and the poorer countries of East and South-East Asia, and an important component of the diet in tropical America. Major opportunities for market expansion lie in the conservation of fresh cassava for urban consumers, and in the use of cassava as animal feed, starch and refined flour. Production is expanding particularly rapidly in Asia, where market diversification has been heavily influenced by domestic and export demand for animal feed. Continued research on cassava can be expected to bring substantial equity benefits to the rural and urban poor. Research may also contribute to growth, especially if the market potential for new uses can be exploited.

CIAT has acquired a special advantage for research on cassava (see 1.). The Center is located near the crop's center of origin, and is well placed to continue exploring the genetic diversity of the crop, applying advanced techniques to its improvement. In the short term, further research will be needed on post-harvest processing techniques to enhance the shelf life of fresh cassava and the utilization of the crop for starch, animal feed and flour. Research on the quality aspects of the crop for a variety of end uses will become increasingly important to guide germplasm development. As the crop continues to expand into marginal areas, research will need to address the long-term sustainability of production on land prone to erosion and declining soil fertility.

CIAT will retain its global mandate for cassava. The Center will continue to work in collaboration with IITA to fulfill that center's regional mandate for Africa. Some additional emphasis will be given to Asia.

Tropical forages (beef/milk). Feed supplies are the critical constraint to increased beef and milk production in tropical America, as in many parts of the developing world. The improved forages that can address this constraint can also make a key contribution to the conservation of the natural resource base.

The cattle herd of tropical America today is estimated at some 250 million head, approximately 20% of the world's total. Beef and milk are traditional staples in the regional diet, and their consumption may be expected to rise rapidly with incomes. Annual consumption of beef in tropical America is already 16 kg/caput/year, significantly higher than in Africa and Asia. Even for the lowest income quartile of the population, expenditure on beef represents between 10 and 25% of total food expenditure, while that on milk and dairy products ranges between 7 and 15%. In addition to growing domestic demand, tropical America has considerable potential for exporting livestock products (see 2.). Increasing the production of beef and milk will thus make a substantial contribution both to growth and to urban equity.

Acid, infertile soils account for about 850 million hectares of land in tropical America. Forages developed for such conditions thus have very broad adaptability, with a very substantial potential impact on beef and milk production. The potential contribution of improved grasses and legume-based pastures to sustainable livestock and crop production on acid soils in the savannahs has already been demonstrated. Further research is now needed to develop similar technologies for other fragile ecosystems, and to match these with appropriate management regimes. CIAT has a special advantage in conducting this research (see 1. and 3.).

Multi-purpose trees can make a significant contribution both to animal feed resources and to the sustainability of agriculture, as well as providing a wide range of other products. Research in West Africa has shown that a major barrier to adoption is lack of adaptability to acid, infertile soils. CIAT will conduct limited research on a few species that show a potential for adaptation to these conditions.

CIAT's global mandate for tropical pastures adapted to acid soils will continue to be exercised largely in tropical America, but some increased attention will be paid to tropical and subtropical acid soil areas (from 0 to 1500 metres above sea level) elsewhere in the world. In Africa, CIAT will continue to collaborate with the International Livestock Centre for Africa (ILCA). CIAT will serve tropical Asia through a germplasm evaluation network. In addition to accepting global responsibility for key pasture legumes and grasses, CIAT will collaborate with the International Council for Research in Agroforestry (ICRAF) in fulfilling a regional mandate for multi-purpose tree species adapted to acid soils.

Soy bean. Demand for soy bean as an animal feed is growing rapidly in tropical America, where Brazil is already a major producer. Urban demand for soy cooking oil may also be expected to rise. Besides meeting the needs of the domestic market, increased soybean production might make a substantial contribution to export earnings in several countries. The case for a limited international effort to improve the productivity of soybean thus rests on its potential contribution to growth.

Provided a number of key constraints are overcome, soybean has considerable potential for development in the savannah lands. The crop is ill adapted to the photoperiod length of the tropics, resulting in reduced yield potential. Seed viability under hot, humid conditions also presents a major problem. Soybean is not inherently tolerant to acid, infertile soils, and is especially sensitive to aluminium and manganese toxicity. Under these nutritional stresses, the crop is likely to be especially vulnerable to pests and diseases. Soybean has good nitrogen fixing potential, but screening for improved rhizobium strains and plant genotypes for savannah soils will be needed.

CIAT proposes a limited, complementary effort in soybean improvement, strictly targeted to the production requirements of the tropical American savannahs. This effort will be undertaken by CIAT's rice program.

Sorghum. Because of its potential for use as animal feed, demand for sorghum may be expected to grow substantially in the coming decades. As in the case of soy, the primary reason for including a modest research effort on sorghum in CIAT's program is its potential contribution to growth. Ideal opportunities for expanding the production of this crop exist in the drier parts of the savannah zone already selected for CIAT's ecosystems research (see 3.). Where upland rice is excluded by moisture limits, sorgum may take its place, forming a key cash component in improved ley farming systems. The most serious constraint to the crop's inclusion in such systems is that the improved germplasm currently available is ill adapted to acid soils. Other important constraints include the toxicity of young foliage to grazing cattle, some potentially serious pest problems (including striga and downy mildew), and several diseases.

CIAT proposes a limited, complementary effort in sorghum improvement, strictly targeted to the production requirements of the tropical American savannahs. This effort will be undertaken by CIAT's rice program.

A New Operational Mandate

During the 1990s CIAT will conduct a program integrating research on the management of natural resources with that on germplasm development.

Natural resource management research will focus on the following ecosystems in tropical America:

- The savannahs
Sustainability with a growth orientation

- The forest margins
Sustainability with a conservation orientation

- The medium-altitude hillsides
Sustainability with an equity orientation

The overall aim will be to reduce the social and market pressures on remaining forests by developing sustainable production systems that meet growth and equity needs within the context of rational land use strategies

Germplasm development research will focus mainly on:

- Common beans
Global mandate for germplasm development and crop management, with the main emphasis in Africa; more attention to snap beans

- Cassava
Global mandate for germplasm development, crop management and utilization, in cooperation with IITA in Africa

- Rice
Regional mandate for germplasm development and crop management in Latin America and the Caribbean, in cooperation with IRRI)

- Tropical forages
Global mandate for pasture germplasm development for acid soils, in cooperation with ILCA in Africa; regional mandate for multi-purpose tree screening and introduction for acid soils in Latin America and the Caribbean, in cooperation with ICRAF

The overall aim will be to overcome major production constraints by applying advanced techniques to the exploration and utilization of germplasm.

Figure CIAT's research priorities in the 1990

Agroecological zones	**Forest margins** **Savannahs** **Medium-altitude hillsides** Highly productive land Semi-arid zone *High-altitude hillsides*
Commodities	**Rice** **Beans** (snap beans) **Cassava** **Tropical forages** (multi-purpose trees) Sorghum Soybean

Key: **Bold: High priority**
Medium: Medium priority
Italic: Low priority

CHAPTER FOUR

NATURAL RESOURCE MANAGEMENT RESEARCH

Divisional Goal

The goal of the division will be:

> To improve the management of the natural resources available for agriculture in tropical America, such that gains in the output of food and other commodities are compatible with the long-term conservation of the resource base.

Divisional Strategy

The strategy of the division will be:

1. To involve policy makers, scientists, extensionists and farmers in the planning and conduct of inter-institutional research on critical natural resource management issues.

2. To design technology and land use strategies that simultaneously increase the private benefits and reduce the social costs of agriculture. This implies:

   - At the macro level, understanding existing land use patterns and developing alternative land use strategies and policies.

   - At the micro level, developing management technologies and integrating them into economically viable and ecologically sound production systems.

Approach to Research

Management

The management of natural resources for agriculture must blend conservation with exploitation, the long-term balance between the two being the crucial determinant of food production and hence of human survival.

This balance is determined by the day-to-day decisions made by farmers, which are in turn critically affected by the incentives provided by government. Practices that conserve natural resources will not be adopted by farmers unless it is in their economic interest to do so. The stewardship of natural resources is not therefore solely in the hands of farmers; it requires, in addition, a conducive policy environment. One of the major purposes of the division will be to link research on technology development with its implications for land use and the policy environment. If the division is to succeed where others have failed, land use specialists and policy makers at national and regional level must be involved in planning the research program collaboratively with CIAT, and - as new technologies and production systems are developed - in formulating and implementing appropriate changes in policy.

Central to the concept of management for the purposes of the division's research is the judicious combination and efficient use of both external and internal inputs. Research on sustainable agriculture in developed countries takes place in the context of food surpluses. These countries can afford the slight decline in yields which low-input approaches to production may incur. In developing countries, however, research must lead to increased food supplies as well as to the conservation of natural resources. The efficient use of fertilizers to complement approaches using endogenous inputs is vital in these countries, where ecosystems are frequently degraded because small-scale producers either cannot afford fertilizers or do not have access to them. However, the overuse of external inputs, and especially pesticides and insecticides, must also be avoided, since this too leads to degradation of the resource base. Both problems - underuse and overuse - are prevalent in tropical America, although the former is more widespread than the latter. Both can be overcome by the development of 'ecoproductive' technology; that is, technology that cuts costs and reduces pollution by ensuring maximum efficiency in the cycling of nutrients and the protection of crops by natural control mechanisms, while using the necessary quantities of external inputs to deliver significant yield increases.

Natural Resources

Soils, water and vegetation will be the major natural resources on which the division will conduct research.

Globally, it is soils and water, rather than inferior plants, that are now thought to be the most significant factors limiting further growth in food production. Edaphic constraints are likely to grow still further in importance in the coming decades.

Soils. In tropical America, acid, infertile soils form a common denominator across ecosystems, such that strategic research to overcome this problem will be an important part of the division's research program. Special attention needs to be paid to the development of biologically efficient multi-species systems (in both space and time) that generate and recycle nutrients.

Water. Compared to Africa and Asia, tropical America is a relatively well watered continent - indeed, many of its soils suffer from leaching - but competition for water, especially in highly productive peri-urban areas, will assume increasing importance in the longer term. In addition, hillside environments are often subject to severe erosion caused by run-off; some hillside areas are now without reliable supplies of water. Solving the water conservation problems of hillside farmers will, by regulating river regimes, bring significant benefits to farming in the plains.

Vegetation. Natural vegetation is inevitably replaced by managed ecosystems as the area under cultivation expands. Yet the rapid clearance of large areas of natural forest in Latin America in recent years has often brought only ephemeral gains in food production, cleared areas frequently reverting to bush only a few years later. The futility of this onslaught on the natural resource base underscores the need for more rational land use. In addition, the forest contains indigenous cultivation systems that may offer valuable lessons in how to sustain agriculture in forest ecosystems without substantially reducing their biodiversity.

Another way of protecting remaining areas of forest would be to incorporate the productive functions of natural vegetation - its use as animal feed, fencing, mulch, firewood, and building materials - into multi-species farming systems. However, the spontaneous adoption of agroforestry usually depends on five conditions: high population pressure (and so high demand for building materials and other tree products); absence of alternative free supplies of tree products (from the surrounding environment); secure land tenure; relatively fertile, well watered soils; and rapid returns in the early years of adoption. Where these conditions are not met, strong policy support will be needed to promote adoption. Multi-species production systems incorporating trees will form an important component of the new division's research, with the emphasis on fast-growing tree species adapted to acid, infertile soils, and the provision of appropriate policy backing.

Tropical America

The division will concentrate most of its research on key ecosystems in CIAT's host region, tropical America. However, there will be spill-over benefits for other regions with similar ecosystems, especially those with acid, infertile soils. Subtropical Mexico, the humid tropical zone of West and Central Africa, highland East and Southern Africa, and the humid zone of South-East Asia are among the other regions that stand to benefit from these spill-over effects.

Private Benefits and Social Costs

The relationships between the private and social consequences of land use are complex, involving considerations of time as well as place. Some of the benefits and costs of agriculture, for example increased income from higher crop yields, are felt more or less immediately, at the farm level by individual producers and their families; others, such as erosion, make their effects felt over time, and/or may be experienced chiefly beyond the farm as externalities, for example polluted water courses, increased siltation, and so on. The short-term benefits experienced by one generation of producers may incur costs for the next.

Macro and Micro Levels

These considerations imply that resource management research must operate at two levels, the macro or ecosystems level, where the social costs and benefits are experienced, and the micro or farm level, where the private costs and benefits are felt. In addition, because the environmental effects of technology may take many years to accrue, resource management research will be long-term in nature.

The division's research at the micro level will be oriented toward the generation and testing of ecoproductive technologies. The approach will be to 'piggy-back' conservation practices on production practices, making them adoptable by farmers. Multi-species systems are conducive to such an approach because they combine crops that complement each other in exploring the space above and below ground and in supplying endogenous nutrients. Studies on the nutrient dynamics of soils as related to different plant characteristics are fundamental to the understanding of this complementarity. Given its strategic nature and links with germplasm development, this field appears particularly suitable for CIAT involvement. Strategic research on soil-plant relationships will be a shared field of interest between the Germplasm Development and Natural Resource Management Divisions, helping to integrate their work.

Research at the macro level would be oriented towards the development of alternative ways of using the landscape. These in turn impinge upon the technology options selected for research and development, and upon the policy environment fostered by governments. The values attached to different resources and products critically affect the willingness of farmers to adopt resource-conserving practices and technologies. Hence the policy environment would be an important element of research at the macro level.

