CIAT Medium-Term Plan

Program Plans and Resource Requirements

1993-1998

CIAT
Centro Internacional de Agricultura Tropical

The International Center for Tropical Agriculture (CIAT, its Spanish acronym) is dedicated to the alleviation of hunger and poverty in developing countries of the tropics by applying science to agriculture to increase production while sustaining the natural resource base.

CIAT is one of 17 international agricultural research centers sponsored by the Consultative Group on International Agricultural Research (CGIAR).

The core budget of CIAT is financed by more than 20 donor countries, international and regional development organizations, and private foundations. In 1992, CIAT donors included the governments of Australia, Belgium, Canada, China, Finland, France, Germany, Italy, Japan, Mexico, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States. CIAT donor organizations included the European Economic Community (EEC), the Ford Foundation, the Inter-American Development Bank (IDB), the International Development Research Centre (IDRC), the United Nations Development Programme (UNDP), and the World Bank.

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Contents

This Medium-Term Plan is a companion document to *CIAT in the 1990s and Beyond: A Strategic Plan*. It presents, in operational terms, the program plans and funding requirements for the 6-year period 1993-1998.

The Strategic Plan was approved by the CIAT Board of Trustees in November 1990, and endorsed by the Technical Advisory Committee (TAC) in March of 1991. Later in the same year, by approving CIAT's budget request for 1992--which called for an increase in available funding of 20% percent for the implementation of the Strategic Plan--the Consultative Group on International Agricultural Research (CGIAR) indicated its agreement that CIAT initiate the operationalization of the Plan in the 1992 fiscal year.

Because of significant underfunding in the approved 1992 budget, the Center had to make an important choice: to delay implementing the Strategic Plan until additional resources become available; or to forcefully and immediately put in operation the Strategic Plan by restructuring and reducing existing activities and introducing the new set of activities—albeit at the minimum possible level. CIAT and its Board regarded the latter option as necessary both to serve the pressing needs as identified in the Strategic Plan, and to establish a research agenda that the CGIAR donor community could immediately identify with and support.

Consequently, CIAT engaged in a comprehensive, zero-based planning and budgeting exercise with the aim of identifying a set of research strategies that would allow the Center to pursue the goals and objectives as outlined in the Strategic Plan within available resources. This resulted in a plan to make far-reaching adjustments in the operation and resource allocation patterns of the Center. In fact, the research strategies of all programs and units of the Center were scrutinized and reoriented, as were all Senior and Support Staff positions. The Board and Management of CIAT agreed to implement this plan of action, which has the effect that the changes that were earlier projected to be implemented over 5 to 6 years would now need to be brought about in 1 to 2 years.

Of course, the greatly reduced availability of funds in 1992 made it necessary for CIAT to proceed with only the bare minimum of activities needed to implement the new strategy. Clearly, in many instances, especially in the area of resource management research, additional resources will eventually be necessary if CIAT's research plan is to be successful. The resource requirements for the core budget as outlined in this Plan correspond to what is considered as the minimum for implementing the Plan, with the expectation that, in addition, a large portion of the proposed complementary activities can also be funded.

The Strategic Plan for the 1990s, which was developed over 2 years, included significant input from national program partners. The planning exercise was based on comprehensive assessments of trends in CIAT's environment, particularly those in agricultural economies of developing countries; national and regional agricultural research; international agricultural research and development community; and agricultural research per se. This analysis revealed that fundamental changes are taking place, to which CIAT must adapt if it is to continue providing science-based solutions to agricultural development problems.

CIAT's mission is "to contribute to the alleviation of hunger and poverty in tropical developing countries by applying science to the generation of technology that will lead to lasting increases in agricultural output while preserving the natural resource base." This mission is pursued through two mutually interrelated approaches to the Center's research in the years ahead: germplasm development and resource management.

As a germplasm development center, CIAT will continue assuming global responsibilities for cassava, field beans, and tropical forages for acid soils; and regional responsibility for rice in Latin America and the Caribbean. CIAT will increasingly emphasize strategic research, while assisting national and regional research partners to assume major responsibilities for applied and adaptive research.

In the area of resource management research, CIAT will assume responsibility for selected, important agroecosystems in Latin America. In close collaboration with other international, regional, and national institutions and NGOs, CIAT proposes to develop integrated technology options for these agroecosystems from two different perspectives: (1) a macroscopic perspective that takes into consideration socioeconomic trends, alternative land use patterns, and policy considerations; and (2) a microscopic perspective, focusing on soil/plant, plant/plant, and plant/animal relationships, and on how farmers manage these relationships. In seeking to provide an ecoregional mechanism, CIAT will develop an international platform for participating institutions to identify a common research agenda to which the various participants can contribute according to their particular comparative advantages.

The above strategies are more fully defined in the Strategic Plan for the 1990s from a long-term perspective. The Strategic Plan also presents the objectives, outputs, expected impact, and assumptions for each program (see Appendix I). More specific short-term objectives and outputs are described for each program in the respective chapters of this report.

Chapter 1, which follows, summarizes the Center's strategies, its operational mandate, and the relative allocation of resources.

CENTERWIDE STRATEGIES AND OPERATIONAL MANDATE

Germplasm development research aims to (1) characterize and broaden the genetic base of selected commodities, and (2) understand the gene-governed mechanisms that determine plant adaptation and productivity in major production areas, including those tropical American ecosystems selected for intensive agroecological research. The goal is to develop the potential of germplasm resources to increase their output and efficiency in using inputs. The germplasm development thrust will require feedback on germplasm performance and needs, particularly in multispecies systems. This feedback will be obtained in collaboration with the Resource Management Research Programs (RMRPs). These programs will provide integrated knowledge of production environments within certain ecosystems, thereby providing a systems focus. The experience gained will act as prototype for research on production environments in other ecosystems not studied by the RMRPs.

Resource management research focuses on (1) important tropical American agroecosystems that are threatened by increasingly intensive land use or natural resource degradation, and (2) those that may have potential for relieving such pressures. The aim is to understand the basic processes operating within agroecosystems in order to make agricultural production more sustainable. The expertise on commodity-focused agroecology built up at CIAT over the last twenty years will be valuable. While investigating technological options in the targeted ecosystems, resource management researchers will require the participation of, and support from experts in germplasm development, as well as access to germplasm stocks held by CIAT, sister centers, and regional and national institutions.

This integrated approach is pursued within a framework of interinstitutional cooperation aimed at enhancing complementarity and increasing cost-effectiveness of research at national, regional, and international levels.

Page 4 (Box 1) shows the operational mandate that governs CIAT's activities for the 1990s.

Germplasm Development and Research Management: An Integrated Approach

The pursuit of sustainable agricultural development requires reconciling the crucial trade-offs between agricultural production and conservation of the natural resource base. To accomplish its mission, CIAT focuses on generating adoptable land use management practices that address these trade-offs through germplasm development and resource management.

These two spheres of activity complement each other by independently and jointly contributing to three interrelated efforts. They are (a) focusing on socioeconomic incentives, (b) efficiently using external inputs, and (c) developing environmental management techniques.

The ***socioeconomic incentives*** approach deals with agriculture-related policies, land use strategies, and sectoral development plans that affect land use patterns across the landscape, and influence farmers' decision making on choice of crops, resource allocation, and management techniques.

The ***efficient use of external inputs*** in the production process seeks increased

Box 1

Operational Mandate for the 1990s

CIAT will contribute to technology development that will lead to long-term improvement in productivity of agricultural resources; to the development of innovative, more cost-effective agricultural research approaches and methods; to the strengthening of agricultural research institutions in participating countries; and to the development of interinstitutional linkages. To that end, CIAT's activities center around the following three areas:

Germplasm development research

Beans: global responsibility for common beans, including a secondary emphasis on snap beans.

Cassava: global responsibility; in Africa, through and in coordination with IITA.

Rice: regional responsibility for Latin America and the Caribbean in coordination with IRRI.

Tropical forages: global responsibility in relation to acid, infertile soils found between sea level and 1800 m.a.s.l.; in Africa, through and in coordination with ILCA.

Resource management research in tropical America

Agroecosystems-oriented research in:

Cleared forest margins.

Hillsides with moderately acid, low-fertility soils, with particular emphasis on the mid-altitudes.

Savannas with acid soils.

Land use research, emphasizing land use strategies and policy alternatives.

Institutional Development

Support activities at national and regional levels.

Note: CIAT will also explore with sister institutions the potential of the crops in their respective mandates (e.g., maize/CIMMYT, sorghum/ICRISAT, MPFTS/ICRAF, soybeans/IITA) as components in production systems within the agroecosystems listed above.

productivity and maximum efficiency in the use of available resources. Innovations will be based on understanding both gene-governed plant responses to external variables (abiotic/biotic) and ecological processes linking biotic and abiotic system components.

The ***environmental management*** approach will focus on the effects of crop/soil and crop/crop interactions on soil structure/ erosion and their effect on soil stability and hydrology. Integrated crop and pest management will be important complementary strategies.

This dynamic interaction between the two spheres of activity will be reflected in organizational areas that are linked by the exchange of materials and information, and by joint research activities.

The essential flows are as follows:

The Agroecosystems Programs provide a systems perspective that allows the Germplasm Development Programs to focus their technology efforts.

The Land Use Program provides agroecological and socioeconomic information that is relevant to the germplasm development programs.

The Germplasm Development Programs provide the Agroecosystems Programs with information on the feasibility of technical change for specific commodities in the relevant ecosystems, and tested components.

The Germplasm Development Programs provide the Land Use Program with commodity-specific information that allows the development of alternative land use scenarios and analysis of the effect of policy changes.

Box 2 (page 6) further specifies the nature and types of linkages that will join the two principal spheres of activity.

Resource Requirements, Allocations, and Program Plans

Detailed information on the proposed allocation of resources is provided in Chapter 8. Table 1 compares the proposed resource allocations for 1993-1998 with the resource allocation patterns for 1991 and 1992.

Analysis of Resource Allocation

1. Analysis by activity category. The trends confirm those outlined in CIAT's Strategic Plan for the 1990s. The operationalization of the Strategic Plan constituted a radical reallocation of resources, brought about by the circumstance that the earlier expected additional resources for phasing in of the Strategic Plan were not forthcoming. Table 1 reflects this basic reallocation of resources. Noticeable is the marked increase in resources assigned to ecosystem conservation and management, which increased from 10% in 1991, to 21% in 1992, and is expected to claim an average of 25% during the 1993-1998 planning period.

This increase is directly related to the creation, in 1992, of the research division for resource management. Similarly, the announced shift in the Strategic Plan toward more emphasis on strategic aspects of germplasm research is reflected in a marked transfer of resources from production systems development activities to germplasm enhancement research; on the average, CIAT plans to invest close to one-third of its core resources in germplasm development, and 15% in production systems development and management.

As part of the Center's new emphasis on agroecosystems research, an important increase in resource allocation to socioeconomic public policy and public management research is evident: CIAT plans to invest about 12% of its resources to this activity.

Training, conferences, and other support activities for NARS are slated to decrease as CIAT's relationships with NARS increasingly

Box 2. Linkages between Resource Management Research (RMR) and Germplasm Development Programs (GD).

Program	Inputs from RMR to GD	Join activities between RMR and GD	Inputs from GD to RMR	Interprogram monitoring and evaluation
Agroecosystems Programs: · **Hillsides** · **Forest Margins** · **Savannas**	-Identification of crop and ecosystem-specific constraints and desirable traits. -Participatory research techniques at the micro-socioeconomic level to identify farmer profiles, production practices and systems, and suitable technology options. -Socioeconomic analyses of specific crops. -Environmental limits of principal production areas, as well as potential input limitations. -Specific indicators of component competition and nutrient cycling. -Needs and opportunities for germplasm development and profile of needed cultivars.	-Design of plant ideotypes. -Development of crop/soil simulation models. -Design, development, and validation of prototype production systems, including specific crop under consideration and crop-specific technology components. -Assessment of role of given crop in critical aspects of nutrient cycling and sustainability. -Design of on-farm evaluation activities.	-Adapted germplasm and associated management technologies. -Information on potential of crop-specific technologies. -Physiological parameters indicating flexible points for management. -Test sites. -Links with institutional and individual collaborators.	-Evaluation of results. -Evaluation of impact of technical change within commodity on rest of system. -Technical, social, and economic information for the design of better technology components.
Land Use Program	-Identification and description of principal crop ecosystems. -Data for assessing alternate strategies favoring different growing areas. -Agroecological data for extrapolating research results. -Determination of demand in different markets. -Characterization and quantification of physical, biological, social, and economic indicators.	-Identification and prioritization of biophysical and macroeconomic constraints. -Identification of representative screening sites. -Genotype-by-environment interaction in relation to ecosystem analysis. -Analysis of commodity policy implications and requirements (e.g., IPM in rice). -Assessment of implications of new plant types for land use patterns.	-Biophysical and socioeconomic parameters for defining major growing regions of crops, and their major comparative regional advantages. -Cultivars' tolerance ranges. -Information on crop-based farming systems.	-Evolution of areas sown to given crop, productivity in selected areas, and market supply and demand. -Relevance of set of characteristics needed in alternative and potential production areas and systems.

Table 1. Core Resource Allocation by Activities: 1991-1992 (actual), 1993-1998 (proposed) in Percentage

Activities[1]	1991	1992	1993	1994	1995	1996	1997	1998	Avg. '92-'98
1. Conservation and management of natural resources	10.0	21.0	25.0	24.5	25.0	25.0	25.5	26.0	26.0
1.1 Ecosystem conservation and management	3.0	13.0	17.5	17.0	17.5	17.5	17.5	18.0	17.0
1.2 Germplasm collection, conservation, characterization, and evaluation	7.0	8.0	7.5	7.5	7.5	7.5	8.0	8.0	7.5
2. Germplasm enhancement/breeding	23.5	33.5	32.0	31.0	30.5	31.5	31.5	31.0	32.0
2.1 Crops	23.5	33.5	32.0	31.0	30.5	31.5	31.5	31.0	32.0
3. Production systems development and management	27.5	16.5	14.5	15.5	15.5	15.0	14.5	14.5	15.0
3.1 Crops systems	21.0	15.0	13.0	14.0	14.0	13.5	13.0	13.0	13.5
3.2 Livestock systems	6.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4. Socioeconomic, public policy and public management research	6.0	9.0	11.5	12.0	12.0	12.0	12.0	12.0	11.5
4.1 Economic and social analysis	5.5	6.5	8.0	8.5	8.5	8.5	8.5	8.5	8.0
4.2 Policy analysis	0.5	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
4.3 Governance and management of public systems	–	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5. Institution building	33.0	20.0	17.0	17.0	17.0	16.5	16.5	16.5	17.0
5.1 Training and conferences	17.5	7.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
5.2 Documentation, publication, and dissemination of information	10.5	10.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0
5.4 Networks	5.0	2.5	2.0	2.0	2.0	1.5	1.5	1.5	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Numbers refer to CGIAR's definitions of "activities" (see Appendix II)

focus on complementary partnership arrangements. CIAT's network coordinating activities are expected to decrease as existing regional networks become stronger and rely progressively less on CIAT's network support activities. In contrast, investment in information, documentation, and publication is slated to be maintained at 10% of expenditures. The information infrastructure plays a significant role in supporting the research carried out by CIAT and its partners.

2. Analysis by geographic area. As shown in Table on p. 94, the average allocation of resources to geographic region is 69% to Latin America and the Caribbean, 20% to sub-Saharan Africa, and 11% to Asia. This is not a significantly different allocation of resources by region compared with 1991 (73%, 18%, and 9%, respectively). Although the addition of resource management research adds significantly to the resources allocated to Latin America and the Caribbean, the move to more strategic research in the area of germplasm development provides relatively more benefit to production areas outside Latin America and the Caribbean.

3. Analysis by agroecological zones. The three agroecosystems chosen by CIAT for attention by its resource management research activities (hillsides, savannas, and forest margins) are all located in tropical America. In terms of the agroecological zones (AEZs) as referred to in the *CGIAR Priorities and Strategies* document, the three agroecosystems fall into the following AEZs:

Warm subhumid tropics	
Hillsides	70%
Savannas	45%
AEZ 3+7: Warm humid tropics	
Forest margins	100%
Savannas	50%
AEZ 4+8: Cool tropics and subtropics	
Hillsides	30%
Savannas	5%

As stated in CIAT's Strategic Plan, CIAT estimates that the legally accessible areas directly included in the agroecosystems under consideration by CIAT encompass about 120 million hectares. A common denominator of the agroecosystems chosen by CIAT is the acid, infertile nature of the soils that characterize these agroecosystems.

The presentation of program plans and associated resource requirements follows the organizational pattern that CIAT proposes to implement during the planning period. The two research thrusts—germplasm development and resource management—are presented first. Following the presentation of the two research divisions, the plans and resource requirements of research support and administration are discussed. This is followed by a separate section on capital requirements.

All resource requirements are stated in terms of core and complementary resources. Core resources are defined as those that are considered to constitute the minimal resources necessary to achieve the stated objectives. This includes those disciplines and activities that are considered absolutely essential in discharging the international and regional research responsibilities contemplated in the Strategic Plan. Excluded from core are those activities that have been, or are being devolved to national programs. Also excluded are disciplines and activities dealing with applied and adaptive research. Complementary resources are those considered directly and highly relevant to the core effort, i.e., resources that will significantly accelerate progress toward achieving the objectives and/or permit the Center to cover aspects of problem setting that are relevant but not sufficiently covered by core resources.

GERMPLASM DEVELOPMENT

Strategic research on the commodities in CIAT's mandate will focus on plant improvement over the next decade. Research during the 1970s and 1980s, conducted in collaboration with national programs, mostly at the applied level, has helped develop an excellent base from which to direct CIAT's germplasm improvement activities toward strategic research for the 1990s. CIAT's move into strategic germplasm research has been facilitated by the evolution in national programs over the last twenty years. The programs have strengthened their ability to conduct research directly related to their national needs. Regional research cooperation on the commodities has also been established, providing opportunities for horizontal collaboration in Asia and Latin America; and in Africa, with the International Institute of Tropical Agriculture (IITA), for cassava.

The commodity programs' mode of operation in the Germplasm Development Division is similar for all programs. Some economies of scale are allowed, particularly with respect to research support from the Genetic Resources Unit (GRU), the Virology Research Unit (VRU), and the Biotechnology Research Unit (BRU). Centralized support facilitates the commodity programs' strategic research, particularly when exploiting modern biotechnology during the next decade.

The bases for each commodity program are the germplasm resources maintained by the GRU (except for rice, the collection of which is maintained at the International Rice Research Institute [IRRI]). Program research aims at genetic solutions for combinations of biotic and abiotic constraints in major growing environments, thereby increasing productivity and stability. Yield potential will also be investigated. In all such research, modern biotechnology and plant physiology will play an important role.

The Germplasm Development Division will maintain very close research linkages with Resource Management Research Division (RMRD) at CIAT, particularly through technology components that will provide the driving force for work in selected ecosystems. The research conducted by the commodity programs will have direct relevance to the Resource Management Programs in that the technology developed by the former influences the ecological adaptation of crops to the growing environment, thereby ensuring sustainable production in the longer term.

The philosophy of the commodity programs remains centered on the development of germplasm-based technology that efficiently uses inputs and is adapted to less fertile conditions in tropical and subtropical developing countries. In general, CIAT's commodities are not widely grown on highly fertile soils, except for irrigated rice, and input-use efficiency is a critical issue for sustainable production. This particular philosophy is essential if resource management and commodity research are to complement each other.

This operational plan describes CIAT's work. As a Center that follows the ecoregional concept, CIAT has also hosted regional programs from other centers in the Consultative Group on International Agricultural Research (CGIAR) and similar organizations. These hosted programs, while having a more general mandate in accord with their own institutional strategies, contribute to CIAT's work through technologies focused on areas where this Center has particular interest. The Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), along with its regional Andean program, has major responsibility for developing maize for acid soils. The International Sorghum and Millet Program (INTSORMIL), another hosted program, has had a successful record of sorghum research for acid soils. CIAT also hosts regional coordination activities of the International Plant Genetic Resources Institute (IPGRI) for South America and activities of the International Fertilizer Development Center (IFDC). CIAT welcomes hosting programs from other institutions (e.g., Sorghum/ICRISAT, Agroforestry/ICRAF, Forestry/CIFOR). In this way, these centers and others can contribute to the objectives of the ecoregional approach to natural resource management.

The following pages describe the research activities to be conducted by the four commodity programs over a period of five years, beginning in 1993. Each program describes its goals, strategies, and objectives, reflecting CIAT's strategic plan for the 1990s, and synthesizes the activities to be conducted in response to these strategies and objectives. The linkages to be established between the Germplasm Development and Resource Management Research Divisions are clarified. In addition, linkages to advanced research institutions in developed and developing countries are discussed, particularly for the complementary activities in soybean and sorghum research for the acid-soil savanna ecosystems in tropical and subtropical Latin America.

Similarly, with the initiation of the Agroecosystems Programs, methodologies for impact assessment in the area of resource management research need to be developed or adapted. While actual fieldwork will be carried out by the respective programs, this work needs to be integrated into the Center's overall impact assessment processes.

The Germplasm Development Division is directed by the Deputy Director General (Germplasm Development). The financial resources assigned to that office are listed in Tables on p. 95 and 97 as "Research Management" under the rubric "Germplasm Development."

The Deputy Director General (Germplasm Development) also directs and coordinates the use of those financial resources in the Division referred to as "Strategic Research Initiatives" (see Tables on p. 95 and 97). These resources are meant to support new strategic initiatives. The majority of such initiatives are expected to be carried out as collaborative projects with advanced research laboratories and with CIAT's Agroecosystem Programs. In this form, new research initiatives will further foster the integration of efforts within and across the two research divisions.

Bean Program

Goal

To make a lasting increase in food availability and incomes of the poor by improving bean productivity through technology developed in collaboration with national institutions.

Strategies

Strategic research will increase as national programs' capacity for applied and adaptive research grows. The focus will be on genetic improvement and crop management research to meet the needs of resource-poor farmers. Advances in molecular biology will be exploited to solve practical problems of genetic improvement. Germplasm enhancement will be emphasized to achieve major strategic breakthroughs and to provide parental materials for national program breeding. In the interim, CIAT's breeding of advanced lines will be phased out. Greater attention will also be given to raising yield potential and overcoming edaphic stresses.

The new CIAT Hillsides Program will assume responsibility for crop management research in bean-based systems in the Andean and Central Andean regions. Finally, as national capacity develops, CIAT will gradually reduce its training and institutional development activities, although Africa will continue to receive priority attention.

Objectives and Activities

The program has five broad objectives, each of which is discussed with its corresponding activities and expected outputs.

Objective 1. Exploit advanced biological methods to better use bean genetic resources

Rapid advances in molecular biology offer substantial opportunities for applying novel methods to more efficiently identify and transfer useful genes, both within common beans and from related species. Advanced laboratories, mostly in industrialized countries, are primarily engaged in basic research that constitutes the foundation of these new methods.

CIAT will interact with these laboratories through the formation of a network of advanced research on beans. The network will direct researchers to use beans as a model system and devote attention to priority bean problems.

CIAT's Biotechnology Research Unit (BRU) will play a key role in bringing relevant advances in basic science to CIAT, and at the same time conduct strategic research to further develop new methods. The Bean Program will apply these methods to solve priority problems that limit bean productivity and will assist in adapting these methods for bean improvement.