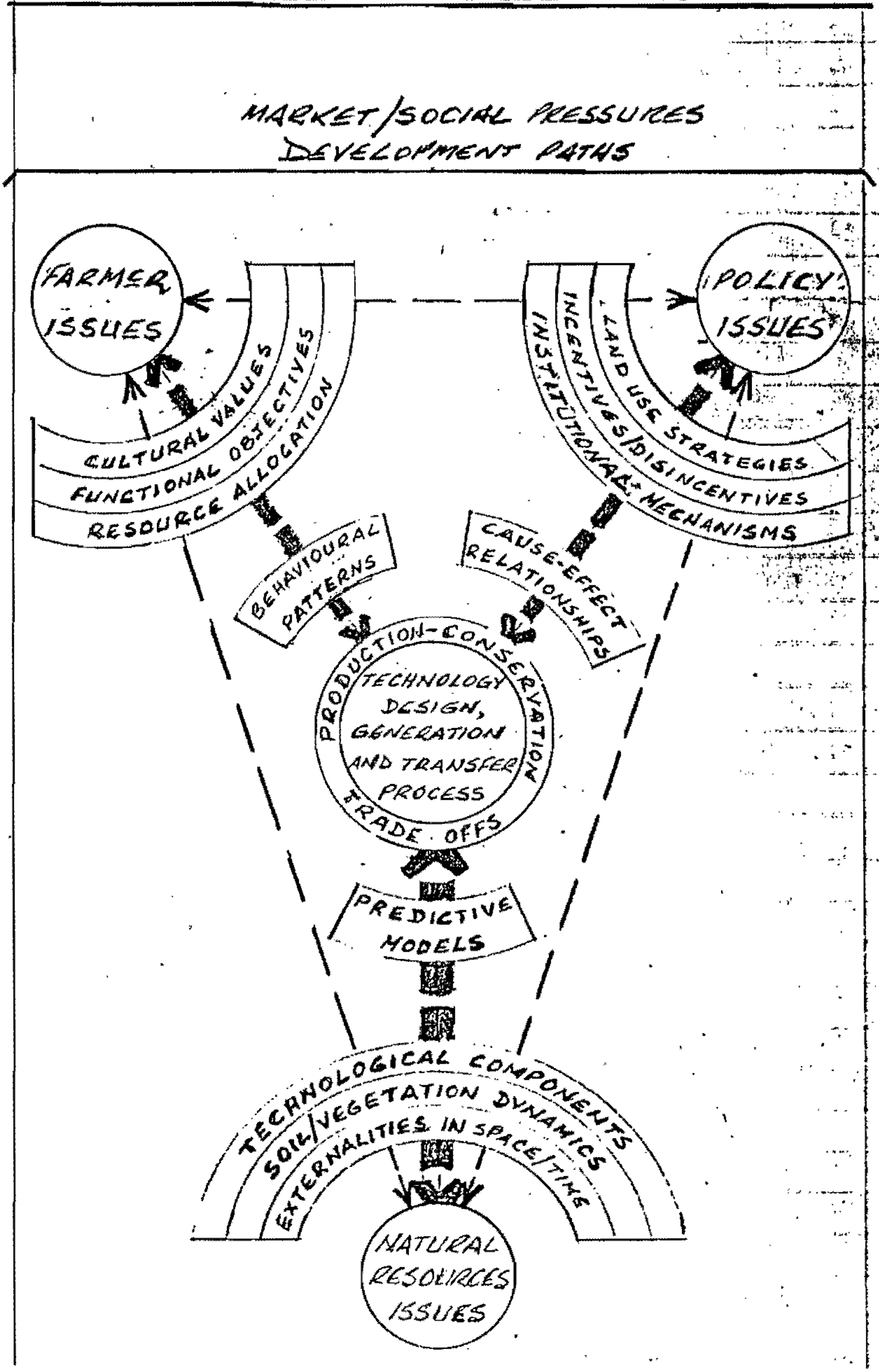
CIAT's contribution to subregional research systems will vary across ecosystems according to available national expertise, but the design of technology will remain the focal point of the Center's work (see Figure). CIAT's special advantage will lie in strategic research in the following areas:

- land use strategies and the policy environment, and how these relate to the allocation of resources at the ecosystems level, to the design of technology, and to the decisions made by farmers

- the resource base and its influence on technology design, as determined by the basic biophysical principles governing soil-plant relationships

- farmers' decisions (in response to potential income generation and other factors) on the allocation of land within the farm and on the choice of technology to use, as influenced by the policy environment.

Figure :
SUSTAINABILITY DIMENSIONS & RELATIONSHIPS



Inter-Institutional Research

Integrating research at these two levels, on a wide range of topics, will not be easy. As well as being multidisciplinary, the research will need to cross sectorial boundaries, involving not merely agricultural, but also forestry, livestock and environmental institutions. In addition, being critically concerned with the relationships between government policy, technical options and farmer behavior, the research process will need to unite a wide range of protagonists, ranging from policy makers, through scientists and extensionists, to farmers. Appropriate mechanisms for ensuring the commitment of these widely differing protagonists and institutions, and the flow of information between them, will have to be developed.

Resource management research is often more site-specific than commodity research. Even in collaboration with others, CIAT will not be able to generate technology for all locations. Instead, a case study approach will be used, whereby adaptive research in a few locations will serve to develop approaches and methods for use by others. This will be complemented by strategic research to increase our understanding of the principles of resource management for sustainable agriculture. Each case study will develop the necessary links between policy makers, scientists, extensionists and farmers.

Organizational Structure

The Natural Resources Management Research Division will have three research programs devoted to land use, tropical forages and ecosystems, and a research support program devoted to institutional development.

The land use program will conduct research at the ecosystems level, linking trends in the resource base with the policy environment and the design and adoption of technology.

The tropical forages program will be responsible for CIAT's major thrust in the design of soil-enhancing technology to support mixed farming systems in a range of different ecosystems and environments. As technologies are designed, responsibility for their testing will be gradually transferred to the ecosystems programs.

The ecosystems programs will be devoted to the three priority ecosystems identified for CIAT's research: the forest margins, medium-altitude hillsides and savannas. The programs will conduct research to design and test technology at the farm level, while retaining a strong ecosystems perspective through their links with the land use program.

Two headquarters-based disciplinary groups will cut across these programs. These will be devoted to the social sciences and to soil-plant relationships. Research on the social and economic factors affecting resource use is, as we have seen, vital in the rapidly evolving context of agricultural development in tropical America. In addition, cutting across ecosystems, the special problems of the region's acid, infertile soils also warrant a specialized disciplinary group. Neither group would have formal organizational status, however.

The Institutional Development Program will consist of three major sections, the Training Section, the Communications and Information Section, and the Project Design and Development Section. Training and information activities are already well developed at CIAT, and will continue to exercise a center-wide role despite being attached to this division. The Project Design and Development Section will support the planning and implementation of multi-institutional research and development projects. Also attached to the program will be a seed unit, helping to develop seed production at national level.

Program Interactions

The land use, ecosystems and tropical forages programs will share many common problems and opportunities. A continual flow of information between them will be necessary. Case studies at divisional level will provide the common ground integrating the work of the various programs.

The division will liaise closely with the Germplasm Development Division (GDD) on the targeting of germplasm and the specification of ideotypes.

Land Use Program

Justification

Large areas of the developing tropical world are subject to serious problems of resource degradation, caused mainly by the inappropriate use of land for agriculture. On the other hand, Latin America has much underutilized land, which could be brought into production with less risk of degradation. The long-term productive potential of both existing and potential agricultural land is limited by production techniques that lead to degradation.

Agricultural research based only on the production system is insufficient to optimize long-term productivity and address resource degradation problems, especially those associated with externalities. There is a need, therefore, to integrate the technical development of production components and systems with the development of appropriate overall land use strategies and policies. This will require detailed studies of production systems within land use patterns, and also more broad comparative studies of land use patterns within different environments and under different policy scenarios.

CIAT has a strong data base on climates, soils, vegetation and socio-economic factors. This information is continentally comprehensive and can be used for comparative studies. CIAT also has experience in rapid rural appraisal and survey design. With its extensive experience in tropical America, the Center can help forge productive links among national agricultural research institutions, natural resource monitoring agencies (national and international) and development entities (governmental and non-governmental). In this way CIAT will be able to integrate the development of production technology with the study of land use.

Goal

To improve the information and institutional bases for the rational management of land resources in tropical America.

Objectives

1. Understand the dynamics of land use

Activities to meet this objective will include the identification of trends in land use patterns, the analysis of causal relations between socio-economic/policy factors and land use, the measurement of the social costs of different land use practices, and the characterization and monitoring of the land resource base.

2. Appraise policy alternatives for improved land use

Activities to meet this objective will include conducting comparative and historical studies of the impact of the policy environment on land use, and the provision of support to national and regional entities in their design of policy scenarios to achieve alternative land use patterns.

3. Link production systems improvement with sustainable resource use

Activities to meet this objective will include studying how technology affects land use dynamics, orientating the design of new technology so that this optimizes land use practices, and monitoring the effects of new technologies on the resource base.

4. Strengthen national capacity for improving the management of land resources

Activities to meet this objective will include developing human resources through joint research and training, providing a forum for the exchange of information among national agricultural research institutions, resource management institutions and policy making bodies, and distributing information through data bases and publications.

Outputs

This program may be expected to have the following outputs:

1. Improved understanding of trends in land use in tropical America.

2. Improved understanding of the effects of technical change on land use and the resource base.

3. Inputs to agricultural research institutions on the design of technology to improve land resource management.

4. Improved understanding of policy impact on land use and the resource base.

5. Policy scenarios to improve land use management (as an input to the development of production technology).

6. Strengthened links between agricultural research and resource management institutions.

7. Improved data bases and land use research methods.

8. Strengthened institutional capacity for improving the management of land resources.

Tropical Forages Program

Justification

Beef and milk are important components of the diet of the urban and rural poor of the tropics, particularly in Latin America and the Caribbean, where they are staple foods. As development takes place and incomes rise, demand for these products will increase.

Ruminant production is a key component of tropical agricultural production systems. More then 90% of the 250 million head of cattle in tropical America are raised on grazed pastures and native grasslands. In areas with access to infrastructure (about 15%), there is a growing tendency towards development and intensification of smallholder dual-purpose (beef and milk) production systems and the integration of crops and pastures.

Throughout the humid and subhumid tropical regions of the world, acid soils are an important but fragile resource. There are 850 million ha of them in tropical America, 450 million ha in tropical Africa, and 210 million ha in tropical Asia. Legume-based pastures can make a significant contribution to the sustainability of tropical agricultural production systems, providing erosion control, improvement of soil fertility, and weed, insect, and disease control through spatial and temporal diversification.

Trees and shrubs, as long-lived perennials, can be important components of sustainable production systems and have many potential uses such as forage, nitrogen fixation, soil stabilization, building materials, live fences, and shade. However, suitable germplasm of tropical woody species adapted to low fertility acid soils (oxisols and ultisols) is not available.

CIAT's tropical pastures program has made solid progress in the past 12 years in the collection and screening of grass and legume germplasm, and its deployment in pastures. A number of key species have been selected for adaptation to very acid, infertile soils in the lowlands of tropical America. This successful research puts CIAT in a unique position to expand its efforts in tropical forage research by further improving the key species already identified, and extending germplasm selection activities to tropical Asia and Africa, thus taking global responsibility for forage development in the acid soils of the tropics.

Pastures and cattle are, and will be, predominant components of production systems throughout tropical America, including the savannas, the forest margins and the hillside agro-ecosystems. This fact, together with the tropical pastures program's experience in assembling and evaluating forage germplasm for adaptation to acid soils, justifies the program's intention to expand its germplasm base to include woody tree and shrub species of forage value for selected agro-ecological zones; and to expand the development of pasture germplasm to higher elevations (up to 1500 meters above sea level), where heavy agricultural exploitation has degraded, or threatens to degrade, the natural resource base.

Goal

To enhance the natural resource base for sustainable agriculture and increase the supply of beef and milk for human consumption.

Objectives

1. To develop productive pastures and herbaceous and woody forage germplasm adapted to acid soils and resistant to biotic and abiotic constraints.

The activities to meet this objective will vary according to different sub-objectives.

Activities to improve key species will focus on genetic manipulation, applying advanced techniques to solve major limitations. The breeding objectives will include insect resistance and quality factors in Brachiaria spp., disease resistance in Stylosanthes and Centrosema spp., improved seed yield in C. acutifolium and S. guianensis var. pauciflora, and acid soil adaptation in A. pintoi, B. brizantha, and Panicum maximum.

Activities to develop pasture germplasm suitable for higher elevations (800-1500 meters) in CIAT's target ecosystems will focus on the acquisition and characterization of new species. They will include the definition of plant ideotypes, the acquisition of existing collections, the conduct of targeted collection missions if existing collections prove inadequate, and the determination of quality and anti-quality factors in new species.

Activities to select pastures and multi-purpose trees/shrubs will center around multilocational germplasm development in collaboration with national agricultural research and development systems. Major screening sites will be established in each of CIAT's priority ecosystems, where selection for adaptation to specific conditions and purposes will be carried out. CIAT will also provide preselected materials for multilocational testing through networks, including

RIEPT, WECAFNET and SEAFRAD. Seed and Rhizobium supplies will be developed for multilocational testing.

2. To understand the mechanisms responsible for ecological compatibility, so as to improve the efficiency of germplasm development.

Again, activities to meet this objective will vary according to different sub-objectives.

To understand plant/soil interactions and identify the mechanisms responsible for adaptation to poor acid soils, and for soil enhancement, the program will undertake anatomical, physiological and biochemical studies on root systems and patterns, nutrient uptake, the contribution of roots and litter to organic matter, the relationships between roots and shoots, and the identification of genes responsible for various adaptive mechanisms.

To understand plant/biotic constraints and interactions, and to identify the basis for plant resistance, the program will conduct studies on key pests and diseases, including the anatomy and biochemistry of spittlebug (in Brachiaria spp.), anthracnose (in Stylosanthes spp.), Rhizoctonia (in Centrosema spp.), and others according to need. Studies will also be conducted to characterize the genetic variability of diseases and pests, and to identify the genes responsible for plant resistances.

To understand the plant/plant and plant/animal interactions occurring in mixed species systems, the program will conduct studies on above-ground and below-ground plant competition, on quality and anti-quality factors for ruminant production, and on the physiological, biological and biochemical factors affecting fiber digestion. The program will also assess the potential uses of various species for animal production and soil enhancement.

3. Strengthen national and regional capabilities to develop, evaluate, select, and deploy pastures and multipurpose forage germplasm.

To consolidate pasture development research cooperation within RIEPT, the program will promote the advanced training of national scientists, seeking to increase the share of responsibilities taken by NARIs in collaborative research. Jointly with the Seed Unit, the program will also promote the development of experimental and basic seed supplies.

To develop germplasm networks for the acid soil lands of tropical Asia and Africa, the program will consolidate WECAFNET (West and Central African Forage Network) in collaboration with ILCA and IEMVT/CIRAD, develop the SEAFRAD (South East Asian Forage Research and Development) network in collaboration with CSIRO, and help to develop improved methods for relevant germplasm screening in these areas.

To develop mechanisms for cooperation in advanced research (including CIAT's Biotechnology Unit, NARIs in the region and specialized institutions in developed countries), the program will conduct specialized training on strategic research and the transfer of improved evaluation methodologies, and liaise between advanced research institutions in developed countries and NARIs, where these have the capacity to adopt advanced techniques.

4. Evaluate the role of pastures in nutrient cycling and soil improvement.

This objective is a transitional one. After 1995 act· ities in this area will be conducted by the savannah program.

To understand the mechanisms of nutrient cycling in grazed pastures, the program will evaluate nutrient pools and fluxes under contrasting pasture conditions (soils, associations, input levels and grazing intensities), develop response functions through research in parallel controlled experiments to expand applicability of the results (including other factors in the system, such as crops), and develop and integrate partial models to expand the applicability of the principles developed.

To develop and adjust methodologies and techniques for nutrient cycling research, the program will identify methodological bottlenecks, test alternative methods and techniques, and train national scientists in selected simple and reliable methods.