The application of molecular techniques is intimately linked to a strong commitment to field breeding. Breeding is essential not only for identifying desirable characters and understanding their genetic control, but also for the agronomic evaluation of new variability. Thus field activities for germplasm enhancement will focus more on character improvement and much less on cultivar improvement, which will increasingly become the national programs' responsibility.

Activity 1. Characterize patterns of genetic variability in beans through the use of molecular markers, field evaluations, and inheritance studies.

Emphasis will be first placed on primary gene pools of cultivated *Phaseolus vulgaris*; then on wild ancestors of *P. vulgaris*; and finally on cultivated relatives (*P. acutifolium*, *P. coccineus*, *P. lunatus*, and *P. polyanthus*).

The Bean Program will be primarily responsible for germplasm evaluation; the BRU, for methods development; and the GRU, for acquisition of germplasm and its conservation, including the development of improved conservation methods.

Activity 2. Develop a saturated bean genome map in collaboration with advanced research laboratories and the BRU.

The program will focus on the use of probes to tag genes associated with desirable traits. This will assist in pyramiding multiple characters. Probes will be developed both for use by national program breeders and for internal applications. This activity will increase during the early 1990s.

Activity 3. Adapt regeneration and transformation systems to solve priority problems.

By the mid-1990s, protocols developed in advanced laboratories and by the BRU should be ready for application by the program. Priorities include refining and applying regeneration and transformation systems; isolating and transferring desirable genes not easily introgressed through classical techniques; and achieving stable gene expression in the progeny of transgenic plants. Known traits that are candidates for transfer include resistance or tolerance of Ascochyta (from *P. polyanthus*); drought (*P. acutifolius*); leafhopper (*P. lunatus*); and bean fly (*P. coccineus*).

Objective 2. Reduce losses to diseases and pests

Improved genetic resistance to major diseases and pests is key to an integrated approach to sustainable management of economically important diseases and pests. Both molecular biology tools and conventional fieldwork will be used to identify, understand, and exploit desirable disease and pest resistance mechanisms. They will also be used to understand pathogen and pest diversity as it interacts with host resistance in beans. The VRU will continue to provide needed support on viral pathogens.

Activity 1. Broaden the genetic base of resistance.

Because many biotic stresses are highly variable and resistance to some diseases and pests is not available, the identification of new and additional resistance sources and their transfer to useful backgrounds are urgently needed.

Activity 2. Improve understanding of pathogenic and pest variability, including its coevolution with beans.

Such an understanding will permit more effective deployment of resistance genes to improve sustainability. Increased knowledge of the biology of major diseases and pests in Africa is a high priority.

Activity 3. Contribute to the development of integrated control strategies.

The growing abuse of pesticides by small farmers throughout tropical America and even in some areas in Africa is becoming an evermore serious economic and environmental problem. The program will develop, together with national programs, sustainable integrated management strategies that complement genetic resistance and reduce pesticide use.

Objective 3. Increase yield potential

Increased bean yield potential in the absence of stress is essential to maintain competitiveness in Brazil and Mexico, which together account for over one-third of the world's bean consumption. The yield potential for beans has not yet increased as much as for other more intensively researched crops.

Activity 1. Identify yield-maximizing optima for physiological traits, including nitrogen partitioning, canopy morphology, and photoperiod and temperature adaptation.

Activity 2. Exploit genetic variation across gene pools while breaking undesirable linkages. By 1995, molecular biology techniques may be used.

Activity 3. Extend maturity of bush beans to increase biomass, and then improve harvest index and plant architecture.

Activity 4. Modify growth habits of preferred large-seeded grain types and, at the same time, extend the range of adaptation of climbing beans.

Objective 4. Improve adaptation to edaphic stresses

Soil fertility is declining in most bean-based crop systems because of the crop's expansion to marginal lands, shortened fallow periods, soil erosion, and, especially in Africa, high costs or limited availability of inorganic and organic fertilizers. Improved biological nitrogen fixation (BNF)—the top priority—can make an important contribution to more sustainable agricultural systems.

The program's strategy focuses on increasing the efficiency of nutrient and water use by the bean plant, taking into account the fact that many farmers will find it economically advantageous to amend their soils.

Efforts in abiotic research will be increased over this period. The synergy between the program's expertise in plant nutrition and BNF and that of CIAT's Resource Management Division in soils and nutrient cycling will be critical to the program's success.

Activity 1. Improve BNF in beans.

Traits in bean genotypes associated with improved BNF will be identified and combined in suitable backgrounds. Inheritance studies will be conducted to choose efficient breeding methods, and screening methods will be developed.

Rhizobium phaseoli germplasm will be collected and characterized. Broadly adapted, competitive, and effective *R. phaseoli* strains will be selected. As *R. phaseoli* traits that contribute to competitiveness and effectiveness are identified, they may be combined in a program of genetic improvement.

Activity 2. Improve adaptation to water stress, phosphorus deficiency, and aluminum toxicity.

Genetic variation for these characters will be evaluated and the physiological traits involved will be studied. Screening methods and optimal breeding strategies will be developed. Desirable traits will be combined in useful backgrounds and made available to national breeding programs. The effect of vesicular-arbuscular mycorrhizae (VAM) on phosphorus nutrition will be assessed.

Objective 5. Strengthen national capacity to improve bean productivity

National research and extension institutions are key actors in improving bean productivity. Progress in this respect depends principally on national efforts.

Many national programs have trained bean researchers with CIAT's assistance. Moreover, their efficiency has increased through their participation in regional networks established by CIAT in the Andean region, Central America, eastern and southern Africa, and the African Great Lakes Region.

The strategy for the 1990s must build on this progress. As national institutions strengthen, CIAT's input will change, and its overall efforts will decrease.

Activity 1. Facilitate stronger links among national research institutions, extension agencies, universities, nongovernmental organizations, and the seed sector.

Improved productivity at the farm level requires that research be articulated with other activities. The Bean Program will encourage the strengthening of these linkages at the national level.

Activity 2. Foster more autonomous operation of regional networks.

These networks provide national programs with the opportunity for the joint planning and implementation of research, training, and germplasm and information exchange. They also encourage the sharing of responsibilities among national programs and effective tapping of regional expertise. CIAT's coordinating role will decrease so that, by the end of the decade, the Bean Program will be a peer member rather than the coordinating hub of the networks.

Activity 3. Provide specialized training for mid-career bean scientists.

Strategic Priority: Africa

Although Latin America remains the world's largest producer and consumer of beans, beans make their greatest contribution to nutrition in the highlands of central, eastern, and southern Africa. Despite the fact that demand for beans is growing fastest in that area, growth in production is drastically lagging. Consequently, a major effort is being undertaken to improve bean productivity in Africa.

Strategic research at CIAT headquarters in Colombia contributes directly to overcoming worldwide disease problems, improving BNF, coping with edaphic stresses, and increasing yields. Nonetheless, strategic research is also required to address major regional constraints in Africa, including, for example, the different species of bean fly, scab, and local strains of bean common mosaic virus (BCMV) and halo blight. Fertility maintenance in African cropping systems also poses unique challenges.

In addition to this strategic research, CIAT is using complementary resources to strengthen regional institutions, train national scientists, and assist in applied research. Emphasis is placed on fostering regional networks to maximize coordination and mutual assistance among national programs facing common problems. Although training is oriented toward research scientists, on-farm research capacity is encouraged, and research and transfer linkages are reinforced.

Although core staff would be concentrated at one location, these complementary activities would be decentralized in accordance with national program needs. Complementary activities in crop systems research, socioeconomics, and training would be undertaken in close collaboration with other CGIAR entities in the region.

Resource Allocation and Requirements

Table 2 shows the Senior Staff positions scheduled for executing the Bean Program's operational plan during the planning period.

Description of Senior Staff Positions

Office of Leader. Provides overall guidance and coordination in the design of interdisciplinary, interinstitutional research and training; principally responsible for developing and implementing strategies for research and institutional strengthening, and for coordinating activities with national programs and other CIAT organizational units.

Germplasm. Improves understanding of *Phaseolus* gene pool through development of molecular markers, contributing to construction of saturated maps; uses these markers, including DNA restriction fragment length polymorphisms (RFLPs), in combination with the program's ongoing agronomic evaluations of resistance to diseases and pests, tolerance of nutrient stresses, and improved BNF. Helps pyramid desirable traits and encourages use of markers by CIAT and national programs.

Genetics: Andean. Develops methods and parental materials for use by national breeders, principally in Africa and the Andean region, with emphasis on adaptation and yield, especially in climbers, BNF, tolerance of low-fertility soils, and resistance to subtropical diseases and pests. Conducts genetic studies to design breeding strategies, introduces useful traits from other gene pools, and obtains high expression of desirable characters from within a gene pool.

Genetics: Mesoamerican. Develops breeding methods and parental materials for use by national breeders, principally in Central America, Brazil, Mexico, and Africa, with emphasis on yield, architecture, tolerance of water deficits, and resistance to tropical diseases and pests. Introgresses desirable characters from other gene pools, develops high expression of useful traits from within a gene pool, and undertakes genetic studies to design efficient breeding strategies.

Genotype by environment specialist. Designs and organizes ecologically stratified global network of germplasm evaluation and exchange; characterizes genetic-by-environmental interactions to refine targeting of germplasm; develops database on germplasm performance; assists national programs in managing genetic-by-environmental interactions, especially in agroecosystems not covered by CIAT's RMRPs.

Table 2. Bean Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Headquarters														
Office of Leader (Economics)	1	313	1	315	1	315	1	315	1	315	1	315	1	315
Germplasm characterization	1	257	1	255	1	255	1	250	1	250	1	250	1	250
Genetics (Andean)	1	251	1	250	1	255	1	255	1	255	1	255	1	255
Genetics (Mesoamerica)	1	266	1	265	1	260	1	255	1	255	1	255	1	255
Genotype/Environment	1	223	1	220	1	220	1	215	1	215	1	215	1	215
Physiology	1	207	1	210	1	205	1	205	1	205	1	205	1	205
Nutrition	1	209	1	210	1	220	1	230	1	230	1	230	1	230
Pathology	1	238	1	240	1	235	1	225	1	225	1	225	1	225
Entomology	1	191	1	190	1	190	1	190	1	190	1	190	1	190
Other	–	180	–	–	–	–	–	–	–	–	–	–	–	–
Outposted														
Africa: Pan–African coord.	1	260	1	260	1	260	1	260	1	260	1	260	1	260
Africa: Germplasm improvmt.	1	270	1	270	1	280	1	280	1	280	1	280	1	280
Africa: Plant protection	1	260	1	260	1	260	1	260	1	260	1	260	1	260
Africa: Socioeconomics	1	260	1	260	1	250	1	250	1	250	1	250	1	250
Southern Cone: Regional coordination	1	185	1	185	1	185	–	50	–	–	–	–	–	–
Central America: Regional coordination	1	320	–	–	–	–	–	–	–	–	–	–	–	–
Total	15	3,890	14	3,390	14	3,390	13	3,240	13	3,190	13	3,190	13	3,190

Physiology. Characterizes physiological factors limiting yield potential; develops screening methodologies to identify superior yield potential and genetic adaptation to meteorological constraints (drought, flooding, chilling, and high temperatures); elucidates physiological mechanisms conferring superior yields and adaptation to meteorological constraints; and develops agronomic technologies to improve bean yields in favorable bean production systems.

Nutrition. Improves productivity under edaphic stresses by helping to develop superior genotypes and improving symbiosis with soil microorganisms. Focuses on improving biological nitrogen fixation and efficiency of phosphorus use. Develops screening methods, identifies mechanisms conferring adaptation, and selects competitive and effective Rhizobium strains.

Pathology. Works closely with breeders and biotechnologists to identify, study, and use durable disease resistance mechanisms; monitors and improves understanding of pathogen diversity as relates to host resistance; emphasizes identification and use of the broadest genetic diversity in the bean plant. Develops methodologies, emphasizing pathogen diversity and screening.

Entomology. Works to overcome global pest constraints, including leafhoppers and bruchids, and regional pest constraints in the Americas, i.e., pod weevil, whiteflies, and leaf miners. Major priorities are host-plant resistance and increased assistance to national programs in devising integrated control systems.

Economics. Monitors world bean production and consumption trends; defines priorities for bean research; conducts micro-level assessments of technological changes in bean production and consequences for research directions; assists national programs in evaluating participatory experiments; and coordinates and supports impact and adoption studies.

Africa: Pan-African coordination. Coordinates research, training, and information and germplasm exchange activities in Africa; liaises with national program research directors to ensure consistency of CIAT's activities with national and regional priorities; liaises with regional networks and steering committees for effective articulation and coordination among regional networks; plans and supervises regional research and training activities.

Africa: Germplasm improvement. Identifies sources and studies genetics of resistance to major African biotic constraints; develops populations, parents, and methods for combining multiple traits for use by African breeders; and develops strategies for improving traditional mixtures. Emphasis on bean fly, scab, and African strains of BCMV and halo blight.

Africa: Plant protection. Leads strategic research and assists national programs in overcoming major disease constraints, focusing on problems unique to the region such as BCMV, angular leaf spot, halo blight, and anthracnose, as well as scab, which is not present in the neotropics; characterizes pathogen diversity; develops screening techniques; and appraises management strategies with emphasis on deploying genetic mixtures.

Africa: Economics. Studies African bean production systems and their amenability to improved bean production technology; takes active role in testing improved technologies and their transfer to national programs, and executes adoption studies; monitors interactions between bean production technology research and resource management research.

Southern Cone: Regional coordination. Assists national programs in bean improvement while conducting strategic research on major regional problems, including Brazilian strains of BGMV, Al toxicity, low P, and water deficits; and coordinates generation and distribution of genetic variability in the region.

Complementary Activities

The Bean Program proposes to complement its core activities with a series of Senior Staff positions which are to accelerate progress at the regional level. Table 3 shows the financial resources implied by these complementary activities. The Senior Staff positions involved are the following:

Africa: Cropping systems. Conducts strategic research on improving overall productivity of bean-based polyculture systems, including intercropping with maize, bananas, cassava, and sorghum; assists national programs in designing cultural practices to increase system productivity and sustainability; and assesses interactions between bean genotype and cropping system.

Africa: Fertility management. Conducts strategic research in the region and assists national programs in fertility management in bean-based cropping systems; characterizes major fertility constraints and appraises effect of farmers' practices on nutrient cycling and erosion; and designs improved fertility management systems, integrating adapted bean genotypes and improved BNF into multicrop and agroforestry systems to improve sustainable bean productivity.

Africa: Social science. Conducts research and develops methods to assist national programs adjust technology designs and evaluate objectives and needs of African growers; emphasizes farmer participation in research and facilitates farmer feedback to scientists on technology design parameters and performance.

Africa: Entomology. Conducts strategic research and assists national programs in dealing with regional pest problems. Emphasizes the development of methods to improve host-plant resistance; priorities include the bean fly species complex, aphids, and Oothecae.

Africa: Breeding, biotic constraints. Assists national programs in their applied breeding and conducts strategic research to develop breeding lines and segregating populations with improved adaptation and multiple disease and pest resistance; introduces and evaluates germplasm from CIAT HQ and elsewhere. Primarily responsible for increasing the levels of resistance to bean fly and incorporating BCMV and halo blight resistance into elite African breeding lines and commercial cultivars.

Africa: Breeding, abiotic constraints. Conducts strategic research and assists national programs in developing breeding lines and populations with improved adaptation to water deficits and low-fertility soils (including low P and high Al), and with improved BNF.

Table 3. Bean Program. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Africa: Cropping systems	1	300	1	300	1	300	1	300	–	–	–	–	–	–
Africa: Fertility management	1	300	1	300	1	300	1	300	1	300	1	300	1	300
Africa: Social science	1	300	1	300	1	300	1	300	1	300	1	300	1	300
Africa: Entomology	1	350	1	350	1	350	1	350	1	350	1	350	1	350
Africa: Breeding, biotic constraints	1	350	1	350	1	350	1	350	1	350	1	350	1	350
Africa: Breeding, abiotic constraints	1	350	1	350	1	350	1	350	1	350	1	350	1	350
Africa – Agronomy	1	335	1	335	–	–	–	–	–	–	–	–	–	–
Snap bean breeding	–	–	1	255	1	255	1	255	1	255	1	255	1	255
Andean Region – Regional coordination	1	425	1	300	–	–	–	–	–	–	–	–	–	–
Biotechnology network	–	–	–	300	–	300	–	300	–	300	–	300	–	300
Phaseolus germplasm	–	200	–	80	–	80	–	80	–	80	–	80	–	80
Molecular mapping	–	54	–	57	–	60	–	63	–	66	–	–	–	–
Bean transformation	–	–	–	15	–	15	–	15	–	–	–	–	–	–
Total	8	2,964	9	3,292	7	2,660	7	2,663	6	2,351	6	2,285	6	2,285

Africa: Agronomy. Assists national programs in conducting strategic research on crop management in bean-based cropping systems, focusing on optimal management of bean genetic mixtures, disease and pest control, and fertility management.

Snap bean breeding. Develops improved parents, populations, and lines with better adaptation to tropical conditions and stresses; works with both bush and climbing-bean types to improve disease resistance and productivity; maintains product quality; develops worldwide networks for snap bean germplasm and information exchange; and assists national programs in selected countries.

Andean region: Regional coordination. Facilitates regional planning and implementation of research, training, and information exchange activities; supports development of regional coordinating institutions with a view to the future devolution of this function.

Bean biotechnology network. Jointly coordinated by the Bean Program, the BRU, and participating institutions. Starting in 1992, it is expected to function for five years. Its aims are to identify new initiatives in bean-related biotechnology; coordinate activities such as scientific meetings, training national program scientists, and communications; and provide financial support for initiating or continuing research projects that will advance bean biotechnology (see also "Complementary Activities" for the Biotechnology Research Unit, Table on p. 75).

Genetic structure of *Phaseolus* spp. See "Activity 4" of GRU (p. 81) for a description of this proposed complementary activity to be carried out jointly by the Bean Program and the GRU.

Expected Outputs

The expected outputs of the Bean Program can be assessed both in terms of projected impact at the farm level and progress in intermediate research products aimed at increasing research efficiency and output.

In comparison with 1990, by 1998, about 70 to 85 new varieties with CIAT-identified genes or parentage will have found their way into commercial production by small farmers (around 12% of the world bean area). If historic trends continue, each of these varieties can be expected to be planted on an average area of 10,000 ha, contributing a value of roughly US$1 million to the yearly impact of the program. This would then suggest that by 1998 the program would have achieved a yearly impact of US$70 million, in addition to the current yearly impact of US$50 million, totalling US$120 million per year. Even if the area planted or the yield advantage per variety falls, it is safe to expect an overall yearly impact of more than US$100 million per year by 1998. This impact refers only to genetic improvement and does not consider impact through management practices.

Specific outputs of the program's five objectives are as follows:

Objective 1. Exploit advanced biological methods to better use bean genetic resources

More efficient breeding.

Applied molecular techniques for plant modification.

Identification of sources of useful traits.

Transgenic parental material for use in breeding.

Objective 2. Reduce losses to diseases and pests

Increased diversity of sources of resistance in parental materials.

Improved knowledge of diseases and pests.

Targeted gene deployment for more sustainable resistance.

Modeling of integrated control strategies for major pests and diseases.

Objective 3. Increase yield potential

Improved knowledge of physiology and genetics of yield potential.

New plant types with increased yield potential, suitable as parents for national program breeding.

Objective 4. Improve adaptation to edaphic stresses

Bean genotypes enhanced for BNF.

Selected, improved strains for symbiosis.

Parental material adapted to edaphic stresses.

Objective 5. Strengthen national capacity to improve bean productivity

More effective national research and technology transfer.

Efficient horizontal transfer of skills and technologies in regional networks.

Increased effectiveness of national scientists.

Cassava Program

Goal

To increase incomes and agricultural sustainability, particularly in less favored rural areas by improving the level and stability of cassava production and quality for different end uses.

The Cassava Program seeks to achieve its goal through interacting with its partners in a global network. This network promotes cassava as an important rural and urban food and develops new end uses suitable for changing economic circumstances. The Cassava Program carries out research from a commodity system perspective, which includes research on crop production, processing, and postharvest utilization, and integrates research on consumer preferences and market demand. The Cassava Program will concentrate its core research activities on germplasm resource development. Crop management and postharvest research of a more applied nature are considered to be complementary activities, largely funded through special projects.

Objectives and Corresponding Strategies, Activities, and Outputs

Objective 1. Generate basic knowledge on the cassava crop

Strategy. A sound knowledge of the crop and the environments in which it is grown is the basis for developing component technologies. Strategic research, carried out at HQ by an interdisciplinary team, examines the plant's mechanisms for adaptation to biological and physical constraints and the physiology of root yield and quality variation. This research, is undertaken in close cooperation with the GRU, BRU, VRU, and with the support of the DSU and Land Use Program. Close liaison is maintained with IITA to complement their strategic research on the needs of cassava in Africa. Links with advanced laboratories are fostered through the BRU and the Cassava Biotechnology Network (CBN). The cornerstone of this work is provided by the genetic variability in cassava and wild *Manihot* species contained in the world cassava germplasm collection managed by the GRU.

Activity 1. Definition of research needs and priorities.

Refinement of participatory diagnostic methods for characterization of such client groups as farmers, processors, and consumers by gender, income, etc.

Refinement of the physical, biological, and socioeconomic definitions of cassava-growing environments.

Participation in collaborative socioeconomic studies of cassava in Asia, Latin America, and Africa.

Ex ante analysis of research alternatives.

Activity 2. Genetic research.

Characterization of cassava germplasm and wild *Manihot* relatives, taking into account environmental constraints and end uses.

Basic genetic and breeding methodology research.

Incorporation of molecular tools and meth odologies resulting from collaboration with the BRU and activities developed by the CBN.

Activity 3. Crop physiology research.

Manipulation of the unique cassava photo synthetic system as a means to improve production.

Mechanisms of drought tolerance; effects of drought tolerance on agronomic and root quality traits; and feasibility of pyramiding water-use efficiency mechanisms for maximizing drought tolerance through genetic manipulation.

Temperature and photoperiod interactions for cassava production in the subtropics.

Development of more effective screening methods for tolerance of water stress and nutrient-use efficiency; basic research on the physiological mechanisms operating in efficient genotypes.

Activity 4. Root quality studies.

Development of selection methods for specific root-quality traits such as low cyanide (CN^{-1}) and use-dependent starch quality variables.

Identification of the physicochemical root tissue characteristics that determine good eating quality.

Physicochemical and functional properties of cassava starch and flour for different end uses.

Cyanide biochemistry of the cassava plant and the relation between CN^{-1} content and other plant/root constituents.

Activity 5. Crop protection research.

Biology and ecology of important but still underresearched arthropod pests, root-rot pathogens, viruses and their vectors, and mycoplasma-like diseases; also on pest and pathogen problems in dried, stored cassava.

Pest and disease tolerance/resistance mechanisms, with emphasis on those that operate against more than one pest or pathogen, including the role of CN^{-1} in pest and pathogen resistance.

Methods for detecting resistance or toler ance breakdown.

Mass-rearing techniques and evaluation methodologies for crop pests and diseases and their natural enemies.

Activity 6. True cassava seed.

Interdisciplinary exploration of the feasibility of commercial production of cassava from true seed.

Expected outputs. These are:

Improved socioeconomic diagnostic methods and characterization of cassava-growing environments in order to identify research needs more precisely and better orient technology development.

Expanded knowledge of the basic mechanisms underlying cassava's reaction to major constraints and of its potential to adapt to new agroecosystems and uses.

Broader and better characterized germplasm that will provide the basis for more efficient, sustainable progress in cassava genetic improvement. Emphases will be drought tolerance, nutrient-use efficiency, CN^{-1} content, starch content and quality, tolerance or resistance to major arthropod pests, root-rot pathogens, viruses and their vectors, mycoplasma-like microorganisms, and genotype/cropping system component interactions.

Faster and more reliable germplasm screening methods that will evaluate the range of genetic variability present in the germplasm collection.

Greater technical, economic, and social understanding of the potential for the commercial exploitation of true seed.

Objective 2. Develop technology components for sustainable production in major cassava-growing ecosystems

Strategy. Component technology development is largely location specific, but certain components and methods can be applied over a broad range of conditions, and general principles for technology design can be derived from comparative studies across ecosystems. This research is therefore undertaken at specific but representative sites, in close collaboration with the RMRD, Asian and Latin American national programs, and IITA in Africa.

The three areas of research are genetic improvement, crop management, and utilization and marketing.

Genetic improvement research is directed toward developing gene pools targeted for regional needs and toward four major cassava-growing environments: humid lowland, seasonally dry, mid-altitude, and subtropical. Brazilian and Thai research institutes share responsibility with CIAT for developing germplasm for specific ecosystems of global and regional importance. The Program works together with IITA on gene pool development for African environments.

Crop management research focuses on integrated pest and disease management. The Program collaborates with and provides expertise to the RMRD and international regional institutions and national programs in Latin America and Asia for the development of integrated crop/soil management practices, including soil fertility maintenance and erosion control.

Utilization and marketing research. Support is provided to national programs in the study of consumption patterns, marketing, and demand to identify product opportunities and quality requirements. The Program's involvement in processing and product development is through collaboration with international and national institutes who specialize in food science and technology and postharvest research. Feedback from this work is fundamental for determining crop quality characteristics for specific end uses.

Activity 1. Genetic improvement activities.

Continued development of broadly based gene pools targeted for regional needs.

Studies on the interactions of genotype with major cropping system components, such as tillage methods, intercropping, fertilization, and weed, pest, and disease control practices, for more effective selection based on farmers' needs.

Provision of basic and improved germplasm in seed and vegetative form to complement national program genetic improvement methodology research.

Introduction to Africa, through IITA, and subsequent joint evaluation and selection of American germplasm appropriate for principal cassava agroecosystems in Africa.

Activity 2. Crop management activities.

Classical biological control of mealybug and cassava green spider mite.

Integrated pest and disease management, emphasizing root-rot pathogens, cassava bacterial blight, and pests such as chinch bug, mites, hornworm, mealybugs, and whiteflies.

Interactions among host-plant resistance, cultural practices, and biological control to optimize the effectiveness of crop protection technologies.

Further development of soil fertility man agement and erosion control practices in selected ecosystems.

Interaction of soil fertility and erosion man agement, crop protection, and cropping systems research to ensure efficiency and effectiveness of new technology.

Activity 3. Utilization and market research activities.

Support national institutions to integrate research on marketing and consumption, processing, and quality, so to identify opportunities for developing cost-competitive, consumer-acceptable products.

Continued research and development (R & D) of appropriate cassava flour and starch processing technology with national and advanced institutions, emphasizing the effects of process variables on end-product quality.

Monitoring advances in cassava processing and product development by other research institutions.

Expected outputs. These are:

Gene pools for broadly defined ecosystems, with a higher frequency of favorable recombinants and constituting the basis for selection by national program breeders.

Crop management practices, and methodologies for their implementation, that permit the fuller expression of the potential of improved germplasm in selected ecosystems. Emphasis is given to integrated pest and disease management and integrated crop/soil management.

More precise knowledge of market opportunities and related end-product quality requirements.

Improved, commercially viable, small-scale processes for producing cassava flour and starch.

Objective 3. Contribute to the consolidation and integration of national, regional, and global cassava research systems.

Strategy. The Cassava Program, supported by the IDS, contributes to the consolidation and integration of national, regional, and global cassava R & D systems through collaborative projects, human resource development, and information exchange.

The Program facilitates and advises on the creation and operation of regional networks designed to interchange experiences, define R & D priorities, and identify opportunities for horizontal cooperation among participating countries and/or institutions. These activities provide important feedback to orient HQ research. Relationships with Asian national programs are coordinated by the Program's Asian regional office in Bangkok. In the

Americas, activities with national programs are handled through HQ. CIAT's Cassava Program scientist, stationed at IITA's HQ in Nigeria, ensures a high degree of interaction between the two centers in areas of direct interest to African cassava-producing countries. Links between advanced research institutes in developed and developing countries are provided through the CBN.

Activity 1. Joint generation of knowledge and technology with national programs, emphasizing genetic improvement, and selected R & D activities in crop management utilization and market research.

Activity 2. In-service, discipline-oriented training in research techniques and methodologies.

Activity 3. Assistance to national pro grams in the design and organization of integrated cassava R & D projects.

Activity 4. Development of human resources in the areas of:

Training of trainers.

Diagnostic skills.

Conceptualization, formulation, execution, and evaluation of integrated cassava projects.

Activity 5. Development of appropriate cassava-seed supply systems.

Activity 6. Help consolidate existing, and create new collaborative regional research and information networks.

Activity 7.* Ex post *analyses of adoption and impact at national and Cassava Program levels.

Activity 8. Continued information exchange through* Abstracts on Cassava, Cassava Newsletter*, and regional conferences and seminars.

Expected outputs. These are:

Trained cadres of national program personnel in cassava research techniques and methodologies.

Regional and national capacity for training technology intermediaries in cassava production and utilization.

Methodologies and training materials for implementing integrated cassava R & D projects and, within these projects, for the *in situ* testing of improved cassava production and processing technologies.

Regional and global cassava R & D and information exchange networks.

Effective national cassava research programs more closely integrated with extension and development activities.

Resource Allocation and Requirements

Table 4 shows the Senior Staff positions required for executing the Cassava Program's operational plan during 1993-1998 and the costs associated with the various research sections.

Description of Senior Staff Positions

Office of Leader. Coordinates and supervises all research activities of HQ and outposted team members; liaises with CIAT's research support units and Resource Management Research Division, with IITA, and other international and national centers in cassava-related areas. Responsible for catalyzing regional research and development networks in Latin America; and for supporting country initiatives to obtain external funding aimed at consolidating and integrating national R & D systems.

Genetics. Contributes to sustained progress in cassava improvement through the

Table 4. Cassava Program. Revised budget for 1992 and projected budgets for core activities 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Headquarters														
Office of Leader (Networking)	1	400	1	400	1	400	1	400	1	400	1	400	1	400
Genetics	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Physiology	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Pathology	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Entomology	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Quality/Utilization	1	250	1	200	1	200	1	200	1	200	1	200	1	200
Genotype/Environment	1	250	1	200	1	200	1	200	1	200	1	200	1	200
IPDM coordination	–	–	–	–	1	416	1	426	1	180	–	–	–	–
Economics	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Others	–	355	–	200	–	200	–	200	–	200	–	200	–	200
Outposted														
Asia: Gene pool	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Africa: CIAT/IITA scientist	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Total	10	2,655	10	2,400	11	2,816	11	2,826	11	2,580	10	2,400	10	2,400

understanding of plant mechanisms for biological and physical stress resistance or adaptation, and the physiological basis of root yield and quality variation. This includes activities related to germplasm characterization, inheritance studies, and genetic manipulation, mainly focused toward the cassava core collection and wild *Manihot* relatives. Conducts research on the refinement of screening techniques, the efficiency of genetic recombination, crossability studies, and the use of molecular markers as an aid to cassava genetic improvement; liaises with the GRU on germplasm conservation and wild species collection and management, and with other program disciplines and support units, especially the BRU, and, through the CBN, with advanced laboratories.

Physiology. Conducts research on genotype responses and underlying response mechanisms to factors such as low soil fertility (emphasizing phosphorus and potassium nutrition), water-use efficiency, and stress tolerance; studies production of true seed, including flowering mechanisms, dry-matter partitioning, and plant architecture, thereby improving selection criteria and contributing to increased efficiency in cassava breeding and to sustainable cropping systems research by the Resource Management Research Division; establishes linkages with advanced research institutions to investigate further and exploit the potential of cassava's unique metabolic system and photosynthetic efficiency.

Pathology. Conducts research on fungal and bacterial disease complexes in key cassava ecological zones, emphasizing identification of disease-tolerant or resistant cultivars for use in cassava breeding and on biocontrol of causal agents of important diseases; conducts maintenance research on the safe and efficient international transfer of germplasm; establishes linkages with the BRU, VRU, and CBN to develop probes for recently reported diseases such as mycoplasma-like microorganisms.

Entomology. Conducts research on major cassava pests; conducts research on biological control through identifying, rearing, and distributing beneficial insects; identifies pest-tolerant/ resistant materials and develops screening methodologies for cassava breeding; coordinates with IITA the biological control of major cassava pests in Africa; links with the BRU, VRU, and CBN to determine the presence of pest biotypes and strains and their natural enemies.

Quality/Utilization. Defines biochemical and physicochemical quality parameters, and develops screening techniques for discrimination among genotypes; develops methodologies for quality improvement during processing; collaborates with the BRU for work on starch and manipulation of the amylose-to-amylopectin ratio for different end uses. Promotes regional networks for cassava utilization and marketing; and provides support to integrated cassava projects in Latin America; liaises with CIRAD/ CEEMAT, NRI, and other food research institutes to develop existing and new processing systems.

Genotype by environment. Develops broad-based gene pools directed to regional needs and to four major environments; screens genetic diversity at representative sites, selects genotypes based on stability and/or specific adaptation to major constraints on cassava production and utilization; collaborates with decentralized breeding and selection activities of Latin American national programs and of outposted CIAT scientists in Africa and Asia; coordinates, with Brazilian national and state agricultural research agencies (EMBRAPA and EMPASC, respectively), germplasm development for semiarid and subtropical ecosystems; and coordinates the program's plant propagation research.

IPDM coordination. Conducts strategic research with Brazilian institutions to implement integrated pest and disease management, including problem diagnosis, and testing and adaptation of component technologies through participatory methods. Provides feedback from participatory research to germplasm and crop management team. Coordinates training initiatives for national program researchers. Assists national program counterparts in training trainers, extensionists, and farmers, and in educational programs for local and regional leaders. Liaises with IITA on parallel activities in Africa. This activity is considered as a core activity during the period 1994-1996.

Economics. Interacts with the Program's germplasm development team to identify and prioritize selection criteria and target areas for efficient breeding strategies. Develops appropriate methodologies and collaborates in the *ex post* assessment of adoption and impact of technology components with NARDS counterparts. Maintains and updates a socioeconomic database that helps set research priorities according to *ex ante* studies. In Latin America, provides an economic framework and backup for cassava integrated projects. In Asia, collaborates with NARDS in bench mark studies to identify cassava constraints and research priorities. Liaises with socioeconomic research in Latin America, Asia, and Africa to provide the basis for setting research priorities and redirecting program strategies.

Asia: Gene pool development. Develops, together with the Thai Cassava Program, improved gene pools for specific Asian environments and end uses; provides guidance to national programs on breeding and selection methodologies; and ensures effective and safe exchange of improved germplasm; responsible for coordinating the Asian regional program and for liaising with national program counterparts in relation to crop management, utilization, and market research initiated by HQ scientists. Provides feedback to HQ on socioeconomic, institutional, and political developments related to cassava production and utilization in Asian countries; acts as secretary to the Advisory Committee of the regional cassava network.

Africa: CIAT/IITA scientist. Responsible for introducing to Africa, through IITA, materials from tropical America and for exploring the potential of the crop in semiarid ecosystems; with IITA scientists, evaluates and selects promising materials under different environmental conditions and provides feedback to HQ on performance; liaises between CIAT and IITA on matters of mutual interest, thereby ensuring complementarity of research activities at CIAT and IITA and a better response to the research needs of African cassava-producing countries.

Complementary Activities

Certain of the aforementioned activities will be supported by special project funds. A description of these activities is given below. Table 5 shows the budget proposed for these complementary activities.

Activity 1. Genetic improvement.

Collection, characterization and evaluation of germplasm for semiarid and subtropical ecosystems and the development of improved gene pools for these environments.

Decentralized activities based at CNPMF (semiarid) and EMPASC (subtropical), Brazil.

Activity 2. Plant nutrition.

Research the basic mechanisms controlling nutrient-use efficiency in cassava, and identify plant characteristics related to nutrient use that may be employed as selection criteria for cassava improvement.

Activity 3. Integrated pest and disease management.

Research with IITA and Brazilian national programs on the implementation of integrated management of biotic constraints, including problem diagnosis, analysis of farmers' current control practices, augmentation and conservation of natural enemies, classical biological control, and effect of cropping systems on pest populations. Strategic and tactical modeling and information management for both African and Latin American subprojects.

Activity 4. Cassava Biotechnology Net work (CBN).

Joint coordination with the BRU and research institution members of the CBN to identify new initiatives in cassava-related biotechnology.

Activity 5. Cassava propagation from true seed.

Overall coordination of interdisciplinary research, with emphasis on biotechnological techniques, to define an appropriate genetic structure for cassava propagation from true seed.

Activity 6. Integrated crop/soil management.

Collaborative research with the RMRD in Latin America and appropriate, but as yet undefined, institutions in Asia. Research will help develop practices for improving cassava productivity, focusing on long-term sustainability in the different agroecosystems where the crop is grown. Emphasis in Latin America will be given to seasonally dry, and semiarid ecosystems, where both edaphic and climatic conditions are major constraints. Basic concepts will be sought on technology generation and the development of appropriate, wide-ranging mechanisms for its transfer and adoption. The research will be conducted with regional and national programs in Asia and Latin America and linked with similar research undertaken by IITA in Africa.

Table 5. Cassava Program. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

Senior Staff Position	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Genetic improvement	–	224	–	224	–	224	–	224	–	224	–	224	–	224
Plant nutrition	–	80	–	130	–	130	–	130	–	130	–	80	–	–
Integrated pest and disease management	1	572	1	912	–	469	–	502	–	215	–	–	–	–
Biotechnology network	–	162	–	312	–	300	–	300	–	300	–	75	–	–
True seed	–	–	–	130	–	130	–	130	–	130	–	130	–	130
Integrated crop/soil mgt.:														
– Dry ecosystems	–	–	–	100	–	100	–	100	–	100	–	100	–	100
– Southeast Asia	–	–	1	200	1	200	1	200	1	200	1	200	–	150
Socioeconomic research and product development in Asia	–	–	–	170	–	170	–	170	–	170	–	170	–	170
Integrated projects in the Americas	1	560	1	560	1	560	1	560	–	300	–	300	–	300
Wild germplasm	–	–	–	90	–	80	–	80	–	80	–	80	–	–
Molecular mapping	–	80	–	80	–	80	–	–	–	–	–	–	–	–
Total	2	1,678	3	2,908	2	2,443	2	2,396	1	1,849	1	1,359	–	1,074

Activity 7. Socioeconomic research and product development in Asia.

Establishment, with CGPRT and CIP, of a regional socioeconomic capacity for ongoing evaluation of the dynamics of root and tuber production and utilization in Asia, and support for product development activities in selected countries.

Activity 8. Integrated cassava projects in the Americas.

Transfer of knowledge to national programs on project conceptualization, design, execution, and evaluation, together with preparation of training materials and guidelines for R & D personnel working on projects.

Activity 9. Wild cassava germplasm.

See p. 81 (GRU) for a description of this complementary activity to be carried out jointly by the GRU and the Cassava Program.

Activity 10. Molecular mapping.

See p. 75 (BRU) for a description of this complementary activity carried out by the BRU in collaboration with the Cassava Program.

Rice Program

Goal

As stated in the Strategic Plan, the Rice Program pursues the goal of improving the nutritional and economic well-being of rice growers and low-income consumers in Latin America and the Caribbean through sustainable increases in rice production and productivity.

This goal translates into concentrating efforts on (a) the development of improved genetic pools; and (b) development of technology components suitable to irrigated and favorable upland rice production systems in Latin America and the Caribbean, so to enable NARS and rice producers to increase resource productivity and lower production costs.

Objectives, Strategies, and Activities

The regional program based at CIAT has three basic objectives, each of which is discussed with its corresponding strategy and major activities and are implemented in collaboration with IRRI.

Objective 1. Achieve a fuller expression of the yield potential and further broaden the genetic base of the upland rice germplasm adapted to the acid-soil savannas

Strategy. Several million hectares of acid-soil savannas, particularly high rainfall savannas, are suitable for rice production. Upland semidwarf rice populations with higher yield potential under the acid-soil, high rainfall savannas have been developed, making it possible to increase yields under a wider range of savanna environments. These populations, however, will require continuous efforts to broaden their genetic base to attain the fuller expression of yield potential through acquiring stable resistance and/or tolerance of regional (or specific) biotic and abiotic stresses, particularly as new environmental niches are addressed.

High priority will be placed on understanding the mechanisms of resistances or tolerances under savanna conditions and on identifying the genes behind these mechanisms, so to improve research efficiency of the population enhancement process.

Activities. Research will be conducted on the environmental and plant components affecting the yield potential of these materials under key sites. These activities will be conducted in close collaboration with the Savanna and Forest Margins Programs and interested NARDS. Growth simulation efforts for improved upland lines will support quantifying the maximum yield potential and the degree of suppression at key sites. Upland germplasm from Asia, Africa, and the Americas that possess useful characters will be incorporated into the breeding populations. Priority characters will be earliness, lodging tolerance, pest and disease resistance, and grain quality parameters.

Resistance mechanisms of developed upland dwarf lines to abiotic stresses in the region will be analyzed. Specific studies on the resistance mechanisms of these lines to moderate moisture stress and acid-soil conditions will be undertaken. Identification of responsible genes for these resistances will be pursued.

These studies will focus on key issues relevant to germplasm enhancement for Latin America and complement research generated at IRRI. These activities will provide key information for germplasm enhancement at CIAT. IRRI and CIAT will seek joint supplementary funding for areas of mutual interest, such as upland-rice root physiology, and plant architecture. The Rice Program will also develop collaborative projects with the Institut de Recherches Agronomiques Tropicales et des

Cultures Vivrières (IRAT) in upland-rice breeding and cropping systems. Anther culture will play an important role in breeding for acid-soil upland conditions. The basic physiological and genetic understanding of the adaptation and inheritance mechanisms will facilitate the transfer of upland-rice root systems to irrigated populations and appropriate strategies for developing sustainable systems for the savannas.

Obtaining information on pests and beneficial organisms will demand a high level of interaction with plant protection experts in national programs to help focus the program's germplasm development efforts for savanna cropping systems. Research on the mechanisms of pest and disease tolerance will require understanding the biology of pests within a regional context, and the possibilities of routine application of advanced biological tools for pathogen characterization. Many of the key sustainability issues will ultimately revolve around the successful management of rice pests. A clear understanding of the socioeconomic factors governing farmers' needs and adoption patterns of rice varieties and associated technologies will help refine research priorities for the Rice Program.

Objective 2. Broaden the genetic resource base for irrigated rice to increase yield potential and production stability

Strategy. Irrigated rice improvement activities throughout Latin America has derived major traits from 14 core landraces. A limited number of genes conferring resistance to major pests and diseases has been combined with this genetic core for commercial exploitation. It is thought that this approach has reached its limit in terms of increasing yield potential as well as adaptation to new environments. New adapted genetic backgrounds with high yield potential will be developed as supplementary genetic cores to enhance rice improvement activities in Latin America and the Caribbean. New sources of resistance to major pests and diseases will be identified and incorporated into the adapted cores. Understanding the pathogen population will facilitate the development of materials with stable resistance.

Sources for desired traits will include improved upland germplasm from the acid-soil, upland breeding pool, as well as introductions from Asia and Africa.

Activities. A research initiative to combine the upland-rice root system with the high-yielding irrigated core will be pursued. This should reduce the water demands and possibly decrease the flooded period during which the greenhouse gas methane is produced. Major plant characters mediating adaptation to the irrigated environments of Latin America will be defined and used to screen germplasm for their potential to develop a new high-yielding genetic core.

Population improvement techniques will be used to incorporate tolerances of blast rice, "hoja blanca" virus (RHBV) and its insect vector (*Tagosodes orizicolus*), sheath blight, the rice water weevil, in order to understand the parent potential of irrigated rice populations, and evaluate the feasibility of a continuous genetic improvement of rice yield. Efforts to reduce the risk of blast and hoja blanca virus outbreaks will also emphasize the clarification of pathogen variability and its effect on pest epidemics and population dynamics. IRRI and CIAT will seek joint supplementary funding to characterize the evolution of the blast fungus.

New tools such as molecular markers will be used for breeding, thus identifying and tagging genes for manipulation and transfer. The relationship between molecular, physiological, and field adaptation traits offers hope for efficient evaluation of quantitative traits. Tissue culture will be used to accelerate molecular marker analysis for combining genes and to increase efficiency of population enhancement activities. Strong linkages with both the VRU and BRU will be required throughout the period. Routine breeding for developing fixed lines for immediate release by national programs will be phased out by the end of 1994. Germplasm exchange within the region will take place primarily through the International Network for Genetic Evaluation of Rice (INGER).

As a new genetic core is developed, and genes of interest and the upland root habit are incorporated into high-yielding backgrounds, regionwide experiments will be conducted to assess the genotype-environment interaction and to ensure that the new backgrounds obtained are suitable to irrigated environments within the region. Appropriate arrangements will be made to devise a system for sharing resources with national programs in conducting these trials. Strong socioeconomics support will be required to have a clear understanding of the factors governing farmers' needs, adoption patterns of rice varieties and associated technologies to establish research priorities in the Rice Program. This will help identify niches where CIAT has comparative advantages.

Further investments in germplasm storage capability for maintaining collection and population backups, and providing access to a fully operational molecular markers laboratory will be undertaken. Strong linkages with IRRI, the rice biotechnology network, and other advanced institutions will be maintained to ensure the practical exploitation of the diverse germplasm sources and emerging genetic manipulation techniques.

Objective 3. Reinforce and promote regional information exchange among national programs

Strategy. Considerable information on different aspects of rice culture is currently being generated at local, national, and regional levels, but its availability to the relevant actors and institutions is limited.

The strategy is to strengthen the flow of information, particularly that on the areas of rice research and production, to improve regional awareness, thus resulting in more efficient use of information in rice research related activities. Making crop improvement data available throughout Latin America will require the creation of new information exchange mechanisms and/or enhancement of existing channels.

Activities. CIAT will strengthen the regional rice research newsletter, *Arroz en la Américas,* through which Latin American scientists can share research results, particularly in relation to specific issues of regional concern, such as blast, RHBV, acid soils, and grain quality. Databases on germplasm performance and key agronomic and socioeconomic characteristics will be maintained and made available to national programs. The Rice Program will receive support from IDS for communication mechanisms and from IM for database management. All work will be closely coordinated with IRRI and other rice research institutions.

Resource Allocation and Requirements

The Senior Staff positions required for executing the Rice Program's operational plan during 1992-1998 and the costs associated with the various research sections appear in Table 6.