Outputs

1. Germplasm: productive, herbaceous and woody (shrub and tree) forage plants adapted to acid soils.

2. Improved pastures for animal production and soil enhancement.

3. Information and methodologies:

   - Understanding of the adaptive mechanisms of plants to biotic and abiotic factors, and of their genetic bases;

   - Understanding of factors responsible for quality and productivity;

   - Characterization of herbaceous and woody forage species in terms of their potential productivity and compatibility;

   - Understanding of the plant attributes contributing to soil enhancement;

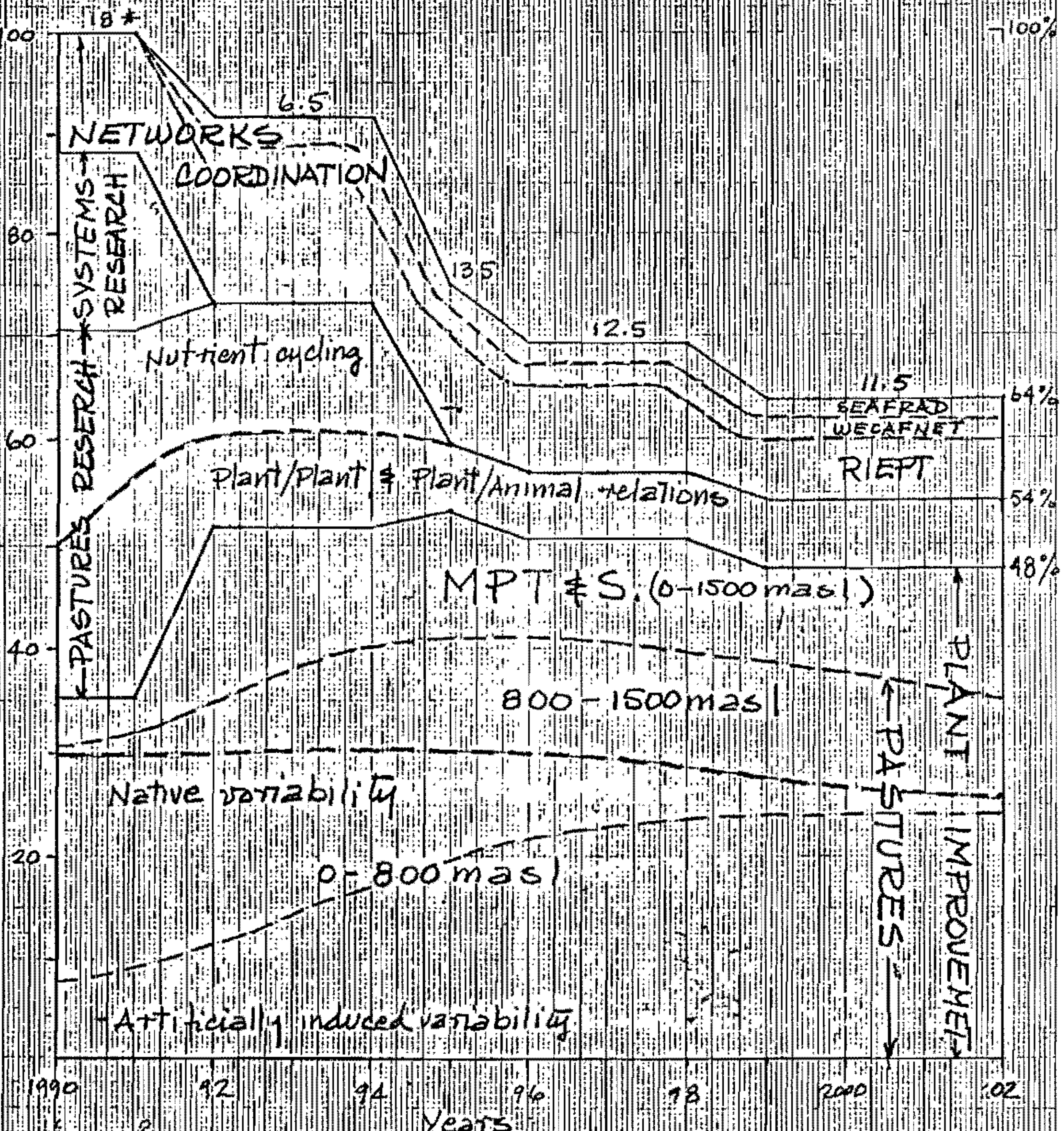
   - Information on potential uses (other than as forage) of acid soil tolerant plants in diverse tropical agricultural production systems;

   - Improved methodologies for germplasm development.

4. Active networks, in tropical America, Africa, and Asia, integrating NARDS interested in the development, evaluation, selection, and deployment of pastures and multipurpose tree woody forage species.

Figure

FROM TPP TO TROPICAL FORAGES PROGRAM (1990-2002)



* Total number of Senior Staff Possitions

Note: An Average of 6-8% of The Programs resources per year is spent in Training activities.

Ecosystems Program

Three programs are envisaged to focus on the major agro-ecological zones selected for priority research by CIAT: the forest margins, the savannahs, and the medium-altitude hillsides.

A number of approaches will be common across these programs. Each program will undertake system diagnosis, consisting of the characterization of production systems, the identification of problems and opportunities, and the analysis of causal relationships between farmers and land use, and between natural resources and technologies. This phase will be carried out in close cooperation with the land use program. Secondly, each program will generate alternative production systems, including a design phase, the ex-ante testing of components, and on-farm testing. Thirdly, each program will undertake training and other activities designed to strengthen the participation of national and other research and development groups.

Each program will be multi-institutional. CIAT's contribution will be fivefold. First, the Center will seek to understand land use systems and devise possible alternatives, so as to derive a common research agenda. Secondly, CIAT will catalyze the participation of other institutions in the implementation of research. Third, the Center will identify the principles of land use decision-making for sustainable production (at both the farm and the ecosystems level). Fourth, the Center will derive the biophysical principles that determine the sustainability of multi-species technology. Fifth, the Center will provide plant components for sustainable multi-species technologies.

Forest Margins Program

Justification

Deforestation is taking place rapidly in tropical America. In the Amazon basin and in Central America 12% and 60% respectively of the original forest has been cleared. Deforestation threatens to reduce global biodiversity and destabilize global climates.

To reduce deforestation two types of action would have to be taken. Macro-economic policies would have to be changed, to discourage large-scale entrepreneurial deforestation for plantations and ranches. Poverty-driven small- to medium-sized colonization would be less sensitive to policy measures, and this problem would have to be addressed differently. Technologies that reduce the amount of land needed to make an acceptable living and that stabilize farming need to be developed. Since the management requirements of the fragile soils of the forest margin can be more easily satisfied on small- to medium- than on large-sized farms, such technology might make a lasting contribution to relieving pressure on forests. The program would therefore specifically address the development of production technology for small- to medium-scale colonizers on already cleared land. The principal objective will be to settle the shifting cultivator.

To avoid detracting from savanna development by making the clearance of forest more attractive, this program will conduct research only in those countries lacking extensive savanna areas and hence having no alternative development paths.

Goal

To reduce the pressure on tropical forests through the development of ecologically and economically sound production systems for already cleared land.

Objectives

1. To assess the effects of technological innovation on migration and deforestation.

Activities in pursuit of this objective will include socio-economic studies to improve understanding of the causes of deforestation, the social and economic circumstances of settlers, and the potential of technology to influence them. The program will describe and analyze current production systems in the forest margins, and attempt to gauge the impact of technology improvement on the demand for land from outside the ecozone. Current migration patterns within and beyond the zone will be analyzed.

As technology is designed and tested in case study areas, its economic, social and environmental impact will be carefully monitored (in cooperation with the land use program).

2. To intensify agriculture so as to reduce the destructive effects of shifting cultivation.

The program will develop sustainable, intensified production systems for degraded lands in areas of small- to medium-sized colonization. With collaborating institutions and farmers, consensus will be reached on the desirable characteristics of these systems. For example, the aim might be to double or treble average per caput income, using an area a fifth of the current farm size.

The basis for technology design will be improved understanding of the interactions between system components, with the emphasis on nutrient cycling. Pathways to achieve the transition from unsustainable to sustainable systems will be identified, together with intermediate targets to measure progress.

3. To liaise with land use and policy bodies to assist in the development of improved land use strategies.

A regional land use plan will be vital to ensure that new technology has a positive impact on immigration and deforestation rates. The program will collaborate with the land use program and with national policy analysts in providing information inputs to such a plan.

4. To strengthen national capabilities for developing improved forest margin production systems.

In pursuit of this objective, the program will derive principles and methods for generating improved technology. It will train regional and national researchers in approaches to production systems research. Collaborative mechanisms for joint technology development and information exchange will be developed at regional and international levels. Eventually, these will also contribute to technology diffusion.

Outputs

1. Information:
   - Understanding of the social and economic forces behind deforestation and the constraints faced by forest margin settlers
   - Understanding of how policy and technology interact in the forest margins
   - Improved understanding of the factors that determine ecologically feasible production systems at the forest margin
   - Research methods for establishing stable forest margin production systems

2. Impact on agriculture and forest conservation:
   - Alternative ecologically and economically sound production systems for the forest margins
   - More efficient use of available natural resources and exogenous inputs
   - Reduced rates of deforestation per settler in case study areas

3. Strengthened institutional capacities
   - Models for collaborative research in the forest margins
   - Mechanisms for generating and exchanging technologies and information at the regional and international levels

Medium-altitude Hillsides Program

Justification

The hillsides of tropical America represent between 40% and 80% of the region's total cultivated land area, and are more densely populated than any of the region's other agro-ecosystems. About 30 to 50 million resource-poor farmers live in the hillsides. The location of many large cities either in or near the hillsides means that these areas produce between 40 and 80% of the staple foods traded in city markets. However, the relative labor productivity of these areas is very low - often less than 50% of the average productivity for the economy as a whole.

Due to their steep slopes, the overriding environmental problems of these areas are soil degradation and water management. Soil fertility is variable, often exhausted by many years of cropping, and soil erosion is exacerbated by unsuitable cultural practices. There is pressure on the small remaining forest areas for firewood, building materials and additional arable land.

Clearing these areas will reduce rainfall catchment and increase erosion risks by bringing still steeper land into cultivation.

The key to resolving these environmental problems will be the establishment of income-generating activities that permit the accumulation of capital and the gradual intensification of agriculture. Hillside areas with good market access will continue to play an important part in supplying high-value food crops to urban centers, and may also permit the diversification of production for export. However, some areas have poor access and long travel times to markets. Income-generating activities should therefore focus on small- to medium-scale agro-industrial processing (dairying, fruit processing, processing of forest products). Basic staple food production will continue to play an important part in these areas.

Goal

To improve the welfare of the hillside farming community by developing commercially viable and sustainable agricultural production systems.

Objectives

1. To analyze soil-plant-animal-water interactions and how farmers manage them.

This research will identify general principles for the design of sustainable hillside farming systems suited to the human and physical resource base. The proposal is to study the mechanisms of resource degradation in a number of contrasting situations and to compare existing with alternative production systems as a means of establishing how to intervene with technology.

The program will conduct diagnostic research to characterize resource management problems in the hillsides and select representative sites for research. Next, partner research and development organizations will be identified, leading to the setting of a common research agenda. Farmers' decisions relating to the management and exploitation of natural resources will be analyzed and modelled. The nutrient balance in contrasting systems will be studied. The program will then construct and/or adapt models for the analysis of alternative technological interventions in terms of their impact on sustainability indicators, such as soil structure and stability, the accumulation of organic matter, water runoff, and so on. Lastly, biological and socio-economic models will be combined to predict income and the degree to which resources will be conserved through given interventions.

2. To generate viable soil and water conservation components and management practices which will provide farmers with productivity and income benefits in the short term and contribute to the conservation of resources in the long term.

Numerous technologies to conserve soil and water have been developed, but farmers seldom adopt them without policy inducements. Trade-offs between income generation and resource conservation that are acceptable to farmers will be location-specific. The program will therefore collect information on and evaluate a broad spectrum of component technologies. A key activity for the program will be to manage data on component technology.

Activities in pursuit of this objective will include the evaluation and adaptation of promising technological components, including germplasm, cultural practices, livestock, etc, for selected research sites. Ex-ante studies of the social and economic viability of component technologies will be conducted, and a central data base on component technologies created.

3. To combine and test on farm technological components that meet established income generation and resource conservation criteria.

Participatory research methods will be used to involve farmers in the design, testing and evaluation of prototype technologies. The project will emphasize flexible adaptation of the prototypes over time, as farmers and scientists assess their management and impact, thus providing feedback to the design stage. The sites used for testing the components will be those identified for objective 1, and the work will be carried out in partnership with local organizations.

Activities in support of this objective will include the on-farm testing of prototypes at various sites, monitoring and evaluation of nutrient balances, energy flows, income generation and food availability, and the development of methods for monitoring and evaluation activities.

4. To strengthen the capacity of national research and development systems to generate and transfer resource-enhancing technology.

Given the complexity of the socio-economic, technical and environmental problems of the hillsides, initiatives to improve natural resource management in this ecosystem must form an integral part of an overall regional development plan which considers agricultural as well as non-agricultural activities. This will require strong emphasis on inter-institutional and inter-sectorial cooperation, so as to permit accurate identification of the problems to be solved and to allow adequate staff and other resources to be deployed for their solution. CIAT will play a key role in catalyzing the interaction of the various organizations working on natural resource conservation in the selected regions. Study tours, training courses and other activities will be carried out.

The most important activities in pursuit of this objective will be the formation of an information exchange network of entities conducting location-specific resource management research and development, the formulation of projects to extend results over wider areas, and training in the areas of expertise developed by the program.

Outputs

1. Better information on the principles of technology design required to motivate farmers to implement resource conservation practices.

2. Techniques for managing soil-water-plant-animal interactions to provide a satisfactory trade-off between income generation and resource conservation.

3. Data base on component technologies and system interactions for the design of integrated prototype sustainable farming systems for the hillsides.

4. Prototype systems established in pilot sites, which generate improved income and welfare while protecting and enhancing the natural resource base.

5. Methods for evaluating systems that conserve natural resources.

6. Projects to replicate the results obtained.

Savannas Program

Justification

Of the 200 million ha of acid-soil savannas in tropical South America, almost 90 million are well drained and relatively flat. These lands are exploited primarily for extensive cow-calf beef production on native and sown grass pastures. Intensive agriculture, involving rice, soybean and maize has played an important part in opening up the savannas. Agriculture and ranching are intensifying in areas with relatively good access to infrastructure (10 million ha). Continuous cultivation of soybean is leading to serious soil degradation through compaction and erosion, while weed and insect buildup is causing heavy use of toxic agrochemicals. Sown grass pastures in many areas are degrading from overgrazing, insect attack, and lack of fertilizer inputs.

The establishment of sustainable, highly productive intensive systems would open up the largest land resource in the continent for use by present and future generations. The intensification of agriculture in the savannas will generate employment both locally and throughout the economy. In addition to promoting overall economic growth, this will contribute to the welfare of the poor through lower prices of critical food staples such as rice, beef and milk. The arable savannas are ecologically less diverse than the tropical forests, and appear to be better suited to agriculture. Development of the savannas may well provide an alternative to the humid forests for food production, as the latter become less competitive due to market prices and infrastructure development costs.

Over the last 15 years, CIAT has acquired a great deal of knowledge on land use patterns in the savannas, the predominant production systems, and their constraints. At the same time, improved varieties and management practices for important crops such as cassava, pastures and rice have been jointly developed by CIAT and national programs.

Goal

To develop sustainable and productive agricultural systems for the acid-soil savannas, thereby contributing to the development of tropical America.

Objectives

1. To identify key agricultural sustainability problems and development opportunities in the acid-soil savannas.

In collaboration with the land use program, national institutions and farmers, the savanna program will characterize existing production systems, identify and prioritize the main sustainability problems, and place these in the context of the policy environment. These studies will compare production systems in which problems are occurring with those which appear more stable. Special attention will be given to the impact of these systems on the overall environment, including existing social and market structures. Issues of particular concern will include soil physical and chemical characteristics, pest management, biodiversity of the savannas, farmers' decision-making processes, seasonality of employment, market access and the dynamics of land tenure. Appropriate partners for research and technology transfer will be identified.

2. To design technological interventions that will lead to increased productivity while preventing or reversing resource degradation.

In rapid rural surveys in Brazil and Colombia, farmers have expressed keen interest in adopting profitable crop and pasture rotations and associations. Such systems may be seen as mechanisms for maintaining and improving the productivity of the land, and for recuperating degraded systems. While CIAT and national programs have developed some components for incorporation into savanna cropping systems, the implications of pasture-crop and continuous crop associations and rotations for sustainable intensive production are unknown.

The nature of moderate-input, sustainable systems implies heavy reliance on gene-based technology. Close interaction with CIAT's commodity programs will therefore be essential. Multi-species pilot production systems incorporating elements of existing systems plus components developed by CIAT, other IARCs and NARDS will be assembled and tested for their agronomic and economic feasibility. The modification and design of sustainable production systems will be undertaken with appropriate institutions under experimental and on-farm conditions, to identify critical socio-economic and agronomic parameters.

Long-term research on soil-plant relations under different cropping and grazing schemes is required to develop methods for monitoring and predicting the sustainability of alternative systems. Such assessments will also include relating different production systems to market access, labor availability, management requirements and other socio-economic parameters.

3. To understand the biophysical aspects of savanna production systems and their management for sustainable production.

At the systems level, basic studies on biotic and abiotic factors, including plant-soil-microbe relations and pest-plant interactions will be conducted to understand the processes contributing to long-term productivity or leading to system degeneration. Input on plant physiology, pest and environmental interactions will be obtained from the relevant commodity programs and from other research institutions. Nutrient cycling models will be constructed using data from the pilot systems and parallel controlled studies. From these models will emerge methods for designing intensive, sustainable systems, predicting the decline of a productions system or recommending early intervention before decline occurs. It is recognized that the biophysical components form only part of a sustainable system; thus studies will address the skills required to manage these systems and their socio-economic implications.

4. To strengthen institutional capacities for the design and monitoring of savanna production systems.

The problem identification and research steps will of necessity be carried out in collaboration with the relevant national systems. This process will include both formal and informal training components, and multi-institutional integration, leading to the development of stronger national capacities.

Outputs

1. Improved understanding of the conservation and development issues of the savannas.
2. Improved technology for more intensive development of the savannas, ensuring the conservation of the natural resource base.
3. Stronger national capacities to conduct research and development activities in the savannas.

Institutional Development Program

Justification

During the 1980s CIAT has contributed significantly to the strengthening of national agricultural research and development systems through training researchers and technology transfer specialists (Figure 1); by producing training materials, and technical and networking publications; by providing bibliographic information; and through the organization and hosting of conferences.

In the 1990s, the Center will need to turn its well established training and communications capacity to new institutional development challenges.

The program's information and documentation services will use state-of-the-art information technology to meet the needs of a broadening audience, which will increasingly encompass natural resources management institutions in addition to agricultural research institutions which have also increased in number and kind.

The Center's publications will also serve this enlarged clientele, with materials highly targeted to specific segments of the audience.

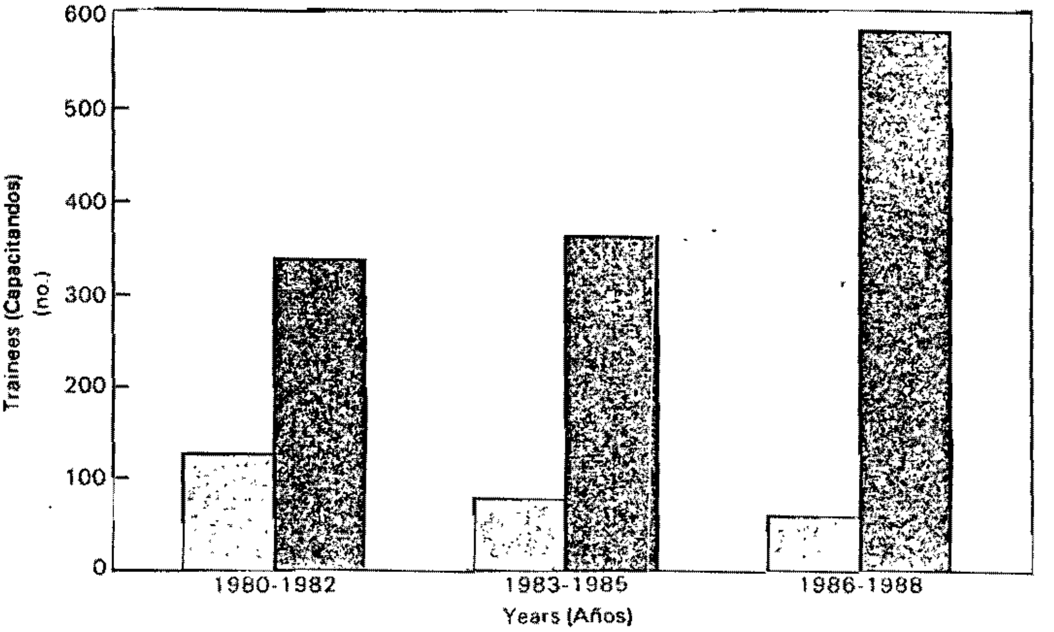


Figure 1. During the 1970s, CIAT's training courses concentrated on commodity research and production. In the 1980s, emphasis was shifted to specialized research training, and the number of professionals trained by CIAT increased steadily.

Figura 1. En los años setenta la capacitación del CIAT se concentró en investigación y producción por cultivos. En los ochenta se desplazó hacia investigación especializada, y el número de profesionales capacitados aumentó progresivamente.

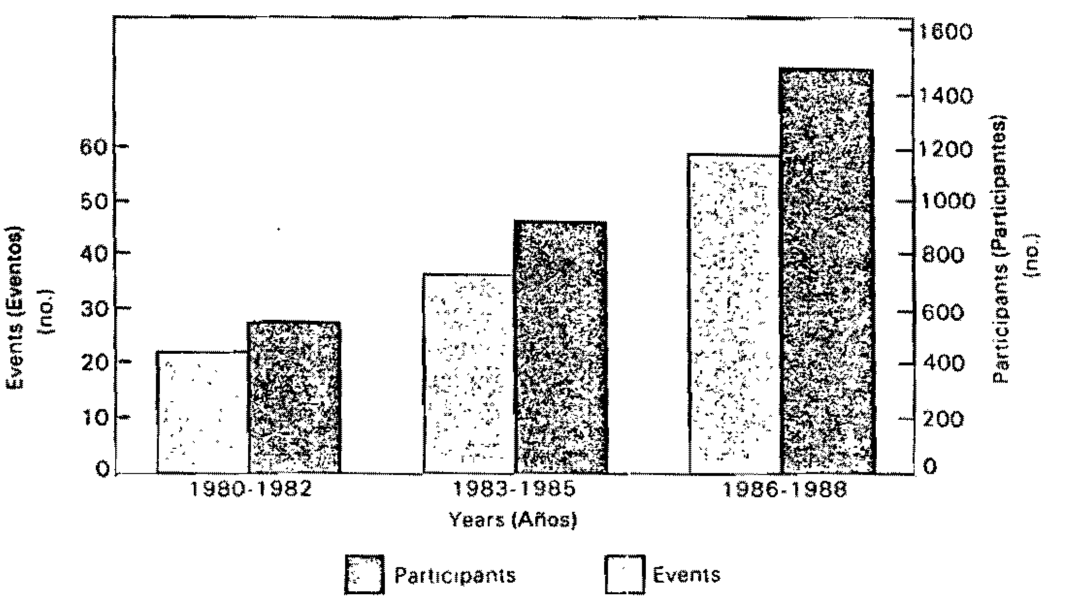


Figure 2. Commodity-specific in-country training in the 1980s

Figura 2. Capacitación sobre cultivos en los países durante los años ochenta.

Most national programs now have a critical mass of well trained professionals for technology transfer and adaptive research on the Center's mandate commodities. CIAT's training will, therefore, become increasingly specialized, meeting emerging needs in applied and strategic commodity and germplasm development research.

Little indigenous training capacity for updating or replacing existing researchers and technology transfer specialists has yet been developed. CIAT will help put this capacity in place, so as to secure the progress achieved through commodity research training during the 1980s.

As the Center gains experience in research on natural resources management, it will gradually move into training national professionals in these subjects.

CIAT has a strong track record in inter-institutional cooperation for increasing the efficiency of national and regional research systems. However, as research becomes more complex, the numbers and diversity of the institutions involved will increase. Forging and implementing a common research agenda in the management of natural resources will be particularly complex. And the outcome of the research will rely increasingly on the successful contribution of each and every participating institution.

Effective links between institutions will therefore be vital to the success of CIAT's research. In helping to build these links, the program will seek to apply the knowledge on the dynamics of inter-institutional cooperation dynamics obtained by ISNAR and other organizations. Training in the management of collaborative research projects will also be offered.

Links between research and development will also need strengthening. Although development is site-specific and typically the responsibility of national institutions, there is a case for international centers to participate in pre-development activities.

Centers need the involvement of end users in technology design, and their early feedback on the appropriateness of new technologies. Also, centers can contribute significantly to the development of methodology for development activities. And finally, by playing a role model, they can stimulate national institutions to adopt technological or institutional innovations. Involvement in pre-development activities would not be a core activity, but would be pursued through special projects.

In summary, CIAT's training, information, communication and inter-institutional linkage activities will address new challenges in the 1990s. To this end, the Institutional Development Program will pursue the goal and objectives, and execute the activities, that follow.

Goal

To strengthen the capacity of national and regional research systems to contribute to sustainable agriculture.

Objectives

1. Increase the effectiveness of national research systems.

To meet this objective the program will pursue three major activities.

It will promote the exchange and provision of information through the products and services provided by its information and documentation group, through assisting in the organization of conferences and other meetings (and the presentations made at them), and through publications targeted for specific audiences.

The program will also conduct specialized training in the disciplinary, methodological and technological activities undertaken by CIAT. This training implies the prior assessment of training needs.

The third activity will be to support the development, strengthening and maintenance of links between institutions (in networks, consortia, and projects with CIAT participation). This will be done through communications support (conferences and publications), by facilitating the application of knowledge on the dynamics of inter-institutional relationships, and by providing training in the management of inter-institutional research projects (with the program itself as the training ground).

2. Link research with development for sustainable agricultural growth.

This objective will be pursued through two major activities.

To promote and support inter-institutional development projects so as to ensure the application of research results, the program will provide expertise in project design, technical advice, liaison with funding agencies, assistance in understanding the dynamics of inter-institutional cooperation, and training of project staff. The program will also study the institutional factors affecting the adoption of research results and how to manage those factors.

To support the development of alternative sources of supply for seeds and other planting materials, the program will study the feasibility of developing such sources, conduct training in their development, and produce relevant information materials.

3. Enhance national/regional training in commodity production and adaptive research

This objective is a transitional one.

To meet this objective the program will train trainers at national level in research and production methods for CIAT's mandate commodities, in the organization of courses, and in adult education techniques. Through dialogue with senior decision makers, the program will seek to institutionalize training on commodity research and production at national level.

Outputs

1. More effective national research systems;
2. Better trained staff;
3. Institutional models and methods for applying the results of research;
4. Institutional models for alternative seed supply systems.

CHAPTER FIVE

GERMPLASM DEVELOPMENT RESEARCH

Divisional Goal

To contribute to sustainable increases in the production of selected commodities by enhancing the exploration and utilization of germplasm resources.

Approach to Research

Organizational Structure

The Germplasm Development Research Division will have three commodity research programs devoted to rice, beans and cassava, and a biological research support group.

Rice Program

The rice program's task is to generate and disseminate improved technology for increased and stable rice production in Latin America and the Caribbean. The program originated from a collaborative rice breeding effort initiated in the 1950s, and renewed in 1967, between the Colombian Ministry of Agriculture and the Rockefeller Foundation. An Inter-American rice program was justified as a means to facilitate research on region- specific production constraints and cropping systems, and to promote the incorporation of Latin American scientists within the global rice research network. Having a regional mandate, it is the smallest of the CIAT's commodity programs and is able to draw upon considerable research resources available from other centers, especially IRRI, which has a global mandate for rice and addresses global strategic research issues.

Being small and confronting heterogeneous rice-growing environments, the program has concentrated on a limited number of topics which promised large impact in the short term. Emphasis has been on incorporating resistance to prevalent blast races and pests into the high-yielding background developed in Asia. To maintain its high level of effectiveness, the program has focussed its research on germplasm development for irrigated rice. Research on other important problems, such as those of the unique Latin American upland rice production systems, has, until now, had to be deferred.

The germplasm-based technology generated, combined with favored moisture and purchased inputs, has resulted in significant yield gains. About 75% of the production of those areas with dependable water supply is now coming from material generated from IRRI/CIAT germplasm. Germplasm exchange networks linking national programs have been established. Researchers can share research results and methods, and can jointly plan research projects. The program has contributed significantly to the strengthening of national rice programs in Latin America. Most rice programs in the region are now reasonably well staffed, at least in the area of varietal improvement.

With CIAT now emphasizing sustainability and natural resource issues, genetic solutions to production constraints will become increasingly important. The program will continue to place heavy emphasis on germplasm development. Adjustment is needed, however, to move from what has been solely a program focusing on high-yielding irrigated germplasm to one that covers a broader range of ecosystems and issues. Currently, 60% of the region's rice production comes from the irrigated sector, which occupies 40% of the rice area. Upland rice is largely concentrated in Brazil, where a team of national scientists conducts research on specific issues relevant to that country's cropping systems.

For rice supplies to keep pace with the region's expected population growth rate of around 2% during the 1990s, substantial production increases must be realized. Since the region's economic difficulties will seriously limit investments to expand the irrigated area, most of the contribution of irrigated rice to increased supplies will have to come through yield increases. However, the region also has vast areas of grass savannas, generally supporting only poor quality native pastures at present. The high and generally reliable rainfall over much of this area suggests that more intensive upland rice production may be a key to increasing the overall productivity of these lands.

It should be emphasized that increased rice production requires more than technological improvements. Political and administrative support is needed if the potential benefits of technology are to be realized.