Description of Senior Staff Positions

Office of Leader. Coordinates rice research and training activities to ensure continuous relevance and complementarity with the activities of other national and international programs (IRRI and WARDA in particular); and provides administrative support to the research scientists for the efficient use of resources assigned to the program. Conducts research on genetics, physiology, and modeling for evaluating adaptation to target environments.

Table 6. Rice Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

Senior Staff Position	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Headquarters														
Office of Leader (G/E interac.)	1	314	1	334	1	334	1	334	1	334	1	334	1	334
Economics	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100
Entomology	0.5	120	0.5	120	0.5	120	0.5	120	0.5	120	0.5	120	0.5	120
Genetics (Irrigated)	1	225	1	214	1	214	1	214	1	214	1	214	1	214
Genetics (Savannas)	1	209	1	203	1	203	1	203	1	203	1	203	1	203
Pathology	1	228	1	228	1	228	1	228	1	228	1	228	1	228
Crop physiology	1	211	1	208	1	208	1	208	1	208	1	208	1	208
Others	–	258	–	133	–	133	–	133	–	133	–	133	–	133
Total	**6**	**1,665**	**6**	**1,540**	**6**	**1,540**	**6**	**1,540**	**6**	**1,540**	**6**	**1,540**	**6**	**1,540**

Genetics (Upland). Manages the upland germplasm development program, expanding the present population and including the development of upland dwarf populations suitable for crossing to transfer useful upland traits to irrigated lines; conducts research on the genetics of adaptation to acid soils with high aluminum saturation; manages crossing program and germplasm introduction; interfaces with Resource Management Research Division to provide adapted materials for cropping system development.

Genetics (Irrigated). Responsible for main germplasm development activities for tropical and temperate irrigated systems; focuses on the development of new genetic cores, incorporating new sources of resistance to or tolerance of priority biotic and abiotic constraints. Assesses new methods (anther culture, RFLP, etc.) of speeding up germplasm improvement; exploits the use of molecular genetic markers and maps in plant breeding and germplasm characterization, working in close collaboration with the BRU, pathologists, entomologists, and plant physiologists.

Pathology. Focuses on priority diseases for the region: rice blast, RHBV, grain discoloration, and sheath blight, emphasizing host-pathogen interactions, pathogen variability, characteristics of durable resistance, interactions with vectors, interactions among pathogens, and environment; aims to understand the epidemiology of key diseases and the implications for germplasm development and management strategies; collaborates closely with geneticists and the BRU to tag resistance genes and devise methodologies for accumulating and deploying resistance genes.

Entomology. Focuses on priority insects in the region responsible for direct economic losses: panicle bugs, *Tagosodes* planthopper, rice water weevil (RWW), and leaf miners; assesses the economic importance of ants and spittlebugs under savanna conditions; orients research toward characterization and manipulation of resistance genes in collaboration with geneticists. Uses biotechnology tools to incorporate and accelerate the development of RWW resistant lines.

Crop physiologist. Works in close collaboration with geneticists to study germplasm developed by the Rice Program for adaptation to direct-seeding conditions and upland acid soils, and to identify opportunities for improving plant type and physiological factors limiting yield potential. Develops understanding of how the upland root functions in combination with the irrigated plant type and identifies characteristics associated with the adaptation of such roots to favored upland environments. Establishes linkages with the Resource Management Research Division for research on sustainable cropping systems where rice is a component, including studies on plant competition and early plant vigor.

Economics. Provides essential socioeconomic data and approaches for determining research priorities and comparative advantages in target environments; develops methodologies to orient research and technology transfer toward critical problems; engages in *ex ante* and *ex post* analyses of the rice sector for monitoring progress in germplasm adoption and its impact; continuously monitors regional rice economic and policy environments for long-term implications for research activities, particularly on alternative uses of rice in agroindustry. Characterizes socioeconomic and agricultural aspects of rice production systems, including analysis of constraints of production and sustainability in the savannas and forest margins of Latin America.

Complementary Activities

Besides germplasm development, the focus of core activities, there is a felt need, and an opportunity to develop crop management research and to further strengthen rice research and training institutions through network support. Recent budget adjustments at CIAT led the Center to decide that core funds will be assigned to germplasm development and information dissemination activities, whereas the program will seek external funding to support crop management networking, and training activities as complementary activities.

Strategy. Collaborative activities have traditionally been aimed at strengthening public sector institutions. Rice research in Latin America and the Caribbean has evolved to include a wide variety of institutions ranging from government to private organizations. The latter are usually self-financed and provide resources for the activities of other institutions.

The role of CIAT's Rice Program, with a regional mandate, is to serve as convener and catalyzer of that wealth of research activity. These will include integrating institutional activities at national and regional levels and the participation in the generation of more environmentally specific technologies.

Activities. The program sees the continued existence of both INGER and CRIN as an essential complement to its activities. INGER-Latin America, although part of the global INGER system administered by IRRI, is headquartered at CIAT and fully coordinated with CIAT's activities. This network serves as an efficient means of communication and germplasm exchange within the region and among IRRI, CIAT, and the numerous Latin American rice improvement programs.

By expanding INGER's scope and introducing CIAT's rice research regional mandate, IRRI and CIAT will seek joint supplementary funding for activities intended to catalyze rice-related activities of various public and private research, extension, and training institutions in tropical Latin America.

The project will have a national and international scope, seeking to better integrate not only national activities within the countries but also strengthening collaborative efforts among countries and regions. The integrated crop management network project constitutes a phasing-out of the integrated crop management activities from the core activities that the Rice Program began in 1985, and the initiation

Table 7. Rice Program. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

Senior Staff Position	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
CRIN coordination	1	200	1	360	1	360	1	360	1	360	1	360	1	360
INGER coordinat. (IRRI/CIAT)	–		–	120	–	180	–	150	–	150	–	150	–	150
ICM/IPM network coordination	–		1	300	1	300	1	300	1	300	1	300	1	300
Biotechnology	–	90	–	90	–	90	–	90	–	–	–	–	–	–
Anther culture network	–	50	–	100	–	100	–	100	–	–	–	–	–	–
Total	1	340	2	970	2	1,030	2	1,000	2	810	2	810	2	810

of stronger, more comprehensive networking by INGER-CIAT in Latin America.

CRIN is an externally supported network, intended to strengthen weak Caribbean rice programs and to realize an economy of scale by sharing special strengths and comparative advantages among the programs. The requirements of the region are such that they cannot be met by the present Rice Program core resources and must be met by complementary funding.

Strong linkages with the International Program on Rice Biotechnology will be maintained to keep the Rice Program abreast of new developments in this area through close collaboration with the BRU. An assessment of regional needs and interest in anther culture as an additional tool to be used in routine breeding work will be conducted. Complementary funds from the Rockefeller Foundation and/or other donor agencies will be required to initiate a network of anther-culture laboratories in the region.

Additionally, a series of complementary activities in the area of biotechnology will be carried out jointly by the Rice Program and the BRU. For a description of these activities, see p. 75 (BRU).

The budget for the proposed complementary activities is found in Table 7.

Expected Outputs

Breeding populations with new backgrounds for the irrigated sector will be created by the end of 1998 for evaluation by national programs across environments. Potential parental lines will be available with precise information on the RHBV and blast resistance gene(s) they carry. Fixed lines combining irrigated plant type and yield potential with upland root systems will be under evaluation by national programs by 1997. Preliminary assessments of the usefulness of recurrent selection in rice breeding for Latin America will be available, and lines carrying specific useful traits in a desirable background will be distributed to the national programs.

Well-adapted, high-yielding germplasm appropriate for incorporating into savanna cropping systems will be in production by year 2000. Expected contributions are 2.5 million additional tons per year. Progress in understanding the mechanisms of adaptation and inheritance will facilitate the transfer of rooting systems to the irrigated populations and suggest strategies for developing sustainable systems for the savannas.

Understanding of the mechanisms of resistance to or tolerance of principal constraints; understanding of factors influencing variability of biotic constraints and population dynamics; combining the knowledge of these two areas with information on interaction of components and probable stability of resistance will help establish broad guidelines for ICM and IPM approaches at the national level.

Understanding of plant genetics/physiology components affecting yield potential, together with understanding of rice root physiology, will provide the basis for continuous enhancement of yield potential under both irrigated and upland savanna conditions.

By 1998, strong information exchange mechanisms, that is, networks; a rice research newsletter; and databases on rice-growing agroecological zones, biotic/abiotic constraints, and germplasm development, will operate among the national programs and at CIAT. The programs can therefore benefit from advances made elsewhere and monitor their investment in rice research.

Stronger rice research systems in various countries, with a broadened base of trained scientists, will interact with neighbors in a systematic network of collaboration and information exchange, using formal mechanisms.

Tropical Forages Program

Goal

The Tropical Forages Program (TFP) is a germplasm development program whose goal is to identify and develop a portfolio of productive grass and legume forage species and cultivars, both herbaceous and woody, adapted to different agroecologies[1] on tropical acid soils. These forages will contribute to increased meat and milk production and to soil improvement and erosion control by their deployment in different cropping systems.

Mandate

The program will assume a worldwide responsibility for herbaceous legume and grass species adapted to low-fertility acid soils of the lowland tropics. In the acid soils of tropical America, the Program's germplasm mandate includes herbaceous legume and grass species for mid-altitudes, 18 °C annual mean temperature (e.g., 1000-1800 m.a.s.l. at the equator), and woody, leguminous forage species for both lowlands and mid-altitudes.

[1]The geographical area in which a land use pattern and an environmental class overlap.

Strategies, Objectives, and Activities

The TFP's fundamental approach will involve the acquisition and evaluation of a broad range of germplasm for adaptation to abiotic and biotic constraints that characterize the principal agroecosystems targeted for research. The TFP will also conduct strategic research to improve efficiency of germplasm development through greater understanding of the plant genotypes involved and their interactions with the range of environmental diversity encountered in the target areas.

Objective 1. Identification of productive herbaceous and woody forage germplasm

Adapted forage germplasm is identified by exploiting the natural genetic variability among and within wild species with forage potential and evaluating this variability under abiotic and biotic constraints in major ecosystems. Acquisition of as broad a collection of relevant germplasm as possible will remain an important objective.

Activity 1. Germplasm acquisition.

Exchange and collection to rectify deficiencies in existing collections of key herbaceous genera. Priority materials include *Arachis pintoi* and other *Arachis* spp.; *Stylosanthes* spp., to cover better the centers of diversity; *Paspalum* spp.; and *Desmodium* spp. and related genera in Southeast Asia. Collections of potentially important species will be enlarged as required, e.g., *Centrosema*, *Cratylia*, *Calopogonium*, *Hyparrhenia*, and *Melinis* spp.

The herbaceous collection will be complemented by new acquisitions (through exchange or collection, as appropriate) of herbaceous and woody forage germplasm with potential for adaptation to mid-altitude, acid-soil environments.

At present, CIAT has a limited collection of leguminous multipurpose forage trees and shrubs (MPFTS) with potential for adaptation to acid soils. Further germplasm will be acquired, in collaboration with the GRU, through institutions, such as ICRAF, ILCA, CSIRO, NFTA, CATIE, OFI, and through strategic collection.

Activity 2. Germplasm evaluation.

Screening of germplasm collections and bred materials and identification of promising forage species will be conducted by regional evaluation. This will include assessment of attributes related to adaptation, production, forage value, ease of propagation, and soil improvement. An additional criterion for screening legume species will be nitrogen-fixing ability. Selection criteria will be added in response to the needs of the Agroecosystems Programs (AEPs) and specific target areas. Parallel research will be conducted to adapt and develop appropriate methodologies for agronomic evaluation and assessment of nutritional quality.

The TFP will be responsible for germplasm evaluation at the level of grazing in mixtures to determine persistence and nutritive value of components. Further evaluation to determine animal performance will be carried out by national partners in the RIEPT with the active collaboration of the TFP's Regional Agronomists and Animal Nutrition Specialist, and by the AEPs as part of prototype production systems. The links between the TFP and the AEPs will be strongest at the level of the Genotype x Environment Specialist and associate economists in the TFP and the Production Systems Specialists in the AEPs.

Multilocational evaluation at major screening sites by TFP will continue to be important throughout 1993-1998. High priority will be given to regional germplasm evaluation by the two Regional Agronomists.

The Germplasm Specialist, in collaboration with the Regional Agronomists, will coordinate the design of evaluation procedures according to species and different utilization strategies. This will include the evaluation of a number of germplasm sets, including relevant checks. The specialist will also continue evaluating new germplasm for the llanos ecosystem. The Regional Agronomist stationed at EMBRAPA/CPAC will be responsible for developing germplasm for the Cerrados (70%) and for the Amazonian humid tropics (30%), at the site selected for the Forest Margins Program and at other institutions based in the region.

The Regional Agronomist stationed in Costa Rica will target the forest margins and mid-altitude hillsides of Central America. Existing sites are all in Costa Rica: at Guápiles for forest margins, at San Isidro for screening, and Atenas for initial seed multiplication. Once the site selected by the Hillsides Agroecosystem Program becomes operational, one of the existing TFP sites will be phased out.

To answer the global mandate for herbaceous species for tropical, acid-soil lowlands, an additional major screening site will be developed in Southeast Asia. Initially, it will be a complementary position until a core position is created in 1996 to provide continuity to the work. Pending funds, the Program plans to outpost a Senior Agronomist to West Africa to implement a second major screening site outside tropical America.

Leguminous MPFTS will be screened at all major screening sites in tropical America, with initial priority given to forest margins and mid-altitude acid-soil sites where this germplasm is judged to have the highest potential. The possibility of associating with ICRAF and CATIE in this endeavor will be explored.

In addition to germplasm evaluation by TFP staff, regional evaluation will be complemented and expanded through regional networks, namely, and in order of priority, RIEPT (Latin America), SEAFRAD (Southeast Asia), and RABAOC (West Africa), which will receive high priority for complementary funding. Concurrently, TFP will promote the further evolution of these regional networks toward strengthening their capabilities and self-reliance.

Limited quantities of seeds of priority materials will be multiplied for (a) experimental purposes, i.e., to conduct germplasm evaluation (approximately 5-30 kg of legumes and 1-10 kg of grasses), and (b) for delivery as basic seed to national multiplication projects (5-100 kg).

Primary (or initial) multiplications will be conducted by the Germplasm Section in collaboration with the GRU. Secondary multiplications will be conducted by both the Seed Section and Regional Agronomists. In the case of quarantine and clean seed multiplications, the Pathology Section, GRU, and VRU will also participate in collaboration with Colombia's ICA Quarantine Officer.

When large volumes of seeds (i.e., more than 30 kg), not commercially available, are required by CIAT Programs, the Seed Section will collaborate in the organization of contract production by third parties via the utilization of a Rotating Seed Fund. This means anticipating production targets by 1-2 years, and clients contributing to the production process and then purchasing seed from the Rotating Seed Fund.

The Program will be responsible for maintaining the existing *Rhizobium* collection and for supplying inoculum for up to 30 kg of seeds for TFP and AEPs' research. Activities can be separated into two categories:

> *Conservation*: the current selection of *Bradyrhizobium* has about 4,000 strains. The majority of these are stored, lyophilized for several years, and require only occasional checking for mutations and viability.
>
> *Inoculant production*: currently, a group of 25 strains are in active use for the production of inoculants, mainly for small-scale research trials for the 5 main genera used by the TFP (*Arachis*, *Centrosema*, *Desmodium*, *Pueraria*, and *Stylosanthes*). The remaining strains are used for another 12 genera of herbaceous and shrubby legumes. Links will be established other centers holding *Rhizobium* collections such as NifTAL and, in the future, ICRAF for MPFTS.

The TFP will make use of CIAT's collection of mycorrhizal germplasm to evaluate the possible benefits of mycorrhizal association on certain key species.

The Program will continue to monitor the evolution of the Latin American cattle industry to determine what demands will be placed on forage germplasm development and to derive suitable prototypes for RIEPT's portfolio of cultivars and species.

Linkages. CIAT's BRU and VRU, and other external specialized institutions will collaborate to identify and evaluate species.
Specific areas of research will include genetics of *Brachiaria*, pathogen diversity of anthracnose and resistance in *Stylosanthes*, taxonomy and

phylogenetic relationships of *Brachiaria* and *Arachis* spp., and chemical characterization of tannins in herbaceous and MPFTS legumes selected for acid soils.

Expected outputs. These are:

Substantial progress in identification of key species for mid-altitudes.

In the lowland tropics of Southeast Asia and West Africa, considerable progress will have been made toward identifying key species for these regions. Large collections of herbaceous legumes and grasses will have been evaluated.

Advances in research methodology.

Regional networks, especially RIEPT, will become more autonomous with some specialization and division of research responsibilities at the subregional level. National institutions will increase the fre quency and improve the speed of effective release of a range of new species and cultivars.

Objective 2. Defining factors influencing adaptation and productivity

As we refine our understanding of the germplasm and its interactions with the environment on a genetic and physiological level, we improve the efficiency of the evaluation/ selection process and of the germplasm's use as cultivars and ultimately as pastures. Studies of genotype interaction with environmental factors should lead to more efficient methodologies to identify tolerance or resistance to key biotic and abiotic constraints. Rapid assessment of genetic adaptation to low-fertility, acid soils as well as resistance to spittlebug are critical to the *Brachiaria* improvement project. An understanding of temporal and spatial variation in *Colletotrichum gloeosporioides*, the causal agent of anthracnose in *Stylosanthes*, will greatly improve the chances of identifying durable resistance to this important disease, particularly in the Brazilian Cerrados. Determination of quality attributes of key forage species will contribute to defining better their role in livestock production systems within agroecologies.

Activity 1. Adaptation to acid soils.

The Program will aim to improve its understanding of the physiological and genetic basis of plant adaptation to nutrient-poor acid soils in order to develop suitable screening criteria and evaluate potential trade-offs.

Identification of major processes affecting plant adaptation to acid soils will help develop more efficient screening methodologies for rapid assessment of genetically altered materials. Knowledge of plant adaptation mechanisms will be useful for evaluating the potential benefits to the plant in terms of nutrient acquisition relative to the carbon costs of acquiring nutrients (e.g., mycorrhizal association).

The TFP and AEPs will form a team to understand the role of legumes and grasses in soil enhancement in legume-based pasture systems. Soil conditions in terms of soil organic matter quality, availability of nutrients, soil physical properties, and soil biological activity will be evaluated in grazed pastures.

Legumes will normally be initially evaluated without inoculation in order to select germplasm which is promiscuous with respect to *Rhizobium* symbionts. When otherwise promising or key species show obvious N deficiencies or marked responses to N, a need-to-inoculate test will be done by the Regional Agronomists in collaboration with the Savanna Program's (SP) Nitrogen-cycling Specialist.

If further strain selection is warranted in new or key species, e.g., *Arachis pintoi*, this work will be done at CIAT's headquarters by the TFP support staff (see p. 36) under the supervision of a technician at the associate level or equivalent and the SP's Nitrogen-cycling Specialist.

Activity 2. Adaptation to biotic constraints.

Mechanisms of resistance to key diseases of forage plants, including the genetics of host/ pathogen interactions, will be defined to develop suitable screening criteria for germplasm evaluation.

Understanding of the temporal and spatial variation in *Colletotrichum gloeosporioides*, the causal agent of anthracnose, is essential for identifying durable resistance to this important disease, especially in the Cerrados. Similar studies are required to obtain durable resistance to rhizoctonia in *Centrosema* spp.

Spittlebug is a major pest of *Brachiaria* spp., some of which have accessions that are highly resistant. The nature of this resistance will be sought and the methods extended to *Panicum maximum*. Some *Brachiaria* spp. are resistant to attack by leafcutting ants. The nature of this resistance will also be investigated.

Activity 3. Defining quality constraints.

Certain key legumes contain polyphenols (i.e., tannins), high levels of which are known to depress animal performance. The nature of this depression in ruminants will be investigated by using key herbaceous and woody legumes with variable levels of tannins.

Some herbaceous and woody leguminous species with potential adaptation to acid soils may have limited forage value because of antiquality factors (i.e., tannins, alkaloids). Defining these limitations and adjusting appropriate assay methods will be important for screening and for identifying superior forage cultivars.

Digestibility in tropical forage species is an important quality attribute. The Program will define the extent of genetic variability in in vitro dry-matter digestibility (IVDMD) within a number of key grass and legume species to be used in selecting and/or enhancing promising materials. Initially, priority will be given to *Brachiaria* spp.

Activity 4. Seed constraints.

The TFP is involved with a wide array of different species whose primary characters of merit relate to their forage value. In many cases, however, characters, such as their flowering, seed setting, seed recovery, seed quality, are either little known or deficient for either regeneration and persistence within the pasture system or seed availability to farmers for adoption and diffusion. Thus strategic research on seed-related constraints is essential.

The seed biology of species in advanced evaluation categories will involve progressively characterizing such components as flowering, seed set, seed recovery, and seed yield and quality. Species profiles will be defined for *Centrosema rotundifolium*, *Arachis pintoi*, and others. Major constraints of each species will then be identified. Possible solutions to the major constraints of seed issues of key species will be sought, by specific research project(s), e.g., seed recovery and seed quality in *A. pintoi*; seed quality of *Brachiaria* spp.; and seed yield of *S. guianensis*. Such research will be conducted at the most relevant locations in collaboration with the TFP's Regional Agronomists, national institutions, the private sector, and others. Collectively, these projects will also lead to improved definition of the role of environmental factors (photoperiod, moisture, etc.) and management on seed yield and quality of key species.

Model seed supply systems will be defined and monitored for key species within different target environments (e.g., small farmers in forest margins, mechanized commercial farmers in savannas) in conjunction with the Program's Economists and AEPs.

The TFP's Regional Agronomists and other CIAT Programs (IDS, Savannas, and Forest Margins) will promote wider participation in seed supply activities (production, commercialization, and research) by regional networks and local government and nongovernmental institutions.

Linkages. Close collaboration with CIAT's BRU and other, external, specialized research institutions will help ensure rapid progress in understanding the mechanisms responsible for ecological adaptation of pasture components. Specific areas of research will include mechanisms of acid-soil adaptation, mechanisms of resistance to key pests and diseases, processes affecting quality/antiquality factors, and mechanisms governing flowering and seed set.

Expected outputs. These are:

Improved understanding of plant adaptation mechanisms to acid soils will contribute to the development of better screening tech niques to evaluate genetically altered materials (e.g., *Brachiaria* and *Stylosanthes* spp.).

Knowledge on dynamics of soil improve ment in legume-based pasture systems will help identify key indicators of soil enhance ment.

More efficient regional testing will lead to durable resistance to biotic stress and increased opportunities for genetic improve ment.

Identification of tannin thresholds and within-species genetic variability for this trait will lead to more reliable screening of legume species.

Species profiles of propagation potential for species in advanced categories and identifi cation of species-specific constraints.

Advances in research methodology.

Improved links with networks.

Objective 3. Developing improved forage plants

Genetic manipulation through applied plant breeding and biotechnology will be used to address discrete, well-defined constraints of important herbaceous species for acid-soil lowlands where these cannot be overcome by reliance on introduced germplasm. As most tropical forage species have not been subject to genetic improvement, applied plant breeding activities will be complemented by strategic studies of the genetics of critical attributes and their interactions with environmental factors, breeding methodologies, and manipulation of reproductive mode to increase the efficiency of genetic advance.