The challenges for the next decade are to:

- develop technologies for increasing the efficiency and stability of the most productive systems

- open up new opportunities in less favored areas through adapted and high-yielding germplasm

- incorporate and adapt advances in the rapidly developing area of rice biotechnology, such that both the products and the methods developed in this field will be relevant and available to national rice programs in the region

- expand existing regional networking activities to realize full multidisciplinary interaction among NARDS around rice production constraints of regional concern.

For areas where the Natural Resources Management Division is focussing its efforts, such as the acid-soil savannas, the program will concentrate on developing germplasm and associated knowledge to meet the needs of specific production systems. This will require research on rice pests and germplasm adaptation to key environmental constraints. In areas where the Natural Resources Management Division is not working, such as the irrigated rice sector, the program will continue to backstop NARDS in their development of well rounded programs addressing growers' needs. In both cases, particular attention will be directed towards generating the technological components essential for developing sound, integrated pest management strategies, and towards facilitating networking on crop management.

National breeding programs are generally under pressure from the rice industry and policy makers to develop technology that addresses current production constraints and will show an immediate benefit. Resource limitations prevent investment in risky or long-term projects which will produce less tangible or quantifiable impact, such as broadening the genetic base of their cultivars. CIAT is less subject to these pressures and is well placed to address long-term issues of regional relevance. As such, CIAT's research objectives have been developed with a longer time horizon and are designed to provide the knowledge base for continued growth in national rice research and production.

CIAT's approach to institutional relations between rice programs will enable national scientists to acquire and maintain the necessary research skills and ensure the flow of information at national, regional and international levels.

Goal

To improve the nutritional and economic well being of rice growers and consumers in Latin America and the Caribbean through sustainable increases in rice production and productivity.

Objectives

1. **To broaden the available genetic resource base for irrigated rice in the region so as to increase the stability of production.**

The widespread diffusion of genetically similar, modern, high-yielding varieties over most of the region's irrigated area indicates that breeding to increase genetic diversity must continue to be a high priority. Furthermore, pest and disease resistance genes already incorporated into irrigated germplasm come from a limited number of sources, compromising the stability of resistance. Farmers tend to respond to this instability by relying on toxic agrochemicals for pest management. CIAT will build upon its considerable experience in incorporating useful genes into adapted backgrounds to provide novel, diverse, stable sources of resistance for regional and national breeding programs.

A further constraint to irrigated rice production is that modern germplasm usually requires adequate water supply for the full expression of its yield potential. Current trends in irrigation development suggest that water availability will continue to decline as a result of lower rates of new systems construction, increased water demand from competing crops, and degradation of existing systems due to siltation. An important part of the rice program's efforts in breeding and genetic diversification will be devoted to incorporating improved root systems and other plant characteristics into broad-based breeding populations to better deal with declining water availability.

To accomplish this objective, some work currently conducted by CIAT will have to be passed on to those NARDS which have the capability. Fixed lines will no longer be developed at CIAT with the principal objective that they serve as potential varieties. Many of the national programs are conducting varietal development activities with proven relevance to the needs of other countries. Where possible, these programs will assume greater responsibility for providing advanced materials for areas with similar requirements. This implies a fundamental shift in CIAT's breeding strategies toward providing good parental material and developing different breeding strategies for different target systems and areas.

Four major activities will be undertaken in pursuit of this objective. The program will aim to transfer upland rooting habits and other traits affecting plant response to water stress to high-yielding irrigated types. In addition, diverse genetic sources of pest and disease resistance will be incorporated into breeding populations with improved genetic background. As CIAT passes more responsibility on to national programs, it will be necessary to develop screening and evaluation methods relevant to NARDS' needs. Lastly, CIAT will continue to provide good parental material to national partners, so as to allow the development of commercially suitable rice varieties for Latin America and the Caribbean.

2. To achieve and sustain a fuller expression of yield potential in irrigated systems while reducing external inputs

The yield potential of available modern varieties is not being realized in many areas, due to pest pressure, inefficient use of inputs, suboptimal management practices, and socio-economic factors. With the increasing sophistication of IPM/ICM practices and the experience being gained in Asia in this area, Latin America and the Caribbean stands to benefit from the experience of others in adopting such an approach. Similarly, with the tremendous advances in rice biotechnology over the last few years, it is likely that new tools for managing pests and crops will shortly be available.

As many important irrigated rice areas are outside the focus of the Natural Resources Management Division, and since the diversification of cropping systems is a key to stabilizing yields and increasing productivity, the program will have to conduct some systems research for the irrigated sector. In many areas, beans are grown on the residual moisture following a rice crop. Collaboration with the bean program will be developed to explore ways of improving this system.

Specifically, the rice program will generate integrated crop management component technologies, seek improved understanding of the factors governing their interactions, and study the implications of socio-economic and long-term market environments in/for upland and irrigated rice production systems for technology relevance, design, and adoption. The program will also address factors mediating the importance, variability and interaction of key biotic and abiotic constraints of regional importance. Rice blast, Hoja Blanca virus/sogatodes, planthopper complex and red rice will receive special attention.

3. To develop high-yielding rice germplasm adapted to the high- rainfall acid-soil conditions of the South American savannas, and compatible with upland production systems

The 2.2 million hectares of high-rainfall savanna upland rice which have not benefitted from germplasm with a high yield potential offer great opportunities. Since populations currently being developed by the program have produced lines with good yield potential which tolerate the harsh soils and biotic stresses of such areas, there is an opportunity to achieve substantial production increases and area expansion in these lands. However, the soils are fragile, such that careful development of sustainable agronomic practices, rotations and associations will be needed.

The program will collaborate closely with the savanna program of the Natural Resources Management Division in developing suitable rice germplasm for diverse production system requirements.

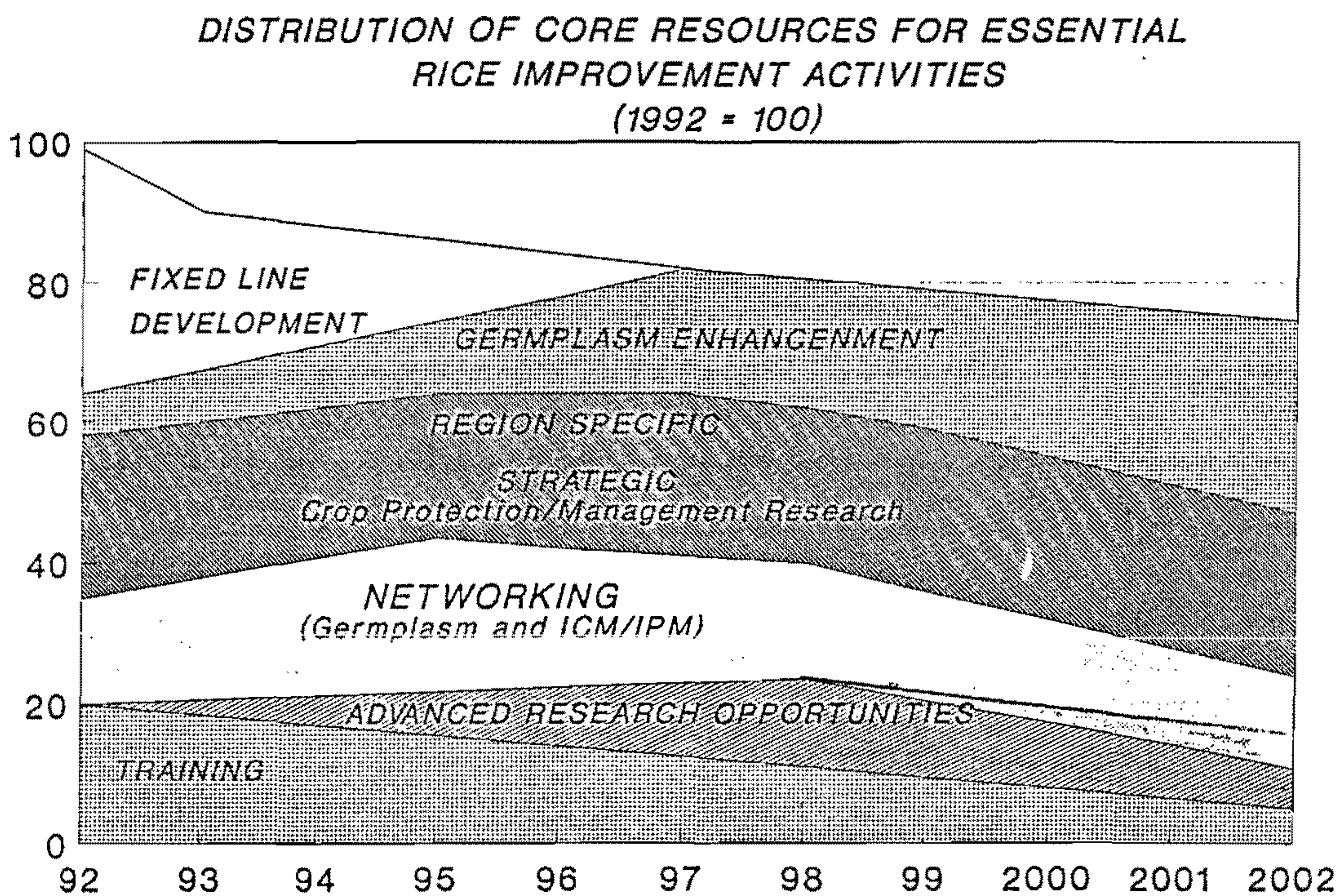
The approach will be threefold. The program will develop breeding populations which incorporate sufficient variability to generate lines addressing production system requirements. It will explore and develop new plant characteristics which may open up new production alternatives. And it will seek to understand the mechanisms of upland rice and tolerance to acid soils.

4. To strengthen NARDS capacity to undertake the scientific research necessary for improving and stabilizing national rice production and to design and implement collaborative national research and training plans.

In-service training will increase in importance, and will include short courses with specific topics. The program will also become a regional center for advanced training in rice research, hosting graduate students from the region who will conduct postgraduate projects in collaboration with program scientists. Postdoctoral fellowships will address specific issues of regional importance.

As the program moves more towards strategic research, it will be essential to ensure that those activities that previously were conducted at CIAT be addressed at national level. Over the next several years, the rice program will cooperate with selected NARDS in the identification of priority constraints. Analyses of the rice production environment will indicate specific training requirements for both in-country courses and in-service training at CIAT. The program expects to collaborate closely with the Institutional Development Program in this area.

The program will adopt the following approaches in concert with the Institutional Development Program. It will seek to meet the needs currently addressed through the general training course by developing national training capabilities that will replace it with more specialized and intensive training opportunities. It will explore the possibility of strong national programs assuming some regional training responsibilities. And it will link specific research activities with the advanced educational and research needs of NARDS' scientists.


DISTRIBUTION OF CORE RESOURCES FOR ESSENTIAL
RICE IMPROVEMENT ACTIVITIES
(1992 = 100)
100
80
60
40
20
0
92
93
94
95
96
97
98
99
2000
2001
2002
FIXED LINE
DEVELOPMENT
GERMPLASM ENHANCEMENT
REGION SPECIFIC
STRATEGIC
Crop Protection/Management Research
NETWORKING
(Germplasm and ICM/IPM)
ADVANCED RESEARCH OPPORTUNITIES
TRAINING

5. To promote effective information exchange among and within NARDS

While the region's germplasm exchange needs can be adequately met through the existing International Network for the Genetic Evaluation of Rice (INGER), there is no structure to support interactions among other national program scientists. A mechanism to facilitate interaction among Latin American rice researchers working in crop management and between these and the members of the existing network is necessary, both to improve the efficiency of technology design and to ensure adoption. The rice program will work in close collaboration with the institutional development and land use programs to address the need for increased communication through newsletters, regional conferences, and databases.

To achieve this objective, the following activities will be conducted: a network of rice agronomists will be established, a Latin American rice research newsletter will be launched, and databases will be developed on present and potential rice-growing agro-ecological zones, germplasm development activities, and biotic and abiotic constraints to rice production in Latin America.

Figure shows the program's projected resource allocations over the next decade.

Outputs

1. Improved parental materials for irrigated rice production.
2. Improved parental materials for upland rice production.
3. Improved pest and disease management.
4. Stronger and better informed national rice programs.

Bean Program

Beans are the most important food legume for over 500 million people in Latin America and the highlands of eastern and southern Africa. They are the leading source of protein for over 100 million poor consumers whose diets otherwise consist principally of low-protein starchy staples. Demand growth for beans is fastest in Africa, where production increases are lagging behind population increases.

Small-scale farmers in Latin America and the Caribbean are producing dry beans and snap beans principally for the urban market. Increasingly, they are using chemical inputs, which are often abused. In contrast, the bulk of production in Africa is by women, working in a subsistence setting without the use of purchased inputs. As much as 60% of beans are grown in association or in relay with other crops.

Accomplishments of CIAT's bean program to date have been significant. Through collaborative effects with national programs, more than 50 improved varieties are now grown by farmers on more than 350 000 hectares in America, Africa and Asia. The value of this increased production is some US$ 50 million annually. Figure illustrates the effect of technical change on bean production in Costa Rica.

Most national programs have made great strides in developing an effective cadre of trained breeders, plant protectionists and agronomists, but the capacity to work on abiotic constraints remains neglected. On-farm research capacity has also increased. National programs are now linked through regional research networks, permitting greater specialization of effort and exchange of results.

As national capacity increases, CIAT's bean program will significantly reduce its effort in applied research and institutional strengthening, while expanding its efforts in strategic research (Figure).

Substantial progress has already been made in strategic research to improve resistance to pests and diseases, the program's top research priority during the 1980s. Increasing yield potential and overcoming edaphic stresses remain major challenges. Significant opportunities also exist for applying advances in biotechnology to beans for more efficient identification and transfer of useful genes. CIAT's effort in strategic bean research will increase, although the overall effort on beans will fall by more than one-third.

Goal

To increase the food availability and incomes of the poor by improving the productivity of beans through the development of technology in collaboration with national institutions.

Objectives

1. To develop advanced biological methods to better utilize genetic resources.

Progress in molecular biology offers opportunities to develop methods for more efficiently identifying and transferring useful genes, both within common beans and from related species. With the world's largest collection of **Phaseolus** genetic resources, CIAT has a special advantage in exploiting these methods. For example, biochemical markers are already being used at CIAT to improve the efficiency of conventional breeding, and genes found only in wild bean ancestors have been successfully transferred to commercial bean types to confer resistance to storage weevils.

In the future, increasing emphasis will be placed on understanding the genetic structure of common beans. Gene pools will be characterized and co-evolution studies between beans and pathogens, insects and rhizobia will be conducted.

The development of genetic probes can significantly improve the efficiency of conventional breeding. The program will be developing genetic probes for use in national program breeding efforts. This will be particularly useful for tagging genes in order to pyramid numerous desired resistances for diseases, pests and nutritional stresses.