During the planned period, applied plant breeding activities will be focused on the genera *Brachiaria* and *Stylosanthes*, with the possible later addition of *Centrosema* spp. (disease resistance, seed yield, and persistence); *Panicum maximum* (better acid- soil adaptation); and/or *Desmodium heterocarpum* (= *D. ovalifolium*) (forage quality). Advanced cellular and molecular biotechniques will be applied for genetic improvement of acid-soil adaptation to the most promising genera, *Brachiaria* and *Arachis*.

***Activity 1. Improving* Brachiaria.**

In *Brachiaria*, the major objectives are to incorporate genetic resistance to spittlebug and improved nutritional quality (IVDMD) in apomictic genotypes that are well adapted to infertile acid soils. Genetic mechanisms controlling these attributes, as well as reproductive mode, will be studied in close collaboration with colleagues at EMBRAPA-CNPGC.

***Activity 2. Improving* Stylosanthes.**

The TFP will initiate a project in the Brazilian Cerrados to enhance seed yield potential and disease resistance of selected promising accessions of *S. guianensis*, as well as to study host-plant resistance and pathogen variation for anthracnose of *S. capitata*.

Activity 3. Improving acid-soil adaptation.

The former TPP identified a number of highly promising forage species during screening and evaluation of germplasm for adaptation in the target area. Further improvement of these species will require physiological and genetic characterization to identify the key traits that can be combined to improve their performance. This will be achieved by an integrated approach that involves conventional genetic enhancement and new biotechnological tools. The TPP has already used materials derived from tissue culture techniques (somaclonal variants of *Stylosanthes* spp.). To define physiological mechanisms responsible for adaptation to acid soils, TFP will extend this work to other key species such as *Brachiaria* and *Arachis* spp. Cellular and molecular biotechniques will be used further to characterize improved germplasm with desirable traits.

Linkages. Very active collaboration is anticipated with BRU and GRU at CIAT and EMBRAPA-CNPGC in Brazil during the planned period.

Expected outputs. These are:

Spittlebug-resistant *Brachiaria* hybrids adapted to low-fertility acid soils.

Progress in improving seed yield potential and disease resistance in *Stylosanthes* spp.

Progress in identifying plants with improved adaptation to acid soils.

Advances in research methodology.

Objective 4. Defining interactions between germplasm and environment

The TFP deals with a wide range of diverse species and does not focus upon a single crop species. As a result, the classical genotype x environment interactions analysis has limited relevance, except for certain key species (e.g., *Brachiaria* spp.) to which it will be applied.

For the present operational plan, environment is considered as the sum of all external, nongenetic, abiotic, and biotic factors that influence plant performance. It is further complicated by management and economic forces that influence the role of forages in farming systems. Factors of overriding importance in assessing plant adaptation are productivity, disease and pest resistance, and persistence under contrasting managements.

The TFP's target area includes a diverse range of environments and economic conditions. The ideal forage would have general utility across the target area, i.e., broad adaptation. The reality is that no such forage exists. The challenge is to provide a portfolio of germplasm options (different species and cultivars) to fulfill the specific requirements of environmental diversity. While some species of grasses such as *Brachiaria* have shown broad adaptation, most legumes tend to have narrow adaptation, e.g., *S. capitata*, which shows a strong preference for lighter texture soils.

In the late 1970s, the former TPP made a detailed physical characterization of its target ecosystems, which since provided the frame of reference for its strategies. Subsequent germplasm evaluation by the TPP and RIEPT provided a vast database on the overall adaptation of a large number of genera, species, and accessions. Regression and pattern analysis of the data simplified interpretation of differences in species adaptation, for example, in *Andropogon gayanus*, *Stylosanthes guianensis*, *S. capitata*, *Brachiaria dictyoneura*, and a limited number of *Centrosema* spp.

The TFP will quantify key biotic and abiotic environmental variables to understand adaptation at species level, and will use empirical and mechanistic models to identify better niche specificity. In collaboration with other CIAT programs, greater emphasis will be placed on this area for selected key species.

This approach will enable TFP to rationalize relative priorities for different key species. For example, a species such as *Arachis pintoi* may have broader adaptation to a number of ecological niches and therefore more utility, or the dimension of those niches may be much greater than for another species with narrow adaptation to edaphic, climatic, and management conditions.

Activity 1. Identification of agroecological niches[2].

Rigorous analysis of regional trial data will be used to determine the range of ecological adaptation of key species and genotypes within species. Explicit definition of the optimal agroecological niches for each will therefore result.

Activity 2. Evaluation in prototype production systems.

The performance of advanced germplasm in prototype production systems will be evaluated by the TFP's Regional Agronomists in close collaboration with the AEPs. The interactions between forage germplasm and production systems will therefore be better understood.

Linkages. Evaluation of a genotype within production systems will require close collaboration between the AEPs, the Genotype x Environment Specialist and the Program's Economists. The appropriate niches will be determined within the production system options for each agroecosystem in which the components of the germplasm portfolio might best be exploited. Modeling will play a key role to determine the outcome of the multiple options at this level. A multidisciplinary team, including the TFP and the AEPs, will seek understanding of the systems' components so to construct meaningful models. The pasture development unit of the former TPP, with some enhancements, provides a prototype of the team approach envisaged. The Genotype x Environment Specialist will play a key role by bringing germplasm from the TFP to the AEPs and, together with the economists, facilitating feedback from the AEPs to appropriate specialists in the TFP.

[2] A geographical area for which a particular species or cultivar is especially fitted.

Collaboration will initially be with the Savanna Program where a large portfolio of germplasm already exists in advanced stages and where technological options are clearer. Collaboration and feedback with the remaining AEPs will be developed progressively as agroecological niches become better defined.

Expected outputs. These are:

Improved definition of range of agronomic adaptation and major environmental constraints for key species.

Identification of geographical areas (niches), their magnitude, and characteris tics.

Feedback of knowledge to TFP (to gener ate better materials through screening and improvement), AEPs and networks.

Improved congruence of selected forage species, associations, and management within specific production systems.

Institutional Linkages

Links with CIAT's Programs and Units

Close collaboration with other CIAT Programs and Units (Box 3) will ensure rapid progress in germplasm evaluation, as well as in germplasm development. Specific areas for research will include germplasm characterization (GRU), genetics of *Brachiaria* (BRU), pathogen diversity of anthracnose (Bean Program) and resistance in *Stylosanthes*, clean seed production (VRU), resistance to or tolerance of spittlebug and ants (Rice Program), taxonomy and phylogenetic relationships of *Brachiaria* and *Arachis* spp. (GRU), and chemical characterization of tannins in legumes (BRU).

Close collaboration is also anticipated for defining factors that contribute to adaptation

Box 3. The Tropical Forages Program's links with other CIAT Programs and Units.

CIAT Program or Unit	Type of Interaction	Index (%)
Rice	Rice-pasture systems, ants, spittlebug	10
Beans	Rhizobium, mycorrhizae, anthracnose, quality aspects	5
Cassava	Mycorrhizae, erosion control	5
GRU	Germplasm acquisition, characterization	10
BRU	Species enhancement, plant mechanisms	10
VRU	Clean seed, viral diseases	5
Land Use	Ecological niches	10
Savannas	Performance	20
Hillsides	Performance	5
Forest Margins	Performance	10
IDS	Seed systems, training, information, project design, networks	10
Total		100

and productivity. The specific areas of research will include mechanisms of acid-soil adaptation (BRU); rhizosphere biology (Beans, Rice, and Cassava), mechanisms of resistance to or tolerance of key pests (Rice) and diseases (Beans), processes affecting quality/ antiquality factors (BRU and Beans); and mechanisms governing flowering, seed set, and seed supply (GRU, BRU, and IDS). Close collaborative links with the Resource Management Research Division are also anticipated to identify niches and obtain feedback on the performance of key materials in prototype production systems.

Links with other institutions

The TFP will maintain its traditional linkages with NARIs through a range of activities within the RIEPT network, particularly with regard to germplasm evaluation. Together with network steering committees and IDS, needs for specialized training will be identified. The TFP and IDS will then help develop and implement appropriate training events in conjunction with other relevant institutions, subject to the availability of funds.

Links with advanced research institutions will be expanded, especially for collaborative studies on genetic improvement and on factors of adaptation and productivity.

Collaborative projects between NARIs and CIAT's AEPs will provide connections with development-oriented organizations. In turn, the latter will act as a bridge to primary producers for studies on prototype production systems.

Table 8. Tropical Forages Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Headquarters														
Off. of Leader (G/E interaction)	1	600	1	600	1	600	1	600	1	620	1	620	1	620
Germplasm	1	210	1	210	1	210	1	210	1	210	1	210	1	210
Genetics	1	190	1	190	1	190	1	190	1	190	1	190	1	190
Pathology	1	190	1	190	1	190	1	190	1	190	1	190	1	190
Entomology	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100
Plant nutrition	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Quality/Ruminant nutrition	1	190	1	190	1	190	1	190	1	190	1	190	1	190
Seed biology	1	180	1	180	1	180	1	180	1	180	1	180	1	180
Economics	–	65	–	65	–	65	–	65	–	65	–	65	–	65
Rhizobiology	–	40	–	40	–	40	–	40	–	40	–	40	–	40
Others	–	220	–	–	–	–	–	–	–	–	–	–	–	–
Outposted														
Screening: South America	1	220	1	220	1	220	1	220	1	220	1	220	1	220
Screening: Central America	1	210	1	210	1	210	1	210	1	210	1	210	1	210
Screening: Southest Asia	–	–	–	–	–	–	–	–	1	210	1	210	1	210
Total	9.5	2,615	9.5	2,395	9.5	2,395	9.5	2,395	10.5	2,625	10.5	2,625	10.5	2,625

Resource Allocation and Requirements

Table 8 shows the Senior Staff positions needed to execute the Tropical Forages Program's operational plan during 1993-1998, and the costs associated with the various research sections. A summary description of each Senior Staff position proposed for the planning period follows.

Description of Senior Staff Positions

Office of Leader. Supervises, coordinates, and guides the establishment of priorities and implementation of forage germplasm development strategies and activities; promotes interdisciplinary activities; establishes links with other CIAT Programs and Units and with national and international institutions.

Germplasm. Responsible for the acquisition of forage germplasm through exchange and direct collection in collaboration with the GRU; conducts preliminary agronomic evaluation and develops evaluation procedures.

Genetics. Responsible for genetic characterization of key species and the genetic enhancement of specific attributes of these; develops novel methodologies for the genetic improvement of largely unknown tropical forage species, including methodologies for efficient genetic recombination and for the assessment of genetic variation; produces advanced progenies for decentralized testing.

Pathology. Carries out surveys to detect and identify pathogens in the collection; responsible for research on the epidemiology of the main pathogens affecting key grass and legume species; develops reliable screening criteria; defines mechanisms of resistance to key diseases; and contributes to clean seed multiplication.

Entomology. Surveys the insect pests affecting the forage germplasm collection; carries out research on plant-pest interactions to identify appropriate screening criteria for key species.

Plant nutrition. Responsible for research on the mechanisms of acid-soil adaptation in contrasting selected species of grasses and herbaceous legumes; contributes to the development of reliable screening indices and to multidisciplinary research on plant-soil interrelationships.

Quality/ruminant nutrition. Responsible for identifying quality and antiquality attributes of promising forage species and for the development of appropriate quality screening methods.

Seed biology. Conducts strategic research on factors affecting flowering, seed set, and seed quality; supports national programs to conduct collaborative research and promotes the evolution of effective seed supply systems.

Screening: South America (Cerrados and Forest Margins). Responsible for the agronomic evaluation of forage germplasm in the Cerrados and Forest Margins ecosystems; coordinates and analyzes multilocational trials in the regions.

Screening: Central America (Hillsides and Forest Margins). Responsible for the agronomic evaluation of forage germplasm; coordinates and analyzes multilocational trials in the region.

Screening: Southeast Asia. Responsible for establishing of a major screening site for initial agronomic evaluation in cooperation with an appropriate national program; coordinates the exchange of germplasm and information across the region and with CSIRO.

Table 9. Tropical Forages Program. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Screening: Southeast Asia	1	210	1	210	1	210	1	210	–	–	–	–	–	–
Screening: Africa	–	–	1	200	1	200	1	230	1	230	1	230	1	230
Ecophysiology	–	–	–	–	1	200	1	230	1	230	1	230	1	230
Stability of savanna resources	1	166	1	166	1	113	–	–	–	–	–	–	–	–
Germplasm biology	–	91	–	76	–	76	–	76	–	76	–	76	–	76
In vitro management of germplasm	–	134	–	125	–	134	–	–	–	–	–	–	–	–
Total	**2**	**601**	**3**	**777**	**4**	**933**	**3**	**746**	**2**	**536**	**2**	**536**	**2**	**536**

Genotype x Environment. Conducts rigorous analysis of regional trial data to identify ecological niches for key species; evaluates the performance of advanced germplasm in prototype production systems; and interacts with AEPs and LUP to facilitate feedback to appropriate specialists in the TFP.

Complementary Activities

Pasture germplasm screening in Southeast Asia. This activity will depend on special project funds to screen pasture germplasm. In 1996, this activity will become a core activity.

Pasture germplasm screening in West Africa. The Program will seek funds to establish a screening site on acid soils of subhumid West Africa, staffed by a senior Regional Agronomist.

Ecophysiology of forage species. Responsible for studying the adaptation of forage plants used by grazing animals; develops an understanding of the mechanisms enabling forage plants to remain productive and persistent in mixed swards under selective grazing by ruminant animals.

Table 9 contains the projected budgets for the above complementary activities.

RESOURCE MANAGEMENT RESEARCH

Social and economic forces drive agricultural development in tropical America. The region has abundant land, but also has rural areas of extreme poverty and unequal land distribution, where the natural resource base is already severely degraded. The results are social conflict and a natural landscape being rapidly, sometimes irreversibly, devastated.

The rapid clearance of natural forests in recent years has brought relatively small gains in food production, because cleared areas often revert to bush within a few years. This futile destruction of natural resources is the region's most eloquent argument for promoting effective land use strategies and policies.

Tropical America is home to the world's largest surviving tropical forest, a resource under increasing pressure. Forest clearance and expansion of cultivated areas have been traditional sources of economic growth in the region. From 20% to 30% of production increases in the 1980s was from area expansion, mainly in the savannas and forested areas.

External pressures on the forests are generated by land speculators attracted by policy incentives, as well as by shifting cultivators emigrating from the hillsides, forced to abandon their land because of soil degradation or lack of adequate water. Others have left overcrowded, impoverished areas to join voluntary resettlement schemes in search of land and a better life. Internal pressures on the forests stem from the degrading "slash-and-burn" practices adopted by those who must eke out a living from that ecosystem.

In the mid-altitude hillsides, pressures from growing populations and expanding economies are causing overexploitation of the natural resources to satisfy immediate needs. Consequently, the depletion of soils, forests, and other vital resources exceeds the renewal rates. Secondary problems such as soil erosion, sedimentation of dams, and water pollution are reaching critical levels. This "mining" of the environment gives farmers short-term subsistence, but leads to long-term decreases in food production, income, and general welfare.

Concern is growing both within and outside tropical America about the environmental consequences of these increasing pressures on marginal lands. In the past, the region's priority has been development. This trend will prevail in the 1990s, as countries try to make up for the "lost decade" of the 1980s. But if future development is to be sustainable, it must be environmentally sound, with minimal adverse effects on the resource base. Development must also be economically viable in both the short and long term, and compatible with local cultures and political systems.

Although these concerns extend far beyond the challenge of increasing agricultural productivity in the region--incorporating global issues such as the protection of biological diversity and regional questions about the intrinsic value of the conservation of nature--CIAT researchers can no longer ignore the specific links between agricultural research and the natural resource problems facing tropical America.

CIAT's germplasm research strategies can hardly succeed in raising overall agricultural output in a region where the inherent productive potential of the resource base is declining sharply. This is particularly true where more and more of the poorest people in tropical America, who depend on CIAT's mandate crops--cassava, beans, upland rice--live in areas of marginal or fragile soils. For them, germplasm improvement alone can never compensate for the productivity lost annually from soil erosion, leaching of nutrients, and steadily declining fertility, which result from inappropriate land use and lack of soil conservation.

CIAT's research goal in Resource Management, as stated in the Strategic Plan, is "to improve the management of resources available for agriculture in tropical America, such that gains in food outputs and other commodities are compatible with long-term preservation of the resource base."

Possible alternatives for achieving this goal are to increase productivity of well-endowed areas, and to shift pressures to underpopulated lands. CIAT will focus on both approaches.

Genetic research at CIAT can produce technology that would help solve some of the region's worst natural resource problems and contribute to agricultural productivity. First, by continually increasing productivity on better endowed areas some relief can and must be provided for overexploited and underproductive lands. Second, improved varieties, characterized by low-input requirements, may contribute simultaneously to increasing food production for poor people and achieving conservation objectives.

Resource management will also focus on the more fragile environments. CIAT believes that increasing the productivity of cleared lands will deflect social and market pressures from the fragile resource base. Regionally, that means increasing the productivity of savannas and reverting the degradation of hillsides to absorb immigration and slow the rate of outmigration.

But appropriate policy incentives and disincentives must be initiated before sustainable land use alternatives can become viable development options. These policies should modify the economic behavior of land users by changing the allocation of costs and benefits. Information is needed on economic causes and effects of land degradation, and on how to effect politically viable changes in the institutional system.

CIAT's Role in Resource Management Research

Sustainability issues result from disparities between private and social benefits and costs. Historically, CIAT's initial contributions to a sustainable approach focused on productivity, mainly through the development of improved varieties that are resistant to insects and diseases. Society benefited from increased food availability, lower prices, reduced environmental pollution, and preserved biodiversity. CIAT's germplasm collection, preservation, and utilization contributed to the arrest of genetic erosion; while germplasm development helped cut pollution by building resistant gene pools. Equity aspects were further tackled in a second stage, promoting development mainly through marketing studies and innovative participatory methods that brought small farmers into the research process. CIAT has now evolved to the stage of emphasizing research on the social costs of sustainability.

Social Costs

Additional social costs of intensified land use in agriculture are increased environmental pollution and land degradation. Resource management research will complement germplasm development by focusing on degradation of land resources, mainly through research on both land use strategies and policies and integrated nutrient management.

The focus on land use strategies and policies deals with incentives for long-term development. Markets are seldom adapted to deal with responsibilities over generations, or to common ownership of property. They usually respond to short-term signals, which can mislead if applied to the long-term needs of sustainable agriculture. Fiscal and other incentives are, therefore, needed to incorporate land degradation costs into economic analyses.

Otherwise, free market forces driven by short-term benefits could cause neglect of social needs, and exhaustion of resources essential for the future.

Research on integrated nutrient management should focus on reducing production costs by decreasing the need for external inputs and maximizing efficiency in the use of needed inputs. This requires biologically based mechanisms relying on multispecies systems in spatial and temporal arrangements that exploit ecological compatibility among soils, plants, animals, and management practices; forming a "mosaic" across the landscape.

Both policy and nutrient-cycling research should be supported by the development of geographical information systems that facilitate their integration into sustainable land use alternatives.

CIAT's Comparative Advantages

We cannot set research priorities for specific area-based studies at this stage; they can only be determined after choosing representative study areas for each agroecosystem and assessing comparative advantages of partner institutions. Nevertheless, CIAT has obvious comparative advantages in fields that address:

1. Issues of *technology needs* and factors that affect their *adoption* by:

understanding relationships among policies, farmers' decision making, and changes in productivity and land degradation; and analyzing land use strategies that make private benefits compatible with social costs.

2. Issues related to *technology options* that maximize the efficient use of external inputs, and so minimize their use and negative environmental impact by:

Designing spatial and temporal arrangements of multispecies systems, thereby addressing trade-offs in production and conservation.

Modeling biological processes that improve soil fertility in tropical acid soils, thereby synchronizing plant demand with nutrient availability through the quantity, quality, and timing of organic and inorganic inputs.

3. Information to support decision making by building:

Spatial databases on natural resources, and socioeconomic information.

Production and environmental impact models.

Expert systems on management and policy.

Strategy evaluation programs.

Operational Strategies

We shall pursue strategies that integrate the ecological, economic, social, and political dimensions that underpin sustainability in agroecosystems and associated social systems. This requires biophysical and socioeconomic research to be carried out at the ecosystem and farm levels to assess the potential for increasing the sustainability of existing land use systems.

Ecosystem Level

Ecosystem studies at regional level address the economic feasibility, political viability, and ecological stability of existing land use systems and alternatives. Specifically, ecosystem studies compare existing and potential land uses by evaluating both the resource base and socioeconomic and political opportunities.

Ecosystem research seeks to explore issues such as crop suitability and comparative advantages across agroecosystems; relationships among different production systems in space and time and their implications for production and income; environmental impact; and policy incentives and disincentives.

Farm Level

The main research focus at the farm level is the generation of technologies that satisfy objectives of both farmer and society. Constraints and opportunities in existing farming systems will be studied, with the main objective of increasing long-term stability and reducing short-term risks; probably through combinations of species and cropping patterns.

But we cannot address agroecosystem and farm level issues separately. Both must be addressed in an interactive manner, so they can complement one another.

Institutional Cooperation

Although the vast majority of the resource management research undertaken by the RMRD will have global significance, the three Agroecosystem Programs and the Land Use Program will focus primarily on the specific environmental challenges of tropical America. This ecoregional approach will help provide an agenda for research and greater opportunities for cooperation among international, regional, national, and local institutions concerned with agricultural production and natural resource management as they relate specifically to tropical America. Ultimately, a major external objective of the Division is, in cooperation with governments, international agencies, and nongovernmental organizations, to promote "the design of land use options aimed at optimizing social returns to agriculture under different trade-off scenarios between production and conservation."

Interinstitutional cooperation will help us reach our goals within available resources. Existing institutions have expertise in different aspects of sustainability, but each operates within a compartmentalized framework, not reflecting the links between environment and development. Consequently, most policies are designed without considering their effects on natural resources.

But no institution can effectively address all dimensions. Sustainable agriculture emphasizes interdependencies, and that requires broad-based collaboration. Thus, different institutions must focus on agreed research agendas that foster complementarity. Mechanisms should encourage and facilitate collaboration among national, regional, and international research systems.

We see two *mechanisms* linking institutions vertically and horizontally. *Vertical* linkages will be used to integrate research and development efforts at ecosystem and farm levels. These efforts will be carried out in specific geographic areas, where interactions can be recognized and investigated. We will collaborate through consortia of institutions operating at various levels, ranging from farm production to policy planning.

The active participation of all consortia members in the identification, planning, implementation, and evaluation of R & D activities is key to this vertical mechanism. CIAT plans two contributions to consortia activities. First, we will assume research responsibilities based on our comparative advantages, identified through joint planning with consortia partners. Second, if partners so desire, CIAT will act as a convener, catalyzer, and facilitator.

Horizontal linkages have a double purpose. First, they should systematically capture across the agroecosystem the rich variety of existing indigenous and exotic knowledge through cross-sectional and longitudinal studies that analyze the agroecological and socioeconomic rationale vis-à-vis the development of improved land use alternatives. Second, this type of mechanism will facilitate information sharing and discussion of issues relevant to sustainable research management within the agroecosystem. Agroecosystem databases and publication of newsletters will be key media; training and communications will be essential to strengthen institutional capabilities. CIAT's role will be to organize and coordinate the resulting network, including the development of project databases and publication of newsletters.

Organizational Structure

Four programs will develop two approaches:

The Agroecosystem Programs will study agroecological and socioeconomic trends in farming systems of three agroecosystems, to identify strategic issues in, and carry out research on technologies for, sustainable agricultural development.

The Land Use Program contributes to the development of alternative land use patterns that optimize social returns under different trade-off scenarios between production and conservation. Such patterns will emerge from analyses of how policy instruments influence farmers' land use decisions and their consequences on resource productivity and degradation.

Outputs of land use studies will be used by the Agroecosystem and Germplasm Programs to generate component technologies and corresponding management practices, adapted to designed land use options. The Land Use and Agroecosystem Programs are complemented by Germplasm Programs to increase the biological limits and efficiency of commodities and the management implications of potential technological changes.

Each approach will have scientists in headquarter-based (HQ) and area-based teams (A), operating in selected geographic areas. The HQ teams will work mainly through horizontal mechanisms in the analysis of data from different areas to identify patterns and develop principles. The A teams and associated partners in the area-based consortia will work mostly through vertical mechanisms, to conduct field research and development studies on alternative production systems and corresponding social organizations.

Area-based research on farm level issues will also serve four other purposes. First, it will provide target areas for an integrated approach to land use among CIAT and partner institutions. Second, such study areas will be experimental grounds for both central and complementary teams to test methodologies and to acquire hands-on biophysical and socioeconomic research experience. Third, the study areas will provide location-specific data on research and development links fundamental to the building of databases. Fourth, they will serve as "role model" sites for complementary research programs, and provide a training ground for interinstitutional teams who wish to follow a similar approach in other agroecosystems.

In summary, program scientists assigned to HQ teams will conduct research at the agroecosystem level, and those on A teams at the area level. The study area scientists will team up with other consortium scientists from national and international institutions to implement joint projects.

CIAT's comparative advantages in resource management research will then be developed through complementary efforts of Land Use, Agroecosystem, and Germplasm Programs. Social scientists from all three types of programs will use a working group mechanism to develop projects on "technology needs" issues of common interest around policy and farmer decision-making research. For example, for the soil-plant focus in "technology option" issues, soil scientists in the Agroecosystem Programs and plant nutritionists in the Germplasm Programs will devote part of their time to common projects, developed by a working group on integrated nutrient management.

The Resource Management Research Division is directed by the Deputy Director General (Resource Management). The financial resources assigned to that office are listed in Tables on p. 95 and 97 as "Research Management" under the rubric "Resource Management."

The Deputy Director General (Resource Management) also directs and coordinates the use of the financial resources in the area of Resource Management Research referred to as "Strategic Research Initiatives" (see Tables on p. 95 and 97). These resources are meant to support new strategic initiatives. The majority of such initiatives are to be carried out as inter-program research projects. In this form, new research initiatives will further foster the integration of efforts within and across the two research divisions. Most projects funded through the mechanism of "Strategic Research Initiatives" are likely to include collaborative arrangements with advanced research institutions.

Agroecosystem Programs

Although each program will focus on a particular ecosystem with its own objectives, the program teams will follow a common methodological approach to developing prototypes of production systems for sustainable agricultural development. This common approach will combine farm experimentation in selected study areas (micro-basins) with specific observations from projects associated in a network across agroecosystems. Site-specific experimentation and observations will produce empirical agroecological and socioeconomic data on research and development issues. These data and those from associated projects will be incorporated into agroecosystem databases. These will be used through GIS to study the relationships among field studies and to test hypotheses on the impact of land use on production and conservation at different levels of aggregation.

Objectives

Each of the three Agroecosystem Programs and the Land Use Program has its own specific objectives (see Box 4), which are highly complementary and closely interlinked with those of other CIAT programs. These objectives should also complement those of sister centers, particularly those working in forestry and agroforestry.

Activities

At headquarters, the program teams will:

Develop and test methodologies for "technology option" studies with emphasis on policy/farmer decision-making relationships vis-à-vis technology design, and on plant-soil relationships in multispecies systems on acid soils, thereby providing feedback to ongoing research in area-based consortia.

Analyze data obtained from research and development activities in sites operating under contrasting circumstances. Patterns can thus be identified from which principles can be derived.

Promote effective and efficient interinstitutional collaboration. True partnership will be based on shared objectives, work plans embodied in feasible research agendas, responsive communication systems, and effective leadership and coordination.

Provide information to interested parties to help develop sustainable production systems compatible with alternative land use strategies.

Area-based activities will complement those developed by consortia partners working on a common research agenda. Activities for each area-based research program will be carried out in four main stages: (1) characterization of land use systems; (2) selection of research study areas; (3) diagnosis of land use systems and identification of management alternatives; and (4) generation of prototype technologies. Although these four stages are presented in a logical sequence, they, nevertheless, form a dynamic and iterative process. Because available knowledge for each stage differs across ecosystems, timing of efforts to achieve expected outputs will differ. Although activities under Stage 4 will be initiated within this planning period, they will certainly extend to the next period.

Stage 1. Characterize land use systems.

The first step toward identifying and designing sustainable production alternatives is to characterize existing farming systems in terms of productivity, equity, and conservation. Primary data and published and secondary information will be collected, analyzed, and interpreted. Particular reference will be given to existing constraints and opportunities for system intervention.

Land use inventories within agroecosystems have been built upon the agroecozone characterization work already done by the Agroecological Studies Unit for CIAT's strategic planning exercise. The most important land use systems within those agroecosystems have also been further characterized by combining information on land units (set by the physical environment) with that on management units (production objectives and resources). Institutions and/or projects operating in each agroecozone have also been identified.

Based on such developments, the process of selecting research study areas has been initiated in all three agroecosystems.

Stage 2. Select research study areas.

Because land use studies examine both the ecological and developmental implications of technologies on the environment, research areas must include several farms within a catchment context. Their selection would be guided by a set of criteria worked out with partner institutions, who, in turn, must be identified.

Logistics indicate that only two research areas can be selected for each agroecosystem. They should comprise a minimal number of contrasting situations, depending on differing pressures on the resource base, farmers' responses to these pressures, and available technologies. Because CIAT is international in nature, the sites for each agroecosystem will be located in at least two different countries.

Existing stations managed by national partner institutions may be used as experimental sites. Although major investments will be avoided, additional capital will be required to adapt or improve facilities at these stations.

As a result of activities developed in 1991-1992, the selection process has advanced in all three agroecosystems:

Hillsides. CIAT and its partners in the Central America Sustainable Agriculture Consortium (CATIE, CIMMYT, IICA, IUCN) are selecting research sites for future collaborative projects in the region. The consortium's team has already visited watersheds and micro-watersheds in Panama, Costa Rica, Nicaragua, and Honduras. A comparative analysis led to the preselection of three areas in the northern Atlantic coast of Honduras (linked to the San Juan River Basin in Nicaragua), the Yajoa watershed in Honduras, and the Bayano watershed in Panama. Interinstitutional teams are now preparing preliminary proposals.

Forest Margins. The consortium, in conjunction with EMBRAPA, has chosen two broad regions in Brazil: one within the Amazon region of eastern Pará, and the other straddling Acre and Rondônia states. Both areas are characterized by slash-and-burn agriculture, extensive cattle grazing, and logging. However, the histories of settlement and land distribution are different and offer important contrasts in problems and potential solutions.

Savannas. As part of a joint effort between CIAT and EMBRAPA, 12 potential areas in five Brazilian states in the Cerrados have been identified and their representativeness assessed. Some are being selected for further diagnosis to develop research plans.

Stage 3. Diagnose land use systems and identify management alternatives.

To remove constraints through improved production systems and/or new land patterns means designing appropriate technologies. However, methodologies for identifying indicators of private and social costs and benefits of such systems must be developed if improved production systems and land use patterns are to reduce the frequent conflicts between social and private interests.

This stage aims to assess farming systems problems and opportunities and, consequently, to develop hypotheses for more sustainable land use patterns and corresponding production systems (see Box 4). Activities will involve:

Rapid exploratory appraisals to develop simple, empirical models for *ex ante* analysis of alternative farming/land use systems.

Analysis of the various technological components in production alternatives in order to understand their effects on soil/plant interactions.

Workshops on each ecosystem, with participation from partner institutions, including local organizations, to discuss problems and opportunities of agroecosystems research. The purpose would be to identify alternative research approaches, common hypotheses and research agendas, appropriate divisions of labor, and potential experimental sites.

Preparation of interinstitutional research projects for submission to appropriate donors.

Stage 4. Generate prototype technologies.

Through concerted efforts with partner institutions, CIAT can generate prototype production systems. As mentioned before, CIAT's comparative advantage lies in strategic research aimed at understanding soil/water/plant relationships and farmer behavioral patterns. Its activities would therefore include those required to document:

Changes in the dynamics of nutrient cycling and plant growth according to production systems, management practices, and land use intensity.

Land allocation patterns within and across farms in catchment areas under different land use intensities to design sustainable systems for various land forms and user groups.

Specific activities to be carried out by CIAT in area-based research will be defined jointly with partners, including those from national systems, sister centers, NGOs, and international programs of extra-regional universities.

Headquarter-based teams will not only contribute to activities related to the four outlined stages in area-based research, but will also identify relevant ongoing research projects in the agroecosystem, with the objective of building research networks. These networks would focus their activities on incorporating available information into research databases. They would be used for agroecosystem-wide analyses of production systems and

Box 4. Objectives of the Land Use and Agroecosystem Programs.

Hillsides	Forest Margins	Savannas	Land Use
1. Characterize the mechanisms leading to resource degradation and assess technological options.	1. Assess the possible social and environmental impact of technological innovation on shifting cultivation.	1. Identify key agricultural sustainability problems and development opportunities in the acid-soil savannas.	1. Understand the dynamics of land use.
2. Generate agroecologically and economically viable components, acceptable to farmers, for soil and water conservation and management practices.	2. Reduce the destructive effects of shifting cultivation.	2. Design technological interventions tailored to savanna environments to increase productivity, while preventing or reversing resource degradation.	2. Appraise policy alternatives for improved land use.
3. Strengthen the capacity of national systems to generate and transfer resource-enhancing technology.	3. Assist in the development of improved land use strategies in humid forest areas.	3. Understand the biophysical aspects of savanna production systems and their management for sustainable production.	3. Assess the impact on land use of new technologies and policies.
	4. Strengthen national capabilities for improving forest-margin production systems.	4. Strengthen national capacities for designing and monitoring savanna production systems.	4. Strengthen national capacity to improve land resource management.

SOURCE: *CIAT in the 1990s and Beyond: A Strategic Plan* corresponding agroecological and socioeconomic processes, to derive principles in the form of stochastic and deterministic models.

Expected Outputs

As a result of these and complementary activities carried out by partners, outputs are expected to be delivered in three 3-year phases.

Phase 1 outputs

On-farm evaluation of the productive potential, cultural acceptability, and economic viability of "best-bet" technologies aimed at arresting land degradation while being compatible with socioeconomic and agroecological constraints and opportunities.

Agroecosystem-wide networks of relevant research projects.

Initiation of measurement of sustainability indicators and strategic coefficients for the understanding of agroecological processes.

Mechanisms that (1) link, in a complementary fashion, institutions involved in adaptive, applied, and strategic research; and (2) link these institutions with those responsible for designing land use strategies and corresponding policy incentives.

Phase 2 outputs

Assessment of the potential social and environmental impacts of tested technologies in selected study areas (e.g., income levels and employment opportunities, deforestation and soil degradation rates). This will be accompanied by improvements in "appropriate" technologies, according to feedback on farmer acceptability and agroecological soundness.

Agroecosystem-wide databases in agroecological and socioeconomic processes.

Establishment of relationships between sustainable indicators and agroecological processes.

Organizational schemes to facilitate the development and application of land management strategies at the micro-basin or catchment level. These schemes should be linked with regional and national bodies responsible for land use policy design and implementation. Operational information and training mechanisms would be developed to disseminate the approach across the agroecosystem networks.

Phase 3 outputs

Models of agroecological relationships that would predict the sustainability of alternative land use strategies and corresponding technologies under different scenarios, based on an understanding of bioeconomic processes. Widespread dissemination of sustainable systems in study areas.

Operational structures responsible for the development and management of sustainable land use systems in the study areas, along with organizational schemes in other areas of the agroecosystem network.

In terms of actual *impact* upon land degradation, by the end of Phase 2, degradation trends should be visibly declining in the study areas. The new policy/technology approach should have set in motion new environment-friendly land use patterns and production technologies. Similar approaches are expected to be initiated in other areas across the agroecosystem. At the end of Phase 3, land use in the selected areas should have reached a new equilibrium, compatible with sustainable development.

Team Composition

A "standard" composition for core teams in the Agroecosystem Programs should include a social scientist specialized in farmer decision-making processes and two specialists in integrated nutrient management: one in multispecies systems, and one in nutrient cycling. Complementary site-based teams will depend on the contribution of partner institutions and on project execution phase.

Team leaders have already been recruited for the three programs, and specialists for the central teams will be appointed early in 1993.

Resource Allocation and Requirements

Tables 10 to 12 show the core Senior Staff positions scheduled to execute the operational plan of the three programs during 1993-1998, and the costs associated with the various research sections.

Description of Senior Staff Positions[1]

Office of Leaders. Guide and coordinate design and implementation of research on farming systems at the agroecosystem level; promote and coordinate multidisciplinary and interinstitutional activities; and establish links with the Land Use and Commodity Programs and with other institutions.

[1] Common to the three programs, except as indicated.

Multispecies production systems, Forest Margins and Hillsides. Studies the contribution of selected crops to the performance of alternative production systems and their requirements, and identifies appropriate niches within alternative systems; studies the ecological compatibility among components in multispecies systems; and participates in selected, highly focused strategic research on soil/plant relations in production systems.

Soils management, Forest Margins. Studies physicochemical soil dynamics under a variety of cropping systems and agronomic practices; and determines long-term trends in organic matter, mineral nutrients, and soil structure in terms of viability of sustainable systems.

Soils management, Hillsides. Studies physicochemical soil dynamics under different management techniques; and determines long-term trends in organic matter, nutrients, and soil structure, with particular attention to erosion control.

Nitrogen cycling, Savannas. Studies nitrogen cycling in tropical acid soils as an essential component of sustainable production where inputs are restricted; determines efficiency of nitrogen fixation and nitrogen losses in tropical production systems in order to

Table 10. Forest Margins Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Office of Leader	1	300	1	300	1	300	1	300	1	300	1	300	1	300
Soils management/organic matter	–	–	1	200	1	200	1	200	1	200	1	200	1	200
Production systems	–	–	1	200	1	200	1	200	1	200	1	200	1	200
Anthropology	–	–	1	200	1	200	1	200	1	200	1	200	1	200
Total	1	300	4	900	4	900	4	900	4	900	4	900	4	900

Table 11. Hillsides Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Office of Leader	1	300	1	300	1	300	1	300	1	300	1	300	1	300
Soils management	–	–	1	230	1	230	1	230	1	230	1	230	1	230
Sociology/Anthropology	–	–	1	200	1	200	1	200	1	200	1	200	1	200
Production systems	–	–	1	200	1	200	1	200	1	200	1	200	1	200
Total	1	300	4	930	4	930	4	930	4	930	4	930	4	930

Table 12. Savannas Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Off. of Leader (C/P/L systems)	1	360	1	360	1	360	1	360	1	360	1	360	1	360
Crop/pasture syst.: Cerrados	1	230	1	230	1	230	1	230	1	230	1	230	1	230
Nitrogen cycling	1	230	1	230	1	230	1	230	1	230	1	230	1	230
Nutrient cycling	1	230	1	230	1	230	1	230	1	230	1	230	1	230
Ecophysiology	1	230	1	230	1	230	1	230	1	230	1	230	1	230
Farming systems economics	0.5	120	0.5	120	0.5	120	0.5	120	0.5	120	0.5	120	0.5	120
Llanos–based research	–	–	–	100	–	100	–	100	–	100	–	100	–	100
Total	5.5	1,400	5.5	1,500	5.5	1,500	5.5	1,500	5.5	1,500	5.5	1,500	5.5	1,500

design stable, economically viable systems; studies processes that control biological fixation, sizes of nitrogen pools in soils and plants, and the fluxes among them; and determines the effects of cropping sequences--particularly transfer of legume nitrogen to nonleguminous crops--and of strategic applications of fertilizer nitrogen to crops in the nitrogen cycle, particularly the effects on the fixation process.

Nutrient cycling, Savannas. Studies mechanisms of nutrient cycling in contrasting cropping systems, particularly phosphorus; evaluates nutrient pools and fluxes under contrasting soil systems, crop-pasture rotations, input levels, and crop sequences; and develops and adjusts methodologies and techniques for nutrient-cycling research.

Ecophysiology, Savannas. Studies factors influencing relations among plants and their changes caused by variations in soil and aerial environments, especially in perennial agropastoral and silvopastoral systems. Seeks to understand the physiological processes responsible; and, based on this understanding, develops models, in association with other team specialists, to predict the outcome of particular management strategies.

Crop/Pasture livestock systems, Savannas (Llanos and Cerrados). Collaborates in the design and implementation of characterization studies, and elaborates appropriate database management tools; and, with other team specialists, develops simulation models to describe and test alternative farming systems.

Anthropology, Forest Margins and Hillsides. Collaborates in multidisciplinary characterization of farming systems, particularly of decision-making processes at farm level under different land use intensities; assists in the identification of socioeconomic research priorities; and contributes to participatory design and testing of alternative farming systems with emphasis on management implications of new technologies.

Economics, Savannas. Studies economic performance of alternative farming systems; contributes to development and testing of appropriate models; participates in multidisciplinary characterization of farming system, and their microeconomic, market, and other constraints, and helps prioritize alternative research strategies; and collaborates in the design and testing of bioeconomic research at the farming system level.

Land Use Program

Goal

To contribute to the lasting productivity of land resources in tropical America, and to provide critical inputs to CIAT's Agroecosystem and Germplasm Research Programs. This will be achieved by improving the understanding of the impact of human activities on the resource base and, consequently, formulating appropriate policies and technologies.

Objectives

Objective 1. Understand the dynamics of land use in tropical America

Land use in tropical America is extraordinarily dynamic. Its patterns are continually altered by frontier settlement, disturbance of natural environments, introduction of new crops and technologies, massive population movements, and rapid economic change. These patterns have not been systematically characterized, and neither are the reasons for rates and directions of change well understood.

Activity 1. Identify land use patterns and problems.

Land use over time, the physical environment, the development of economic infrastructure, and demographic pressures will be characterized, with strong emphasis on developing geographical information systems. The existing CIAT agroecological database on tropical climates, soils, and crops will be expanded, making use of primary and secondary data and remote sensing.

The program will assist the Agroecosystem Programs to select regions for case studies and to prioritize problems across agroecosystems. It will also assist germplasm development programs in agroecological analysis, to define environmental homologues, and to develop selection criteria for germplasm development.

Activity 2. Analyze causal relations among agricultural technology, socioeconomic trends, policy, and land use.

Geographical and economic modeling will be used to trace the historical determinants of land use patterns, and to assess the following factors: the influence of the physical resource base on land use, changes in production technology, development of infrastructure, direct land tenure policies, and indirect policies such as exchange rates.

This research will help evaluate the relative importance of factors determining land use and the optimal methods for modifying it. Priority will be given to the Agroecosystem Programs' target regions.

Activity 3. Measure social costs of land use practices.

A broad range of existing land use practices are degrading natural resources, resulting in widely varying social costs at highly variable rates. The program will examine these practices and the discrepancies among values for social and private use of natural resources. These studies will show which natural resources are at greatest risk and which land use practices are the most deleterious. They will suggest where interventions are most needed to adjust imbalances between social and private costs. Conventional economic evaluation of resources will need to be complemented with innovative measurements of environmental impact. Results will help prioritize research issues in the Agroecosystem Programs.

Objective 2. Appraise policy alternatives for improved land use

Policy is often crucial in determining resource use, for example, it determines access to natural resources and influences the level of return to private exploitation of land resources. Much of the policy affecting resource use is framed within objectives that lead to unexpected and unintended land use. Attention will therefore be paid to policies that regulate access to land and affect prices, credit, and infrastructure investment.

Activity 1. Conduct comparative and historical studies of policy impact on land use.

To obtain insight into relationships between policy and land use, inter-country comparisons will be carried out. Themes will include policy impact on land use and technology adoption, and impact over time of different policies on the same environment.

Understanding the behavior and objectives of farmers as land resource managers will help clarify the links between policy and resource use. Likewise, agricultural technology has a major impact on land use, and policy is often key in determining the economic advantages of alternative technologies.

Policies must be understood, not only for their impact on land use, but also in terms of the socioeconomic forces underpinning them. Because socioeconomic factors may be more important than land use outcomes to policy makers, such factors must be taken into account when devising sound land use policies.

Spatial models will be developed to reflect the costs and benefits of policy and technology alternatives. These models will require innovative interdisciplinary inputs to integrate crop and farm systems with regional environmental impact and socioeconomic variables.

Activity 2. Support national and regional entities to design alternative land use outcomes.

Both natural resource management and agricultural policy institutions are responsible for policies affecting land use. The program will identify institutions interested in participating in land use policy studies. Although the program will not make policy recommendations, it will focus on methodologies to assist national policy analysts in presenting policy makers with a range of options and assessment of their probable impact on land use. Different policy implications for technology design and transfer will be examined, particularly in reference to the environmental impact of agricultural production.

Objective 3. Assess the impact of new technologies and policies on land use

New crops, plant varieties, management practices, and spatial and temporal arrangements of production systems greatly influence land use and resource degradation. Agricultural production techniques have been changing rapidly in tropical America, with minimal attention to their impact on the resource base. Thus ongoing research to increase agricultural productivity should take into account the ecological impact of new technology.

Activity 1. Orient design of new agricultural technology to optimize land use practices.

Through its studies on land use trends and social costs of existing land use practices, the program will assist in designing parameters for new agricultural technology. It will work with the Agroecosystem and Germplasm Programs and national research institutions to evaluate the expected environmental impact of prototype technologies and to ensure that they not only increase productivity but also conserve the resource base.

Activity 2. Monitor effects of new technologies on the resource base.

Ex ante assessment of the impact of new technology on natural resources is a highly imperfect art. In the context of rapid technical change, the program will assist in adoption studies of new technology, focusing on changes in land use patterns and environmental impact within a regional framework.

Objective 4. Strengthen national capacity to improve land resource management

Land in tropical America is the resource on which people depend for their well-being. Consequently, to ensure sound management of the region's land resources, the institutions and people of tropical America must enhance their capacity to manage technical and socioeconomic change.

Activity 1. Develop human and institutional resources through collaborative research and information exchange.

Most research will be carried out by the program in collaboration with national institutions. All partners will have distinct comparative advantages, and all will profit from working together. The program will conduct strategic research to establish priority issues and develop methodologies, whereas national partners will focus on solving country-specific problems. The program will encourage the national programs to exchange lessons learned from these collaborative experiences.

Activity 2. Facilitate articulation among agricultural research, resource management, and policy institutions.

Land use is affected by the actions of many entities, which are often not coordinated with each other. Information exchange through workshops, publications, and other media will help bring together the major actors in land use--both to increase their understanding of the complex issues involved and to provide a forum for initiating actions to solve common problems.

Team Composition

Team composition is based on the research priorities described under "CIAT's Role in Resource Management Research" (p. 48). Thus, the composition of the central Land Use team will reflect needs for specialists in agricultural production, environmental degradation, economics, sociology, policies, and decision support systems. "Counterparts" in the area-based teams will complement this research; their specialization will depend on the main land use problems in each study area.