Through the use of gene maps developed in the first instance by basic research laboratories in developed countries, CIAT will isolate specific desired genes and adapt to beans methods of asexual transformation and regeneration for direct gene transfer.
The genetic base in common beans will be broadened. As well as an increased capacity for intro-specific gene transfer, methods will be developed to permit inter-specific introgression in order to access desired traits known to exist in closely related species. Manipulation of quantitative trait loci will be undertaken. The potential will be assessed for improving rhizobia for nodulation and the efficiency of biological nitrogen fixation.

Much of this work will depend critically on access to and conservation of precious genetic resources. Studies of conservation methods will be undertaken and patterns of genetic diversity will be studied to prioritize selective genetic resource acquisition. In particular, the potential for increased utilization of wild ancestors and related species will be evaluated.

A greatly increased program effort in developing these methods is foreseen. This fundamental shift depends critically on access to progress in basic research conducted by laboratories in the developed countries. CIAT's role will be to harness the new techniques available for improving beans. Links with advanced research institutions through a bean biotechnology network will be a key aim. Likewise, the success of this strategic shift depends on national program capacity to use the methods, components and parent materials developed by CIAT.

2. To increase the yield potential of beans

The yield potential of beans has not increased as much as for other, more intensively researched crops. Only a small part of the genetic variability in beans has so far been used in breeding. Yield potential in beans varies substantially by plant and grain types as well as by maturity class, so that yield improvement strategies will be framed by these variables, e.g. large-seeded determinates or small-seeded indeterminates.

An increased effort will be undertaken to exploit variation across gene pools while breaking undesirable genetic links. Yield-maximizing optima for physiological traits such as photoperiod/temperature adaptations, canopy morphology and patterns of nitrogen uptake and partitioning will be identified.

An effort will be made to modify the growth habits of the preferred large-seeded determinates, in order to achieve the increased yield potential of indeterminates. Delayed maturity and improved plant architecture will also be sought. Overall program efforts to improve yield potential will more than double.

3. To improve adaptation to edaphic constraints

The overall soil fertility of bean-based systems is declining because of the expansion of beans into marginal soils, shortened fallow periods, soil erosion, and high costs and/or limited availability of fertilizers, especially in Africa. Biological nitrogen fixation in beans is low compared with other legumes, and can be improved. The mechanisms of bean adaptation to low phosphorus or acid soils have yet to be determined. Water stress is the most important cause of unstable production, but little is known about drought tolerance. In general, national programs have done little in this area, in which problems are not yet fully diagnosed.

The program will focus first on identifying superior genetic adaptation to edaphic stresses, and then, in collaboration with advanced research laboratories, on understanding the mechanisms conferring adaptation. Methods for germplasm enhancement will be developed and parental populations will be provided to national programs. Support will also be given to national program research on fertility management in bean cropping systems. Efforts on abiotic constraints will initially increase, but as progress is achieved these efforts will decline modestly by 2002.

4. To reduce losses from pests and diseases

Knowledge of the biology of most major diseases and pests of beans is now adequate, and sources of resistance are available for many biotic constraints. Nonetheless, because biotic pressures are highly variable and evolve over time, it is urgent to broaden the genetic base of resistance so as to ensure sustainable control of pests and diseases in the long term.

Sources of resistance to some major diseases and insects have not yet been identified in common beans. Some, though, are known to exist in related species. The utilization of desirable genes from related species will become a significant part of genetic enhancement efforts. Molecular tools will be increasingly used for pathogen and insect studies.

The growing use of pesticides, even by small farmers in tropical America, is becoming an ever more serious environmental and economic problem. The program will support national programs in their development of sustainable integrated control strategies to complement genetic resistance and reduce pesticide applications.

Due to the progress already achieved and expected in the near future, it is anticipated that the resources allocated to field studies of diseases and pests, along with conventional screening and breeding activities, will decline by about half.

5. To strengthen national capacity to improve bean productivity.

The bean program has helped to strengthen national research capacity in tropical America and Africa through training; network formation; and collaborative applied research on cropping systems and cultivar improvement. Training has been oriented not only toward the on-station research of national bean research scientists, but also toward applied on-farm research and small-farmer seed production systems.

In the future, total training efforts will decline to about one-third of current efforts, as training in Latin America and the Caribbean will be focussed solely on the needs of on-station research. In Africa, the training needs are greater for both on-station and on-farm research, so the decline in training effort in Africa will be more gradual than in tropical America.

During the 1980s, CIAT has sparked the formation of regional research networks. These networks provide an opportunity for joint planning by national programs of priorities, research activities, training, and exchange of germplasm and information. They encourage the division of responsibilities among national programs for research on problems of regional interest, as well as more effective tapping of regional expertise for training and networking. Such networks are now operative in the Andean Region (in conjunction with PROCIANDINO), Central America, Eastern Africa, the African Great Lakes, and Southern Africa (in conjunction with SACCAR). While CIAT has to date had the responsibility for coordinating these networks, the goal of the national programs and CIAT is that these networks should become autonomous, with CIAT being a member of the network rather than the coordinating hub. Some coordinating responsibilities are already being assumed by participating national programs, and a greatly decreased CIAT role in network coordination is foreseen.

On-farm research is important for priority setting and technology evaluation. This applied research will increasingly be done by national programs alone rather than with CIAT. In tropical America, only a few modest joint research activities will be carried out with national programs in agro-ecozones not included in the work of the Natural Resources Management Division, for example, in highland Mexico, northeast Brazil, southern Brazil, coastal South America, and the Andean highlands. By 2002, this activity will be phased down to less than one-fifth of current efforts.

Cultivar improvement, resulting in the development of finished varieties, has been carried out collaboratively between CIAT and national programs. In tropical America, where CIAT has already been working closely with national programs for over a decade, this activity will be rapidly assumed by national programs. In Africa, there will be an initial increase in collaborative projects with national programs on cultivar improvement as new scientists are trained. However, by 1997 CIAT's efforts will begin to decline as national programs increasingly meet their own needs for finished varieties.

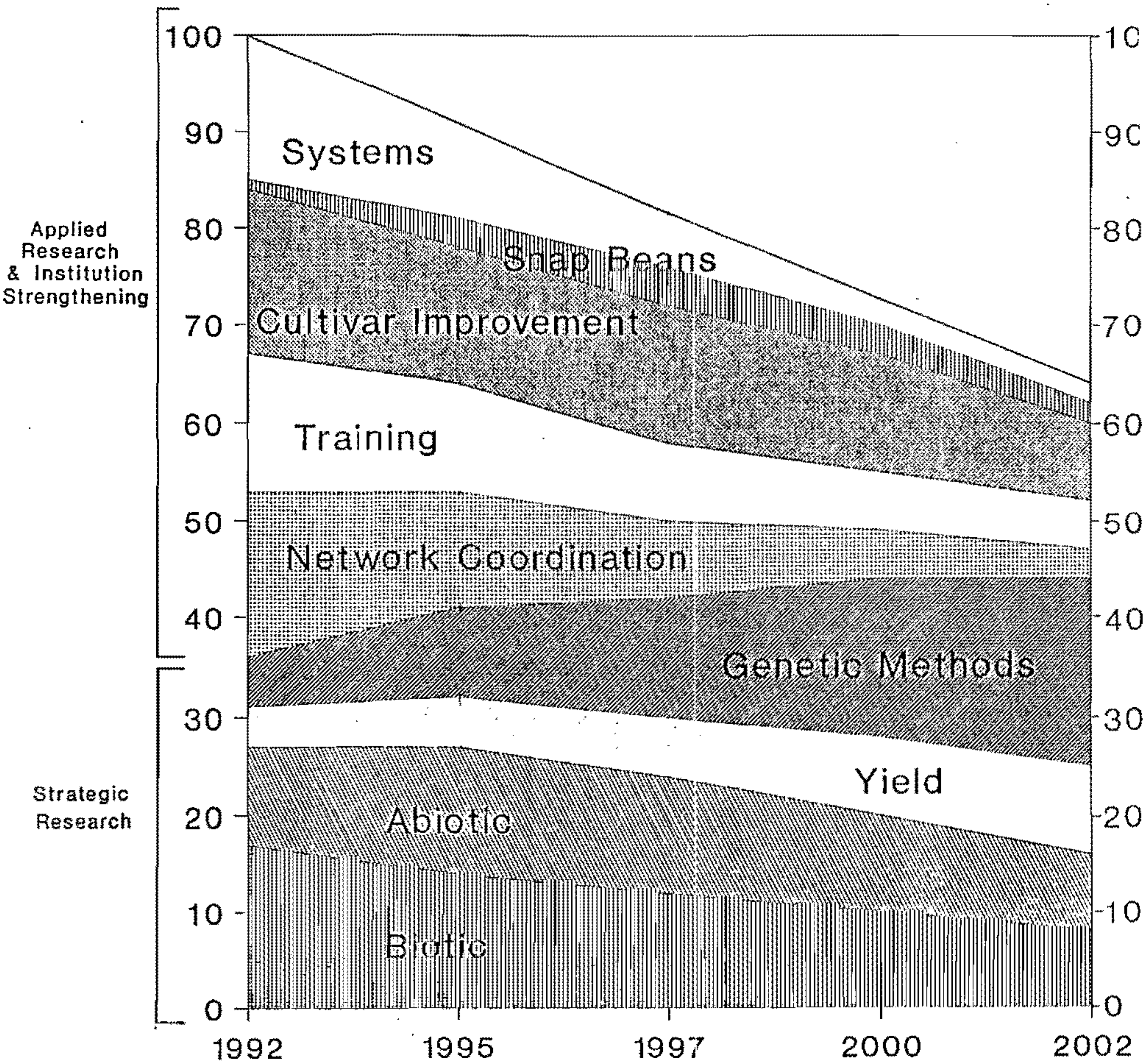
If an international agro-ecosystems center for Eastern Africa were to be formed by the CGIAR, CIAT's effort in bean-based systems research could be reduced below that shown in Figure , while efforts on training bean research scientists, supporting bean research networks, and cultivar improvement, would be unchanged.

The program will expand somewhat its current very minor efforts to improve the tropical adaptation of snap beans. The demand for snap beans is growing rapidly along with other vegetables, and they are an excellent income source for small farmers. Much of the program's strategic research on dry beans, especially as regards insect and disease resistance, is easily transferable to snap beans. Emphasis will be placed on work in tropical America, but materials developed there will also be useful in Asia and Africa.

Outputs

1. Improved parental materials for higher-yielding lines.
2. Reduced losses from edaphic constraints and from pests and diseases.
3. Stronger national bean programs.

Figure 2. Essential Effort to Bean Improvemen
(1992 = 100)



Cassava Program

Demand studies have shown that cassava can compete in many world markets and can play an important role in the world's marginal agroclimatic zones largely untouched by the Green Revolution. In these areas, cassava is often the only crop able to provide resource-poor farmers with a living. Thus, research on cassava is by definition targeted for the direct benefit of the rural poor.

The significant progress made by CIAT's cassava program and its national partners over the last decade has led to the development of a unique cassava research and development process (Figure). The opportunities identified by demand studies provide the basis on which to generate and evaluate appropriate production and processing technology components while taking into account market demands and consumer preferences. The technology developed is subsequently tested and adapted with farmers under market conditions, through the implementation of research and development projects in representative cassava growing regions. Monitoring and evaluation activities help to fine-tune the technology for consequent diffusion over a wide area, and to provide feedback on new research opportunities. In tropical America this process has led to the development of small-scale agro-industries in cassava producing regions. These industries generate higher-value agricultural products, strengthen farmer integration with the market economy and motivate them to invest in improved crop production technology. Figure illustrates the rapid expansion of these industries in Latin America.

This research and development process makes possible the identification of key constraints and opportunities in cassava production and processing where CIAT can complement national programs through strategic research. Some of these constraints may be solved through the application of biotechnological techniques developed in advanced laboratories. The relevance and viability of this basic research can best be maintained through close links between international and national institutions and these advanced laboratories. These links must be designed and strengthened to effectively use the limited resources available and to accelerate advances in cassava research and development.

The challenge for the program in the 1990s is to promote the consolidation of national cassava research and development systems and to provide a link from them to institutes carrying out advanced research on cassava. While maintaining a commodity system perspective, the program will increasingly emphasize germplasm resource development. Applied crop management, utilization and market research will gradually be devolved to national organizations according to their capacity to undertake this type of work. Strategic research in these areas will concentrate on the elucidation of general principles and methods for the design of improved component technologies (Figure). The overall core resources available to the program will remain stable over the period.

Goal

To increase incomes, particularly in the less favored sectors of the rural population, and improve the overall availability, quality and convenience of cassava products in the tropics.

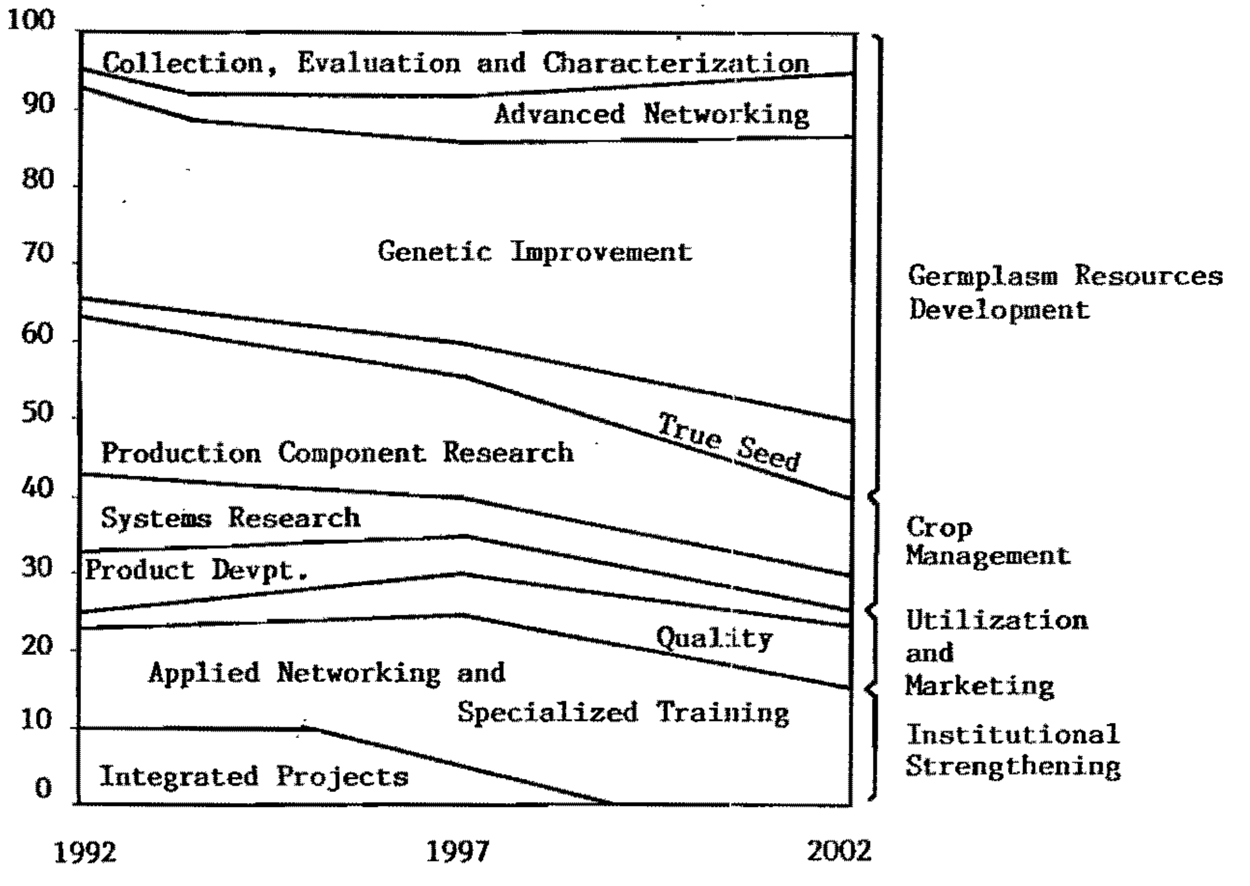


FIGURE 3. Projected Cassava Program Core resource allocation for the decade 1992-2002.