Resource Allocation and Requirements

Senior Staff positions and the costs associated with the various core research sections appear in Table 13.

Description of Senior Staff Positions

Office of Leader. Provides overall guidance and coordination in identifying research priorities to develop working plans with the interdisciplinary team; develops and implements interinstitutional strategy for land use analysis in national and regional institutions; and coordinates with other CIAT units.

Agricultural land use. Assesses patterns of agricultural land use over space and time; characterizes relations between changes in agricultural technology and land use; and monitors technical change and its impact on land use dynamics. The specialist will need sufficient practical knowledge of agricultural production to interact with agronomists in the Agroecosystem Programs.

Environmental impact economics. Appraises the regional effect of changes in agricultural technology and land use on environment from an aggregate, social perspective; monitors environmental impact of new technologies; and orients technology design away from ecological degradation.

Information management. Manages and integrates unified GIS databases, including environmental variables (climate, soils, vegetation), agricultural variables (crop and land use distribution, technology, rotations, input levels), economic variables (infrastructure, transport costs, land, and other factor costs), and social variables (human settlement, migration, population growth); develops systems to merge these databases at different levels of aggregation for analysis, ranging from continental to local; and contributes to studies on relationships of these environmental variables with land use patterns.

Resource economics. Analyzes land use patterns from an economic perspective, focusing on influence of land prices and infrastructure development on land use; assesses social costs of resource degradation under varying

Table 13. Land Use Program. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Office of Leader (Land use policy)	1	300	1	300	1	300	1	300	1	300	1	300	1	300
Agricultural land use	1	230	1	230	1	230	1	230	1	230	1	230	1	230
Environm. impact economics	–	–	1	200	1	200	1	200	1	200	1	200	1	200
GIS/Information management	1	200	1	200	1	200	1	200	1	200	1	200	1	200
Resource economics	–	–	–	50	–	70	1	150	1	150	1	150	1	150
Sociology	–	40	–	50	1	150	1	150	1	150	1	150	1	150
Total	3	770	4	1,030	5	1,150	6	1,230	6	1,230	6	1,230	6	1,230

land uses and agricultural technologies; and identifies regional comparative advantages.

Economic policy. Studies effects of policies--including taxation, credit, infrastructure investment, and subsidies--on land use patterns and agricultural technology; and appraises effect of alternative policy scenarios on land use patterns. This specialist is not included in the core budget as he or she will come from IFPRI.

Sociology. Analyzes relationships among social variables (migration, settlement, urbanization, demography, population growth), land use patterns, and agricultural technologies; and develops database systems on social variables so to understand their effect on resource use and degradation.

Land use policy. Distinguished decision makers and/or researchers will be invited, in the capacity of visiting senior fellow, to study for one year the politics of decision making behind policies related to land use patterns. Complementary funding will be sought for this activity.

Expected Outputs

The information and analysis generated by the Land Use Program's research is an intermediate output, that is, it will be used by the Agroecosystem and Commodity Programs and sister institutions (e.g., ICRAF, CIFOR), and for policy formulation. Within the next 6 years, the Program therefore expects to prioritize problems and select sites for the Agroecosystem Programs; collect information and develop analytical models of trends in land use management of selected agroecosystems with particular emphasis on zones where area-based research is located; improve understanding of policy options; and improve the efficiency of national institutions working on land use issues in resource management.

The specific outputs expected for the Program's four objectives are as follows:

Objective 1. Understand the dynamics of land use in tropical America

Improved understanding of interactions between human activities and the land resource base, with emphasis on zones where area-based research is located.

Better appreciation of social and environmental costs of alternative land resource uses in those zones.

Methodological frameworks and information for further land use studies.

Objective 2. Appraise policy alternatives for improved land use

Improved understanding of policy impact on land use, with emphasis on zones where area-based research is located.

Development of alternative policy scenarios to improve land use management in those zones.

Objective 3. Assess the impact of new technologies and policies on land use

Improved understanding of the implications of technical change for natural resources.

Contributions to the design of technology for sound land use.

Objective 4. Strengthen national capacity to improve land resource management

Strengthened institutional capacity for land use analysis and management.

Tighter linkages among institutions influencing land use.

Complementary Activities

Outlined area-based research in each agroecosystem is considered as complementary. The composition of complementary teams will depend on the strengths and weaknesses of consortia members. CIAT may develop complementary projects and recruit in research fields other than those viewed as comparatively advantageous, if weaknesses in consortia demand temporary "gap filling." Examples of these are specialists in silviculture, forest management, land use policy, forest policy, agroforestry, and on selected crops highly relevant to the Agroecosystems Programs. However, sister institutions (e.g., ICRAF, CIFOR, IFPRI, ICRISAT, IFDC, and IBSRAM) will probably wish to enhance the effectiveness of their own programs by deploying staff to integrate their research with that of other partners in the consortia-sponsored area projects. Table 14 depicts the proposed CIAT complementary projects to conduct relevant strategic research within the consortia-sponsored area projects, reinforce feedback to HQ strategic research, and strengthen links and support for national programs. Although defining specific expertise is premature at this moment of writing the plan, a minimum of three experts per agroecosystem may be required. These requirements, those of ongoing projects, and network coordinators for the Hillsides and Savannas Programs are shown in Table 14.

Table 14. Resource Management Division. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Forest margins area projects	–	–	2	350	3	550	3	550	3	550	3	550	3	550
Hillsides area projects	–	–	2	350	3	550	3	550	3	550	3	550	3	550
Network coordination:														
Hillsides	–	–	–	–	1	150	1	250	1	250	1	250	1	250
Savannas	–	–	–	–	1	150	1	250	1	250	1	250	1	250
Hillsides:														
Integrated crop/soil management	–	130	1	130	1	130	1	130	1	130	1	130	1	130
Savannas:														
Improved native grassland	1	65	1	65	1	65	–	–	–	–	–	–	–	–
Total	**1**	**195**	**6**	**895**	**10**	**1,595**	**9**	**1,730**	**9**	**1,730**	**9**	**1,730**	**9**	**1,730**

INSTITUTIONAL DEVELOPMENT

CIAT's Strategic Plan for the 1990s describes two interrelated perspectives of the center's approach to technology development. They are an increased emphasis on the production systems in which agricultural development occurs; and the realization that integrated solution models require the participation of many actors. In the case of commodity research, the systems perspective focuses on germplasm development and component technologies for specific agroecological production environments. In the case of resource management research, this perspective focuses on selected, important agroecosystems within which resource management problems can be coherently approached. The second perspective implies that technology generation is a highly participatory endeavor in which interinstitutional coordination and mutual support are as important as the research activities themselves.

CIAT is in a unique position as an international research organization to assume strong leadership, not only in high-priority research but also in providing an international focus for other institutions' research. By contributing appropriate platforms, CIAT can make it possible for international centers and national and regional programs to contribute their energies and expertise in a collaborative fashion to well-defined research agendas.

Consequently, the Center plans to contribute to interinstitutional work through roles that would advocate the need for research and development in CIAT's commodity and agroecosystem domains; develop international information support mechanisms; and provide training in areas of CIAT's research.

Although the various institutional development roles are assumed by the respective research programs and the Center as a whole, a well-defined support program--described below--assists them to exercise these roles effectively.

Institutional Development Support (IDS)

Goal

To assist CIAT's research programs in strengthening the capacity and increasing the efficiency of national and regional research systems to contribute to sustainable agriculture.

Strategies

Strategy 1. Strengthen national research institutions by providing advanced training for scientists and delivering specialized information through documentation systems, library-based services, and publications.

Strategy 2. Enhance the efficiency of national research systems and facilitate their linkages with development activities through multi-institutional collaborative projects.

Strategy 3. Contribute to the formation and strengthening of national and regional training organizations to train professionals dedicated to commodity production and adaptive research.

Activities

Activity 1. Training.

The aim is to move gradually from a general to a specialized focus, that is, introductory research training will be phased out as it is taken over by national or regional institutions with the support of Activity 2. At the same time, individualized training at headquarters will become highly specialized, focusing on mid-career scientists, and master's and doctoral candidates. As many as 100 such trainees would be expected every year once the shift from introductory to advanced research training is accomplished.

Group training will also become more advanced and specialized. The number of courses will decrease from the current five to two or three advanced courses per year, involving as many as 60 participants.

Activity 2. Training of trainers.

With respect to Strategy 3, the objective is to phase out training of technology intermediaries and entry-level researchers. A two-pronged approach will be followed: encouraging institutionalization of national and regional training bodies for entry-level researchers and technology intermediaries; and training trainers in research and production methods, course organization, and adult education. These efforts will be accompanied by the development of training materials to be used by the new trainers.

A major effort in training trainers is already under way. It focuses on commodity-specific training programs at subregional levels where a cadre of commodity specialists exists and there is political support for such efforts. This is the case for Central America and the Caribbean for beans, the northern Andes for rice, and the Southern Cone for cassava.

Activity 3. Conferences.

Conferences are a major tool for facilitating interactions among CIAT, its partners, and other stakeholders through information exchange, discussion of research issues, and interinstitutional cooperation. The program's support for conferences includes planning, logistics, and assistance in facilitating participant interaction.

During the last decade, CIAT held an average of four "large" and four "small" conferences per year, each with approximately 80 and 15 participants, respectively. During the planning period, the number of conferences for the Germplasm Development Division is likely to be unchanged. A reduction in applied and adaptive research meetings will be offset by an increase in advanced research network meetings. In addition, the Resource Management Research Division will convene about eight working meetings per year.

Core funds will cover only the salaries of a minimum cadre of conferences support staff plus "seed money" for the first steps toward the organization of conferences. Complementary sources will be sought to meet the remaining funding needs (see p. 68-69).

Activity 4. Communications.

Information gathering and dissemination are, respectively, an input to and an output of CIAT's program strategies. Communication media production for both purposes is the responsibility of the IDS. The main communication objective will be to serve a larger and more diversified audience with products targeted to specific audience subgroups.

New members are joining the germplasm development research audience: natural resource researchers, technology intermediaries, and professionals in higher education. In addition, CIAT's shareholders, national and international decision makers, and public opinion groups at large must be informed of the Center's activities with a view to sustaining and strengthening their favorable attitudes toward CIAT.

The contents of communication media will include, *inter alia*, consolidated research results, research methods, sustainable agriculture, management characteristics of technologies, seed-embodied technologies, collaborative research activities, and scientific events. Formats and types of communication media will include bulletins, monographs, reports, manuals, proceedings, catalogs, newsletters, audiovisual units, videotapes, and diskettes.

Activity 5. Bibliographic information services.

Rapid access to worldwide bibliographic information is essential for CIAT scientists: this is the central responsibility of the program's Information Unit. These services are shared with national program colleagues, thus contributing to Strategies 1 and 2. Other contributions are networking with national program libraries, training their staff in advanced information management, and assisting national program scientists in accessing bibliographic sources.

CIAT's bibliographic information services have been recently modernized. Future activities will seek to keep CIAT at the forefront of information management developments; to further facilitate access by national program members to CIAT's information resources; and to enhance national program information systems through networking, training, and role modeling.

Information products and services are current awareness publications (on paper or diskette); national, germplasm development-oriented bibliographies; quick bibliographies on current germplasm development-related topics of interest; bibliographic searches in the Center's databases (CATAL, CINFOS, SERIAD) and CD-ROM databases; worldwide on-line searches in external databases; and photocopying services.

Activity 6. Support through interinstitutional mechanisms.

CIAT has a strong record of successful networking and interinstitutional cooperation. Collaboration in this area will increase, particularly in resource management research.

Interinstitutional efforts will be supported by the IDS with partner identification, project design, and establishment of effective interinstitutional linkages. Each collaborative project will therefore receive enhanced performance planning and monitoring that will contribute to increasing the project's accountability. Interinstitutional projects will be used as training grounds for national program scientists and decision makers.

To support interinstitutional activities, the IDS has set up a Project Design Office, led by a project design and development specialist.

Activity 7. Institutional information system.

To support the program's strategies, an information system on partner and collaborating institutions is being established. This system will also assist other CIAT programs' collaborative efforts and help prioritize and target the Center's institutional development activities. The system, which will be built upon existing databases and with the cooperation of other programs and units, should be fully operational by 1994.

Resource Allocation and Requirements

Senior Staff positions scheduled for the execution of the operational plan of Institutional Development Support during 1993-1998, and the costs associated with the various operational sections, appear in Table 15. A summary description of each Senior Staff position proposed for the planning period follows.

Description of Senior Staff Positions

Associate Director for Institutional Relations. This position has two roles: (1) to provide continuity to interinstitutional agreements and arrangements, and to represent CIAT

Table 15. Institutional Development Support. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

Senior Staff Position	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Associate Director for institutional relations	1	228	1	228	1	228	1	228	1	228	1	228	1	228
Professional development	–	460	–	460	–	460	–	460	–	460	–	460	–	460
Conferences	–	240	–	240	–	240	–	240	–	240	–	240	–	240
Information and documentation	1	585	1	550	1	550	1	550	1	550	1	550	1	550
Communication/Public affairs	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031
Project design [a]	1	–	1	–	1	–	1	–	1	–	1	–	1	–
Other	–	368	–	–	–	–	–	–	–	–	–	–	–	–
Total	5	2,912	5	2,509	5	2,509	5	2,509	5	2,509	5	2,509	5	2,509

a. Paid from indirect costs recovery.

before other institutions; and (2) to provide leadership and assume responsibility for IDS activities, which are carried out in close collaboration with CIAT's research programs and units. Coordinates postgraduate training and training in adult education, group dynamics, and interpersonal communication skills; and oversees support to CIAT conferences.

Communications and Public Affairs Unit:

The Unit will have the following staff:

Unit Head. Designs and implements information strategies aimed at promoting CIAT's research among the Center's shareholders and relevant policy-making groups; and oversees the development, production, and distribution of CIAT's research information output.

Science Information. Produces CIAT's research information products.

Information and documentation. Maintains cost-effective bibliographic information services at the technological forefront.

Project design. Provides expertise on project design and development.

Complementary Activity

CIAT will seek special project funds to undertake a major effort in support of Strategy 1 and corresponding activities, particularly those of training trainers. This effort aims to consolidate national programs' capacity to train their entry-level researchers and technology transfer cadres. The resulting training teams will undertake responsibilities traditionally carried out by CIAT staff, thus relieving the Center of a heavy training load.

This activity will be jointly carried out by CIAT and collaborating research and development institutions. It seeks to identify and analyze national and regional training needs and resources for technology transfer; provide groups of qualified professionals with opportunities for training in the planning, execution, and evaluation of training programs and events for technology transfer personnel; and follow up and evaluate the ultimate effect of such training on agronomic practices by farmers and technology transfer agents. The proposed budget for this complementary activity appears in Table 16. Part of the resources will be for developing training materials that can be used as teaching aids by trainers and adapted as technology transfer tools for technicians.

Expected Outputs

The IDS's general output, to be achieved in collaboration with the other CIAT programs, will be national research institutions with an increased technical capacity to perform their role, and more effective and efficient national and regional research systems for sustainable agriculture.

Component outputs for this enhancement of research institutions and systems will be:

Trained researchers. Individualized and group training will open about 800 training opportunities for researchers during the planning period. However, the actual number of persons involved will be 400-500 because some individuals will participate in various events.

Subregional training bodies for entry-level researchers and technology intermediaries, endowed with well-prepared trainers and appropriate training materials. Six subregional teams will be formed, with 25 trainers each, equipped with 40 instructional units consisting of written and visual aids and evaluation instruments. These training teams are expected to offer commodity-specific production training to about 2500 technology transfer professionals over the planning period.

Improved access and therefore greater use by national professionals of relevant information; national programs supported by a stronger network of agricultural libraries, especially in Latin America and the Caribbean; improved access to information by scientists; and increased information use by research systems.

Improved communication of CIAT achievements to a larger and more diverse audience, with products targeted to specific subgroups; additional capacity for writing

Table 16. Institutional Development Support. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Development of regional training capacity	–	600	–	600	–	600	–	600	–	400	–	200	–	100
Conferences	–	–	–	300	–	300	–	300	–	300	–	300	–	300
Total	–	**600**	–	**900**	–	**900**	–	**900**	–	**700**	–	**500**	–	**400**

and audiovisual production will be developed; and publication facilities upgraded to include desk-top and electronic publishing and printing equipment as required by increasing demand for publications and other media. Production volume is expected to increase significantly over the planning period.

Interinstitutional research and development projects.

RESEARCH SUPPORT

The Biotechnology Research Unit (BRU), the Genetic Resources Unit (GRU), and the Virology Research Unit (VRU) provide research support to CIAT's Programs. Research Support also includes Visiting Scientists and Postdoctorals, Research Services, Research Stations, Information Management Systems, and Impact Assessment Research.

Table 17 provides an overall summary of projected budgets for the research support core activities during the planning period.

The Deputy Director General for Research guides and oversees the various research and support units to ensure integration of efforts and cost effectiveness. Organizational responsibilities are depicted in Figure 1 (p. 105). Impact Assessment reports to the Director General.

Biotechnology Research Unit

Goal

To develop applications of modern biological methodologies for increasing the efficiency and cost-effectiveness of CIAT's strategic research. The Biotechnology Research Unit (BRU) is designed to perform as a problem-solving, scientific bridge to the development of productive, stress-tolerant germplasm for sustainable agroecosystems

Strategies, Objectives, and Activities

Strategy 1. Integrating biotechnology with CIAT's strategic research

First, in cooperation with CIAT scientists, the BRU will identify those relevant constraints, objects of CIAT's strategic research, that are amenable to biotechnology solution or more basic research. The BRU will globally monitor basic research developments and bring CIAT new information and methodologies. The BRU will cooperate with program and unit scientists to use and scale biotechnology methods and techniques. Integration with advanced research networks will be essential to implement this strategy.

In integrating biotechnology with CIAT research, the BRU will address three general objectives: (1) characterization of germplasm genetic diversity: plants and associated micro-organism populations; (2) broadening the genetic base of crop species; and (3) crop germplasm enhancement.

Strategy 2. Networking

The BRU will cooperate with CIAT research programs and units to bring prioritized research constraints to the attention of the world scientific community and donors. This exercise will lead to international cooperative efforts and establish effective research links between basic research institutions with CIAT's strategic research. In bridging biotechnology with the NARS of developing countries, the Unit will cooperate with CIAT research programs and the Institutional Development Support (IDS) to provide training opportunities in biotechnology methods and techniques.

Table 17. Research Support. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

Senior Staff Position	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Biotechnology research														
Tissue culture/Physiology (Unit Head)	1	170	1	170	1	170	1	188	1	188	1	200	1	200
Molecular biochemestry	1	165	1	165	1	165	1	170	1	170	1	175	1	175
Molecular genetics	1	165	1	165	1	165	1	170	1	170	1	175	1	175
Virology research														
Virology I	1	176	1	176	1	176	1	176	1	176	1	176	1	176
Virology II	1	176	1	176	1	176	1	176	1	176	1	176	1	176
Genetic resources	1	649	1	680	1	700	1	753	1	763	1	783	1	783
Research services	–	438	–	438	–	438	–	438	–	438	–	438	–	438
Research stations														
Field operations	1	871	1	773	1	773	1	773	1	773	1	773	1	773
Carimagua – Llanos	–	347	–	347	–	347	–	347	–	347	–	347	–	347
Information management	–	283	–	286	–	286	–	286	–	286	–	286	–	286
Biometry support	–	224	–	224	–	224	–	224	–	224	–	224	–	224
Visiting scientists and postdoctorals	–	532	–	532	–	532	–	532	–	532	–	532	–	532
Impact assessment	–	–	1	200	1	200	1	250	1	250	1	300	1	300
Total	7	4,196	8	4,332	8	4,352	8	4,483	8	4,493	8	4,585	8	4,585

Objective 1. Characterization of genetic diversity, broadening crop genetic base, and germplasm enhancement

Activity 1. Understanding genome structure.

Development of genetic fingerprinting and molecular maps will help characterize more precisely the core collection of beans and cassava, and describe and interpret genetic variation in beans, *Brachiaria* and *Arachis* germplasm, associated microbial (pathogenic and beneficial), and arthropod populations. This work will lead to the detection of useful genetic variability in crop gene pools, localization of important traits by gene mapping, and methods for monitoring microbial and arthropod population dynamics.

Activity 2. Plant manipulation for broadening the genetic base and germplasm enhancement.

Molecular markers, such as RFLPs and RAPDs, and linkage maps; tissue culture clonal multiplication and plant regeneration from somatic and reproductive tissues; gene isolation and cloning; and genetic transformation techniques will be developed to strengthen methods for genome manipulation, ultimately broadening the genetic base of CIAT crops for better adaptation to agroecosystems.

Broadening the genetic base of crops and germplasm enhancement will follow three interrelated routes:

Enhancing intraspecific genetic recombination through haploid and double-haploid induction in cassava and *Brachiaria* spp.; somaclonal variation of *Brachiaria* sp., *Arachis pintoi*, *Stylosanthes*, and beans; molecular markers assisted gene tagging and analysis of quantitative trait loci in beans and cassava.

Enhancing interspecific genetic recombination through immature embryo rescue and culture for introgression of useful traits to common beans from *P. acutifolius* and other *Phaseolus* spp.; through species-specific molecular markers for introgression of wild *Manihot* traits to cassava; and ultimately, development of interspecific gene pools for use in germplasm enhancement.

Development of nonsexual recombination methods through gene transfer and expression in cassava, beans, and *Stylosanthes*. *Agrobacterium*-mediated and direct DNA gene transfer methods of genetic transformation will be developed. Useful genes for transformation will be made available through the advanced networks, collaborative projects, donations, and eventually by CIAT's own research.

Activity 3. Cryopreservation of genetic variability.

Tissue culture and cryopreservation techniques will be developed for the long-term *ex situ* conservation of vegetative and reproductive plant tissues and organs in cassava, and selected tropical forages, trees, and shrubs.

Objective 2. Studies in adaptation mechanisms for broadening genetic base and germplasm enhancement

Activity 1. Strategic research on mechanisms in pathology, entomology, plant physiology, and nutrition in CIAT programs will increasingly benefit from the Unit's research with biochemical and molecular genetic methods. Identification of the factors underlying selected plant-biotic and abiotic stress interactions will be followed by development of effective germplasm screening techniques.

Modern methodologies for gene identification, isolation, and cloning will be undertaken in cooperation with advanced research institutions.

Activity 2. Host-insect pest relations: burrowing bug and whitefly in cassava.

Activity 3. Host-pathogen relations: anthracnose in Stylosanthes and beans; bacterial blight in beans.

Activity 4. Photosynthetic adaptation mechanisms: cassava.

Activity 5. Nutrient uptake efficiency and root structure: beans, tropical forages; aluminum tolerance in tropical forages.

Objective 3. Institution building

Activity 1. Consultation with scientists from developed and developing countries to

set up priorities for biotechnology research and organize biotechnology research networks for cassava, beans, and selected tropical forages.

Activity 2. Training activities will take the form of short- and medium-term in-service training, short-term study leave, intensive short duration courses, and advanced degree theses.

Activity 3. The Unit will organize updating seminars and courses on cellular and molecular genetics or specialized topics of biotechnology for CIAT research programs.