Objectives

1. **Effectively utilize *Manihot* genetic resources (cultivated and wild) to improve the expression of yield potential and the stability and overall acceptability of cassava under prevailing farm and market conditions.**

CIAT provides national programs with breeding methodology, and extensive, well characterized genetic diversity from which they can develop productive, stable and high-quality new varieties. The program works to bring this about through a world germplasm collection, a multiple ecosystem evaluation and selection effort, and extensive collaboration with national programs and advanced laboratories. The germplasm requirements for African countries are secured through coordination with IITA. In the next decade, each of these program elements will evolve substantially.

The steadily improving ability of national programs in cassava breeding will create a demand on CIAT for more precise germplasm characterization, training in advanced breeding techniques, supply of genetic diversity in a range of forms, and networking to share advances among national programs. Designing production systems based on true seed now appears technically feasible, and this will receive major effort during the decade.

To ensure effective germplasm utilization the following activities will be carried out. The program will establish a wild *Manihot* collection and characterize it for potential contributions to cassava improvement. More precise characterization of cassava germplasm will be achieved through molecular fingerprinting, gene mapping, and more efficient screening techniques, especially for pest and disease resistance, drought tolerance, photosynthetic efficiency and quality factors.

The program will ensure the provision of well characterized basic germplasm as sources of specific traits, and the development of populations and elite clones targeted toward broadly defined ecosystems. Lastly, the program will select germplasm and design socio-economically viable production systems to provide producers with the option of cassava propagation from true seed.

2. **Improve cassava production by making available crop management practices for sustainable farming systems in selected agroecosystems.**

Given the heterogeneity of conditions under which cassava is cultivated, improved crop management technology has to be developed for each of the major ecosystems in which the crop is grown. The target ecosystems have now been defined, and emphasis in the future will be given to technology development for the drier regions of tropical America, Asia and Africa; the African highlands; and the subtropics of Latin America and Asia. Cassava- based production systems research for the hillside, savanna and forest margin ecosystems in tropical America will be conducted in collaboration with the Natural Resource Management Division.

Several technology components are already available to national programs and are being validated under farmer management in selected sites representing a wide range of cassava production systems. The feedback from this work orients the program's strategic research.

As cassava is increasingly displaced from more to less fertile environments, yields are restricted by low soil fertility and nutrient depletion, exacerbated by erosion. A major challenge for the program, together with the Natural Resource Management Division, is to make these soils more productive through research on fertility improvement and erosion control. Integrated pest and disease management research will continue to be emphasized to ensure cost-effective alternatives for maintaining and improving yields.

Emphasis will be given to the following activities. The program will improve knowledge of the interactions between the physico-biological environment and plant growth and development. It will also improve knowledge of the interactions between the socio-economic characteristics of representative cassava agro-ecosystems and crop management practices that affect the sustainability of production. Technology components which reduce the costs of production and are suited to the ecological and socio-economic characteristics of target agro-ecosystems will be designed for subsequent testing by national programs. Lastly, the program will conduct research across representative cassava agro-ecosystems on the interaction between crop production and management practices, as a means of deriving general principles on which to base the design of improved technology.

3. To realize the demand potential for cassava through improved quality for diverse end uses.

Genetic, environmental and processing factors affect the quality of cassava end-products. Little research has been undertaken on quality-related issues in cassava, and this will constitute an important new area of activity, ensuring that new varieties are appropriate for their intended end uses and meet the requirements of the farmers that are going to grow them.

During the last decade CIAT has played a major role in developing technology for the post-harvest conservation and processing of cassava, together with the market and consumer research techniques essential for the successful adoption of novel cassava-based products. In the 1990s, a major task will be to form cooperative links with food science and technology institutions to which this type of processing and product development work may be devolved.

Research activities in the area of cassava utilization and marketing will include: participation with national organizations in defining market opportunities and potential for cassava-based products; studies on the major quality factors of cassava roots and leaves, especially starch and cyanide, which will provide principles for better deployment of genetic resources, agronomic practices and processing variables to improve product quality; promotion among appropriate national institutions of the integration of market/consumption, processing and quality research to develop cost-competitive and consumer-acceptable products; and lastly, participation in the formation of regional post-harvest networks for the exchange of information and setting of regional research priorities in tropical America and Asia.

4. To strengthen the research and technology transfer capabilities of national research and development systems.

CIAT has played a major role in the development of national cassava research programs, especially in Latin America and Asia. However, several of these programs are underfinanced and understaffed to meet the increasing demand for improved cassava technology. Because of the limited resources available to these programs, CIAT's cassava program faces a major challenge in motivating and strengthening them. The integrated cassava research and development projects now under way in several Latin American countries have both attracted resources for carrying out research and provided the focus needed for generating relevant technology. The program will build on this positive experience, supporting national research and development organizations in the design, planning and organization of integrated projects. Contract research will play a similar role in Asia.

The scope of the active breeding and agronomy research networks in Asia will be broadened to encompass socio-economic and post-harvest issues. In Latin America similar networks will require consolidating. While continuing to provide organizational support to these regional activities, the program will be seeking appropriate mechanisms for making the networks autonomous by the end of the decade.

In this area the following long-term activities will be carried out. The program will provide advanced and selective training to national research and development personnel. It will define appropriate links with research and development institutions in developing and developed countries. And it will establish regional networks among research and/or development institutions.

Activities of a transitional nature will include efforts to enhance the capacity of research and development institutions to diagnose problems and opportunities and develop cassava research methods, and the training of trainers with a view to devolving selected research and technology transfer activities to national systems.

Outputs

1. Improved parental materials for higher-yielding cassava lines
2. Cassava propagation from true seed
3. Improved crop management practices for difficult environments
4. Improved market potential for cassava-based products
5. Stronger national cassava research and development systems

Biotechnology Research Support Group

(To be written)

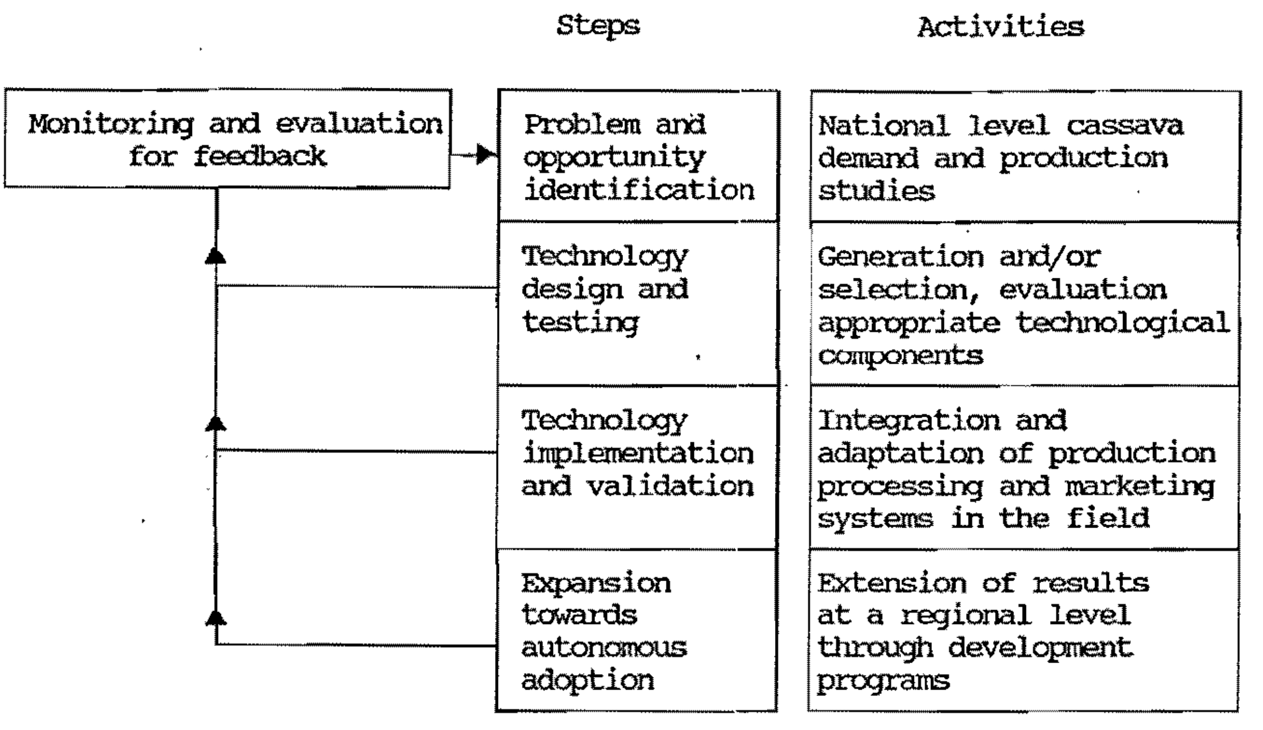
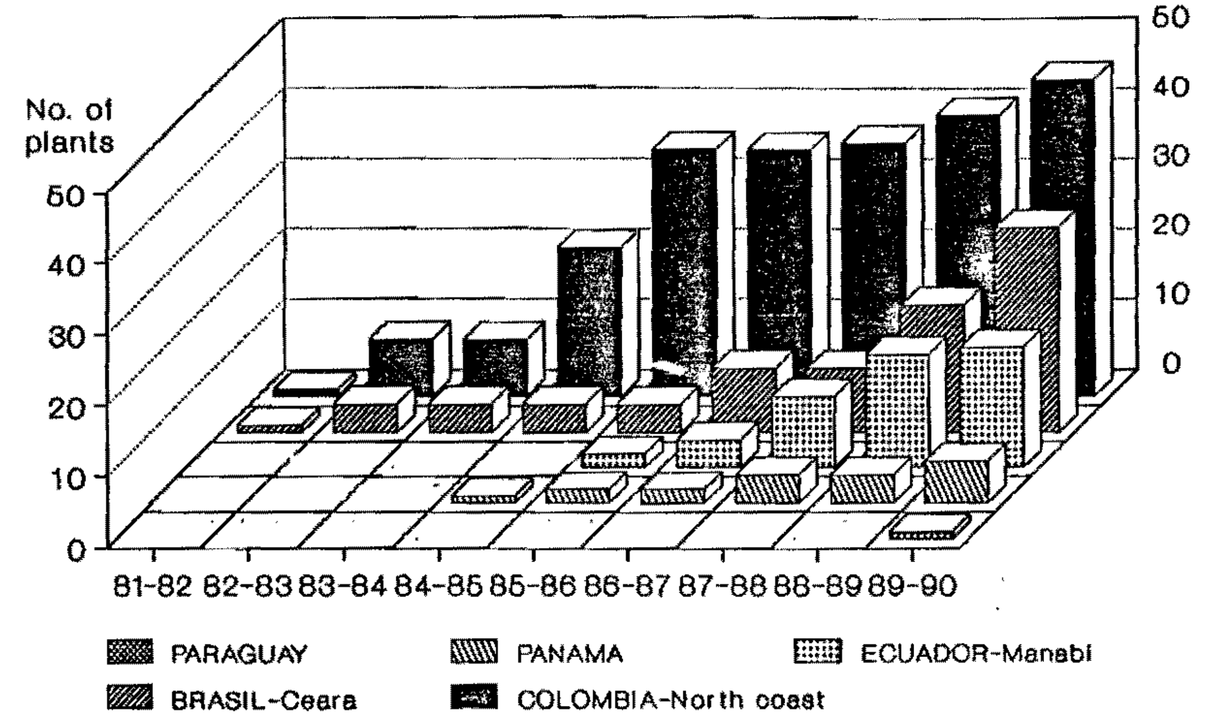


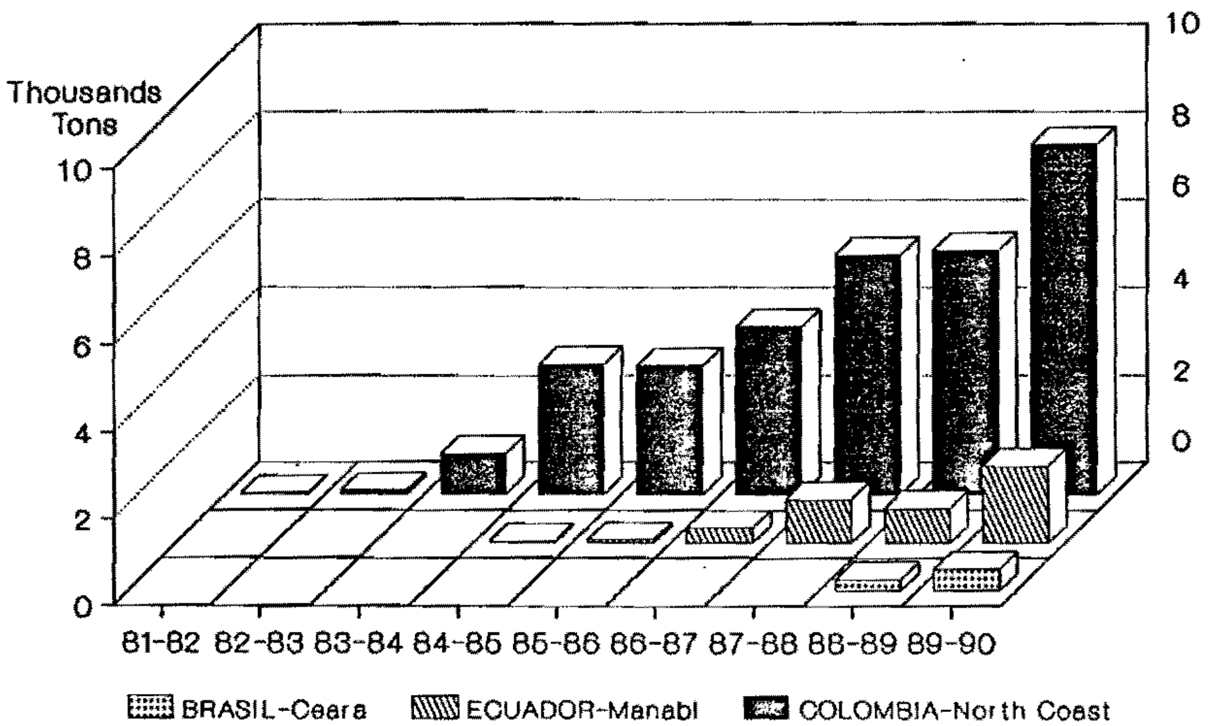
FIGURE 1. Cassava Research and Development Process

Expansion of cassava drying plants in selected countries in Latin America (1981-90).



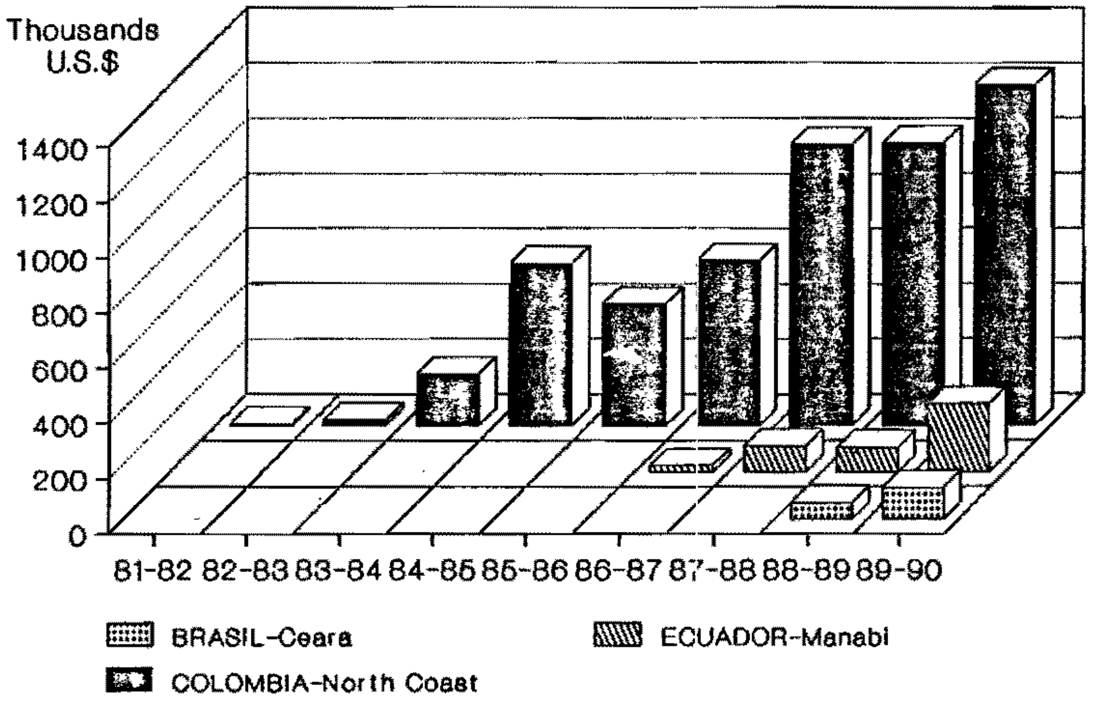
Source: CIAT.

Cassava drying production in selected countries in Latin America (1981-90).



Source: CIAT.

Value of production from cassava drying plants in selected countries in Latin America (1981-90).



Source: CIAT.

CHAPTER SIX

RESOURCE ALLOCATION

This chapter summarizes the criteria that were used to define the areas of emphases to be given by CIAT over the planning horizon, and describes the planned allocation of resources for selected years (i.e., 1997 and 2002).

Defining the Action Radius

In defining the work to be engaged in by CIAT in future years, the following basic considerations were made:

First, the location of CIAT in Latin America, together with years of close association and collaboration with the regional agricultural research and development sector, have provided CIAT with a strong comparative advantage both in the generation of production technologies for a set of important food commodities, as well as in developing science-based solutions to problems related to the management of natural resources in the region.

Second, there are growing expectations that vis-a-vis the major regional concerns for the interrelated processes of economic growth, poverty alleviation, and protection of the agricultural resource base, CIAT-- in carrying out its mission-- should explicitly use the criteria of growth, equity, and sustainability in the selection of its portfolio of activities.

Third, years of relevant research experience has shown that while commodity-research with a sustainability perspective is a necessary condition to ensure relatively high and stable agricultural production levels, this approach alone is insufficient in addressing the major and growing regional concerns for sound natural resource management. There are clear expectations that CIAT frontally addresses the issue of sustainability through a resource management research approach.

Finally, it was recognized that for reasons of cost effectiveness the Center's work in the area of resource management would need to be largely restricted to the immediate region. On the other hand, it was clear that for the commodities for which CIAT assumes a more global responsibility, CIAT would need to continue to maintain a research leadership position that impacts on all areas where the respective commodities are grown.

The Commodity Portfolio

In developing its Strategic Plan, CIAT carried out a zero-base analysis to identify potential candidates for inclusion in the Center's commodity mix. The criteria used were potential contributions to growth, equity, and sustainability; the existence or non-existence of other research entities with a comparative advantage (including CGIAR centers, other international, regional, and national centers; and the private sector); the relative strengths of national programs vis-a-vis given commodities; and CIAT's current comparative advantages. The results confirmed the continued appropriateness of the current portfolio of commodities, and pointed to the relative high potential importance of soybeans and sorghum for specific ecologies and production systems. The same results also showed that a modification in the mandate of the tropical pasture program is called for, such that the program would assume responsibility for forage germplasm with primary emphasis on acidic soils in low to medium altitudes in Latin America and similar soil/altitude environments throughout the tropical world.

Resource Management Research

An in-depth analysis of major agroclimatic classes and associated production systems in the Latin American region led to the identification of four major agro-ecological zones that merit high priority in terms of growth, equity, and sustainability. One of these zones, the semi-arid tropics, was deleted from the proposal, primarily due to the absence of a comparative advantage on the part of CIAT to undertake research for the benefit of that zone.

Minimum Critical Mass

Upon identifying the potential portfolios of commodities, and of agroecological zones on which to focus resource management research, the planning process concentrated on the question of the minimum efforts and resources required to deliver the required outputs in collaboration with the respective research partners. In the process of this analysis it was realized that work on soybeans and sorghum might lead to resource requirements beyond realistic expectations of resource availability. This led to a definition of reduced focus of the proposed work on these two crops; research is proposed to be limited to acid soil adaptation and the development of these commodities as complementary crops in the crop production systems contemplated for the savannah ecology.

Table 1 summarizes the minimum critical mass required in each of the proposed program areas, expressed in senior staff person/years. Shown are the resources allocated in financial year 1990 (actual), and the proposed allocation for the years 1997 and 2002. The respective numbers incorporate the appropriate allocation of resources included in centralized research support units.

From the data in Table 1 it is evident that toward the end of the planning horizon CIAT proposes to allocate 57 percent of its research effort (47 senior staff) to germplasm development research, and 43 percent (34 senior staff) to natural resource management research. Included are considerable reductions in beans and pasture research, and modest reductions in cassava and rice research. It is planned that the commodity programs will fully exercise global responsibilities (except for cassava in Africa where CIAT will backstop IITA in that center's regional responsibility for cassava, and rice which will continue to restrict its focus to tropical America).

Table 1

Proposed Resource Allocation: 1990 (Actual), 1997 & 2002
(Senior Staff Positions)

Program/Area	1990	1997		2002	
Beans	24.4	18		16	
Cassava	12.3	12	51	11.5	47
Rice	9	8		7.5	
Forage Germplasm	19.3	13		12	
Land Use	1	7		9	
Savannah	--	9	31	7	34
Hillsides	--	8		9	
Forest Margins	--	7		9	
Inst. Development	6	8		8	
Mgmt/Admin/Cent.Services	10	8		8	
Total	82	98		97	

Table 1 shows that by 1997, CIAT expects to have all its program in natural resources management research fully operational, and to have this effort fully consolidated by the year 2002.

Table 2 (yet to be developed!) is a preliminary attempt of breaking out the proposed CIAT program in terms of the TAC grouping of categories of activities, broken down by geographic areas (i.e., Latin America, Africa, Asia).

Figures 1, 2, and 3 show the anticipated organizational structures of CIAT as they are envisioned to be in 1991, 1992-1997, and 2002, respectively.

Figure 1: Organigram in 1991

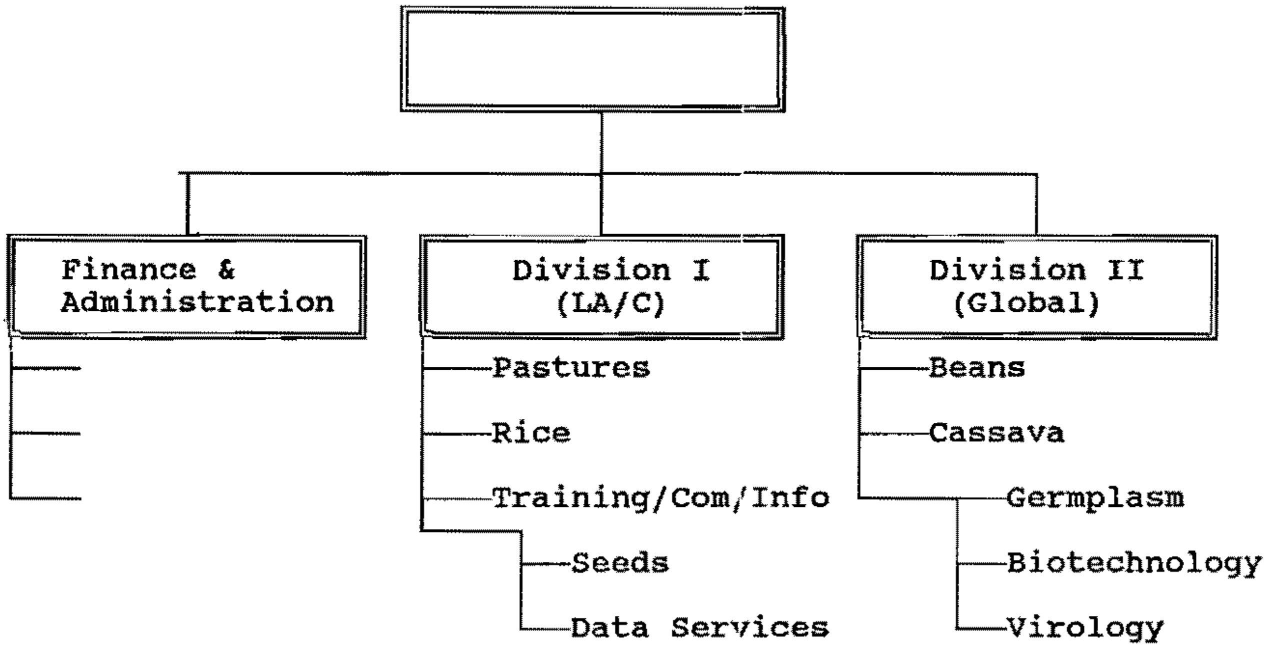


Figure 2: Organigram in 1992-1997

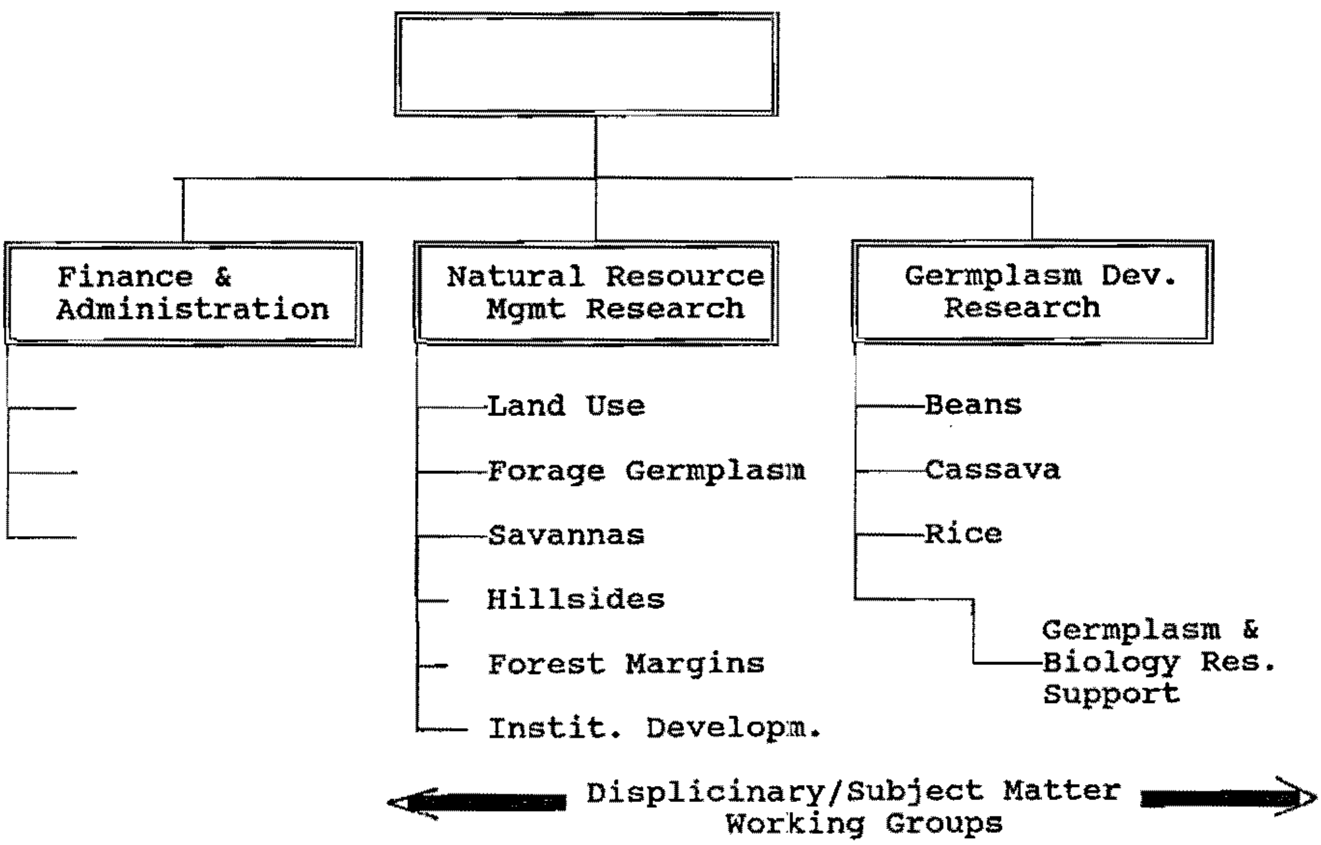


Figure 3: Organigram in the Year 2002