Activity 4. The Unit will inform and keep national programs up-to-date on issues such as biosafety and preventive and defensive protection of intellectual property.

Resource Requirements

The BRU's requirements for core resources are listed in Table 17.

Description of Senior Staff Positions

Three core positions in the areas of plant and cell physiology, molecular biochemistry, and molecular genetics are considered the minimum essential strategic research team for the development of biotechnology methods at CIAT in the period 1993-1998. A complementary position in the area of microbial genetics is proposed.

Plant physiology (Head of Unit). In charge of cell and tissue culture research and genetic transformation/plant regeneration. Links the Unit and programs' research activities in the area of cell and tissue culture. Responsible for assisting CIAT commodity programs to organize and initially coordinate the respective biotechnology networks, and to organize CIAT biosafety guidelines and matters relating to preventive protection of biotechnology products and processes, and biotechnology training activities.

Plant molecular biochemistry. Provides basic research support to commodity programs in the characterization of pathogenic microorganisms, and plant biotic and abiotic interactions at biochemical and molecular levels. The aims would be to identify the factors involved, and help with germplasm screening and enhancement activities involving the use of immunoassays, genetic probes, and biochemical assays. Provides necessary technical support for genetic manipulation of CIAT crops. Links the Unit and programs' research activities in the area of biochemistry and molecular biology.

Plant molecular genetics. Develops applications of molecular genetic markers and maps in germplasm characterization and enhancement to facilitate gene tagging of important traits and genetic fingerprinting of selected germplasm. Links the Unit and programs' research activities in the area of molecular genetic markers and mapping.

Complementary Activities

CIAT will seek extra-core resources for the Unit as listed in Table 18. Included in these resources is a principal scientist position for microbial genetics. The principal responsibility of this scientist will be to characterize the genetic mechanisms of plant-microbial associations, with special attention to the rhizosphere and plant endophytes. The purpose is to improve nutrient uptake and cycling processes of CIAT crops, as well as to explore the development of safe integrated management of pests and pathogens. This scientist will interact closely with CIAT research programs in the areas of microbiology, pathology, and soil/plant nutrition.

Should the complementary resources described here and those for coordinating advanced research networks (as described

Table 18. **Biotechnology Research. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).**
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Microbial genetics	–	–	1	215	1	215	1	215	1	215	1	215	1	215
Bean molecular mapping and resistance mechanisms [a]	–	54	–	57	–	60	–	63	–	66	–	–	–	–
Cassava molecular mapping [a]	–	80	–	80	–	80	–	–	–	–	–	–	–	–
Rice biotechnology [a]	–	90	–	90	–	90	–	90	–	–	–	–	–	–
Bean transformation [a]	–	–	–	15	–	15	–	15	–	–	–	–	–	–
Total budgeted in research programs [a]	–	224	1	457	1	460	1	383	1	281	1	215	1	215
Total budgeted in Biotechnology	–	–	1	215	1	215	1	215	1	215	1	215	1	215

a. Project is also shown and accounted for in the proposed budget for complementary activities of the respective research program; the project is repeated here for the purpose of comprehensiveness.

under the Bean and Cassava Programs) be available, the Unit can engage in the following additional activities:

Objective 1. Characterization of genetic diversity, broadening crop genetic base, and germplasm enhancement

Activity 1. Understand the genome structure.

Develop genetic fingerprinting and molécular maps of cassava and wild *Manihot* spp. in cooperation with the Cassava Program; collaborate on genetic fingerprinting of rice blast with the Rice Program; develop the molecular map of other *Phaseolus* spp., starting with tepary bean.

Activity 2. Plant germplasm enhancement.

Enhance intraspecific genetic recombination of rice through double-haploid induction; molecular marker-assisted gene tagging and analysis of QTL for rice biotic stresses.

Develop nonsexual gene transfer methods for rice and beans.

Activity 3. Germplasm cryopreservation.

Develop tissue culture techniques for cloning and cryopreservation of MPFTS in cooperation with the GRU and the Tropical Forages Program.

Objective 2. Studies in adaptation mechanisms for broadening genetic base and germplasm enhancement

Activity. Host-insect pest relations: bruchids in beans, spittlebug in* Brachiaria *spp.

Objective 3. Institution building

Activity 1. Cooperate with CIAT research programs in organizing advanced network meetings, training, and production of network communication media.

Activity 2. Organize short-term advanced training courses on biotechnology methods for Latin American scientists.

Activity 3. Conduct advanced thesis research projects.

Expected Outputs

Objective 1. Characterization of genetic diversity, broadening crop genetic base, and germplasm enhancement

Molecular maps. The first framework of the cassava and tepary beans linkage maps will be available in 1994 and the number of molecular markers of the bean map will be increased, using cDNA probes and RAPDs.

Genetic fingerprinting. Methods will become available for characterizing cassava and *Phaseolus* beans core collections, and selected MPFTS genetic variability, using hypervariable probes and synthetic oligonucleotides with PCR. Current DNA fingerprinting techniques for pathogenic microbial populations, such as *Pyricularia* in rice, *Xanthomonas* in beans, and *Colletotrichum* in *Stylosanthes* and beans, will be further developed and used in CIAT research programs. Similar techniques will allow a better understanding of microorganism population dynamics, especially in the rhizosphere. This information will be useful for the management of pest and pathogen biocontrol and for enhancing nutrient use efficiency by the plant.

Gene tagging. Technology for establishing tight linkages of relevant traits with molecular markers (RFLP and RAPD) will be used in germplasm enhancement by CIAT scientists with rice and beans first, then with cassava, and possibly with *Brachiaria* spp. Similar approaches will be developed to allow analysis of quantitative traits at the molecular level with all CIAT crops.

Trait introgression. Tissue culture techniques will be expanded to help achieve introgression of useful traits from distant *Phaseolus* spp. sources to common bean through interspecific hybridization. Molecular linkage maps and DNA fingerprinting techniques will be also used to increase introgression efficiency. Later, a similar approach will be developed for cassava and selected tropical forages. Interspecific gene pools will be developed for use in germplasm enhancement.

Cryopreservation. Cryogenic techniques for long-term conservation of cassava germplasm that save labor, space, and costs will be available in 1994-1995. Implementation of this technology for other CIAT crops will be evaluated.

Nonsexual gene transfer. Genetic transformation methodologies for the introduction and stable expression of selected genes, such as the coat protein gene in cassava and beans, will be developed. Use of *Stylosanthes* and rice as model systems will accelerate progress in this field. Plant regeneration techniques, a prerequisite for genetic transformation, will be developed and/or improved.

Intravarietal genetic variability. Efficient plant regeneration protocols from somatic and reproductive (microspores) cells will be developed to generate lines with variable root-shoot morphology and physiology. These techniques will be used as tools in plant/root-soil nutrient studies with *Stylosanthes*, *Brachiaria*, and *Arachis*.

Objective 2. Studies in adaptation mechanisms for broadening genetic base and germplasm enhancement

Basic analytical biochemical and molecular tools for identifying factors involved in plant-biotic and abiotic stress interactions will be implemented by the Unit, that is, separation techniques (HPLC), detection techniques (immunoassays), construction of genomic and cDNA libraries, gene isolation and cloning, and *in situ* hybridization techniques.

Efficient screening and better manipulation of traits will be developed on the basis of prior identification of (1) resistance-tolerance factors underlying plant-biotic and abiotic stress relations such as the burrowing bug and whitefly in cassava, spittlebug in *Brachiaria*, bruchids in beans, and anthracnose in *Stylosanthes* and beans; or (2) adaptation mechanisms such as photosynthetic efficiency in cassava, and nutrient uptake efficiency and root structure in beans and tropical forages.

Objective 3. Institution building

A two-way bridge between developed country institutions and national programs of developing countries will be established to transfer information and technologies, and to develop awareness of critical issues on biotechnology research and technology transfer.

Genetic Resources Unit

Goal

To assemble, conserve, and characterize all critical germplasm resources in Phaseolus, Manihot, *and several genera of tropical forages, and to research those collections so that they can be used more fully by international organizations and national programs*

Strategy and Activities

All research activities will focus on aspects of strategic value for future research purposes in collaboration with CIAT's programs and units. The Unit's research covers a wide field that includes taxonomy, reproductive biology, evolution, genetic diversity, germplasm conservation methodology, and seed physiology. Ultimately, the Unit is responsible for increasing knowledge on germplasm, which, in turn, will help improve efficiency in germplasm management and enhance germplasm use.

Activity 1.* Phaseolus *(bean) germplasm.

Acquisition and introduction will involve the following:

Backlog germplasm. About 6000 bean accessions have been introduced to CIAT but have not passed through the quarantine process and are thus not available for use. This backlog germplasm, introduced mainly from other continents, will be processed under quarantine regulations established by the Instituto Colombiano Agropecuario (ICA). A new quarantine greenhouse in Bogotá will become available early in 1992.

Wild Phaseolus species. Even though CIAT does not have a world mandate for wild Phaseolus species, this germplasm will become important to the Center's strategic research, especially in light of recent biotechnological developments.

Bean genetic stock collection. The use of genetic stocks--such as biochemical and morphological mutants, isogenic lines, and aneuploids--has been instrumental in modern biology advances. The use of such mutants will become increasingly important for strategic research on common bean germplasm.

Duplicating the collection and long-term storage capacity involves:

Duplication. Safe duplication of the collection is being carried out under agreements with CATIE in Costa Rica and the Centro Nacional de Recursos Genéticos (CENARGEN) in Brazil. Thus far, 21,390 and 3,019 accessions, respectively, have been sent to these two centers.

Storage. The GRU has a cold room (-20 °C) for long-term storage of germplasm; however, only 4200 accessions are now stored because of lack of seeds.

Health status of the collection. Preserving the seed health of germplasm for international exchange is a major concern of the international germplasm community. The unit will soon implement a new system of seed production under strict quarantine conditions and proper pathological checking.

Core collection. Passport information for germplasm from centers of primary genetic diversity has been updated and will be used as a base for selecting accessions for the core collection. The value of the core collection will be assessed in subsequent years.

Collaborative germplasm research includes studying:

Outcrossing (allogamy) frequency. All of CIAT's common bean accessions are grown in the field for seed increase. If outcrossing occurs during seed increase, some of the seeds harvested will be genetically contaminated. Thus, research on allogamy frequency was recently initiated as part of a collaborative project between CIAT and the IBPGR.

Genetic diversity. Understanding the genetic structure of bean germplasm is key to the efficient management and use of germplasm. Biochemical markers have been successfully used, contributing to better understanding of gene pools and the origin of bean species. In collaboration with the BRU and other advanced laboratories, germplasm will continue to be analyzed, especially with new molecular markers.

Linkage maps of all cultivated bean species. The use of three cultivated bean species (*P. acutifolius, P. coccineus*, and *P. lunatus*) as sources of important traits for common bean improvement has been of major interest to bean geneticists. The recent development of an RFLP map for *P. vulgaris* is an opportunity to develop RFLP maps for related species. The maps will provide better understanding of the mechanisms underlying cytogenetic barriers that have prevented the effective use of those species. This work will be carried out in collaboration with the Bean Program and the BRU through complementary funding.

Activity 2. Tropical forage germplasm.

Acquisition and introduction. There are already large comprehensive collections of key tropical legume and grass species. Their growth will slow down as they are limited to germplasm essential for filling known genetic or geographic gaps. About 400 accessions from the joint collection missions in the African countries by CIAT and ILCA have yet to be introduced to CIAT. Given the new orientation of CIAT's Tropical Pastures Program (now Tropical Forages Program), new herbaceous germplasm with adaptation potential for higher altitude, acid soils will be acquired.

MPFTS, adapted to acid soils, will also be introduced, in collaboration with national and international institutions such as the ICRAF and the IBPGR. The GRU will assist the Tropical Forages Program to introduce material in such aspects as joint collection, coordination with national and international institutions, and quarantine.

Duplicating the collection and long-term storage. In the past, more than 2300 samples were prepared for safe duplicate deposit even though CIAT had no agreements for safe duplication with other institutions. At present, about 3600 samples are under long-term storage; monitoring of their seed viability will start. Further efforts for seed increase of key genera will be made.

Characterization of key genera. CIAT has assembled large collections of grass genera such as *Brachiaria*, *Hyparrhenia*, and *Panicum*, which play a key role in pasture improvement. However, they still lack proper characterization.

Documentation and data management involves:

Plant descriptors. CIAT should take a leading role in developing and establishing plant descriptors for tropical forage germplasm, taking advantage of existing considerable expertise in germplasm characterization and preliminary evaluation.

Characterization and passport data. Although tropical forage germplasm was characterized by the former Tropical Pastures Program and the GRU, these data are not easily accessible. Passport data of many accessions registered since the 1970s are incomplete.

Computing germplasm management. For more efficient germplasm management, data on seed increase, distribution, and inventory, as well as from field collections, need to be correlated with each other and with the general database.

Activity 3. Cassava* (Manihot) *germplasm.

The GRU will take full responsibility of cassava germplasm management. This includes the collection, conservation (field and in vitro), characterization, and documentation of cassava and wild *Manihot* species. In close collaboration with the Cassava Program, the BRU, the VRU, and the DSU, the following activities will be carried out:

Incorporation into the germplasm collection of additional existing Latin American and Asian materials and new accessions collected in field expeditions, mainly in Brazil.

Selection and study of representative subsets of the collection as a means of streamlining the conservation and characterization of genetic variation within *M. esculenta*.

Acquisition and introduction. By 1997, the cassava field germplasm bank (4677 accessions at present) will have been increased by about 1500 accessions. CIAT recently received about 800 accessions from Brazil, which makes the collection comprehensive in terms of germplasm from centers of primary genetic diversity.

Health status of the collection. Germplasm exchange of clonally propagated crops needs extra care. Frog skin disease is of special concern because it is endemic to Colombia and adjacent countries and there is no reliable serological method for detecting it. In collaboration with the VRU, the GRU will "clean" and index all important accessions in the germplasm bank.

Establishment of a comprehensive wild *Manihot* collection. Although the potential value of wild *Manihot* species as new sources of useful traits for cassava cultivar improvement has been well established, there is no germplasm bank holding an adequately comprehensive number of wild *Manihot* accessions. The GRU will make the wild collection available for the Cassava Program which will evaluate the collection for its potential contribution to cassava improvement.

Duplicating the collection. CIAT's cassava collection is maintained in two germplasm banks: field and in vitro. Thus, technically speaking, the collection is duplicated and no major worries exist for loss of important germplasm. However, both germplasm banks are located at CIAT and are not conserved in other places. Two approaches are being considered: first, the Cassava Program will collect open-pollinated true seeds from the field collection to be used as a means of gene conservation; and second, the BRU is developing a cryopreservation technology for cassava, which, if successful, will facilitate duplication of the collection in other places at reduced costs, compared with the meristem culture system.

Fingerprinting the collection by biochemical and molecular markers. In the past three years, 4205 accessions have been characterized by esterase isozymes. DNA markers are also being used for additional fingerprinting of the collection.

CIAT, within the CGIAR system, has accepted responsibility for conservation of cultivated and wild cassava germplasm. The mission can only be accomplished through working with others in this endeavor. At present, there are 55 national and international cassava collections maintained in 45 countries. There is also a large amount of cultivated cassava diversity in Africa, which is probably not under immediate threat of genetic erosion, but which must be collected. CIAT, in collaboration with IITA, IBPGR, and some key national programs, will seek to develop a global approach to secure conservation of the remainder of this important germplasm and to enhance its future use through the integration of the work of many institutions worldwide and through appropriate conservation and utilization methodologies.

Resource Requirements

Table 17 shows the resources allocated to the Genetic Resources Unit in terms of Senior Staff positions.

Complementary Activities

CIAT will seek extra-core resources for the Unit as shown in Table 19. With the availability

Table 19. Genetic Resources Unit. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Sorghum and soybean germplasm	–	80	–	50	–	50	–	–	–	–	–	–	–	–
Forage germplasm biology [a]	–	91	–	76	–	76	–	76	–	76	–	76	–	76
Forage in vitro management [a]	–	134	–	125	–	134	–	–	–	–	–	–	–	–
Phaseolus bean germplasm [a]	–	80	–	80	–	80	–	80	–	80	–	80	–	80
Wild cassava germplasm [a]	–	–	–	90	–	80	–	80	–	80	–	80	–	–
Total budgeted in research programs [a]	–	**385**	–	**421**	–	**420**	–	**236**	–	**236**	–	**236**	–	**156**
Total budgeted in Genetic Resources	–	**80**	–	**50**	–	**50**	–	–	–	–	–	–	–	–

a. Project is also shown and accounted for in the proposed budget for complementary activities of the respective research program; the project is repeated here for the purpose of comprehensiveness.

of complementary resources, as described here, the GRU will be able to implement the following complementary projects:

Activity 1. Sorghum and soybean germplasm.

The GRU will assist in the introduction of highly selected (for potential adaptation to acid soils) sorghum and soybean germplasm. Additional resources (greenhouse workers and new quarantine screenhouses) will be added through complementary projects in this area.

Activity 2. Forage germplasm biology.

A clear understanding of reproductive biology is very important for managing germplasm. In collaboration with the Tropical Forages Program, the GRU will investigate reproductive biology (allogamy frequency, pollination mechanisms, apomixis, and genetic structure) in key species.

Activity 3. In vitro management of forage germplasm.

In vitro culture is an essential tool for supporting forage genetic resources activities and for overcoming constraints in the provision of forage germplasm. The objective of this complementary project is to develop and establish in vitro culture techniques for the proper management of specific tropical forage germplasm, with special emphasis on some grass and MPFTS species.

Activity 4.* Phaseolus *bean germplasm.

Better understanding of the genetic structure of *Phaseolus* spp. is crucial for its effective use in strategic germplasm development. There is a strong need to further study founder effects; origin and gene pools of the four cultivated species in *Phaseolus*; allogamy frequency of bean accessions; genetic structure of wild bean populations; effects of different management practices on gene frequency changes; and application of highly variable DNA markers for fingerprinting of the collection.

Activity 5. Wild cassava germplasm.

This project aims to complement the establishment of a comprehensive wild cassava germplasm bank by developing broad knowledge on crossability of species in the germplasm bank; and evaluating potential traits in wild species accessions.

Expected Outputs

Activity 1.* Phaseolus *(bean) germplasm.

About 3500 backlog accessions processed and incorporated into the existing collection.

The world's largest collection of wild *Phaseolus* germplasm assembled at CIAT.

The bean genetic stock collection established and seeds distributed to bona fide users; all accessions available for distribution duplicated at CATIE by 1994; and a total of 12000 accessions duplicated at CENARGEN by 1997.

All accessions with CIAT G number under long-term storage at the end of the planning period.

Availability of approximately 4200 accessions free of bean common mosaic and bean southern mosaic viruses.

Allogamy frequencies estimated for a sample of bean accessions.

Better understanding of the genetic structure of bean populations in nature and in the germplasm bank.

RFLP maps established for *P. acutifolius* and two other species, if time permits.

Better knowledge on how to improve efficiency in germplasm introgression.

Activity 2. Tropical forage germplasm.

Completion of the collection of key genera as gaps are filled; about 9000 accessions, with emphasis on key genera, duplicated at a reliable institution.

Availability of forage germplasm adapted to tropical acid-soil environments from sea level to 1800 m.a.s.l.

A collection of MPFTS for tropical acid soils assembled through germplasm exchange and direct collection.

Accessions of key genera conserved in long-term storage; seed viability of samples in long-term storage ascertained.

CIAT's *Brachiaria* and *Panicum* collections characterized for morphological traits.

Publication of plant descriptors for key tropical legume and grass genera in collaboration with the IBPGR; documentation of characterization data for tropical forage germplasm; completion of passport data for accessions registered until 1990, and publication (in collaboration with the Tropical Forages Program) of several regional germplasm catalogs.

Implementation of a computerized system for germplasm management in collaboration with CIAT's Information Management Systems Unit.

Estimation of the allogamy frequencies of key species at CIAT's multiplication sites.

Better understanding of pollination mechanisms; characterization of grass collections for their reproductive mode (sexual versus apomixis).

Increased knowledge of seed physiology.

Activity 3. Cassava* (Manihot) *germplasm.

Consolidation of the world's largest and most comprehensive cultivated cassava germplasm collection.

About 5000 clones properly indexed and ready for exchange as pathogen-tested material.

A comprehensive wild cassava germplasm bank; potential traits in wild species accessions evaluated.

Conservation of true seeds of all flowering clones in cold-room storage.

Broad knowledge on crossability of species in the germplasm bank.

Implementation of cryopreservation for safe and long-term conservation.

The whole collection fingerprinted by esterase isozyme; other isozymes used for additional fingerprinting and genetic diversity studies.

Virology Research Unit

Goal

To support CIAT's research programs and some units in the area of plant virology for detecting, identifying, and controlling viruses of economic or quarantine importance. Specific attention will be given to viruses affecting beans, cassava, rice, and tropical pastures

Strategies and Activities

Strategy 1. Detection

The presence of viruses, particularly new strains and exotic viruses, are constantly surveyed in bean, cassava, rice, and tropical forage pastures areas. The detection of plant viruses in reproductive plant materials is also critical for the safe exchange of plant germplasm between international centers and collaborating agricultural research institutions.

Strategy 2. Characterization

The pathogenicity and transmission of viruses are studied under field and greenhouse conditions, and their physicochemical properties characterized through electron microscopy, centrifugation, spectrophotometry, electrophoresis, serology, and molecular techniques.

Strategy 3. Control and monitoring

Practical control methods, mainly sources of resistance, are identified and breeding materials evaluated under artificial (greenhouse, screenhouse, growth room) and field conditions. Finally, the implementation of virus detection methods permits monitoring virus incidence and pathogenic variability in key production areas.

Activity 1. Identification of viruses affecting CIAT's commodities.

The VRU will concentrate research efforts on unknown viral pathogens of cassava, particularly the virus complexes found in Colombia, and tropical forage pastures, with emphasis on legume and grass species currently exchanged with collaborating national research institutions.

Activity 2. Characterization of economically important viruses affecting CIAT's commodities (biology).

After viruses have been identified and shown to be economically important--that is, not opportunistic--they are characterized for their pathogenicity, variability, mode of transmission, and key physicochemical properties. They are then used to produce reliable detection methods, such as antisera and probes.

A number of bean viruses, such as bean severe and cucumber mosaic viruses, must be fully characterized. The same is true for those cassava viruses found in South America, which have only been partially characterized. The identification and characterization of unknown forage legume and grass viruses will continue throughout the planning period. Molecular characterization of the rice "hoja blanca" virus (RHBV) should be completed within the same period.

Activity 3. Search for sources of virus resistance (plant protection components).

During the planning period this activity will play a major role in supporting CIAT's germplasm development activities. Suitable sources of genetic resistance need to be identified for the following viruses: cassava viruses in general; bean severe, bean yellow, and cucumber mosaic viruses in *P. vulgaris*; and for tropical pastures, potyviruses in *Arachis, Centrosema, Stylosanthes*, and *Brachiaria* species. For rice, the crop's genetic base of resistance to RHBV should be broadened.

Activity 4. Development of reliable virus detection methods for epidemiological and quarantine purposes (ecology).

This is probably the VRU's most constant and resource-demanding activity. All viruses infecting CIAT's commodities--regardless of their economic importance--must be identified for quarantine purposes to guarantee germplasm, introduced or exported by CIAT, as virus free.

The VRU will replenish and produce polyclonal and monoclonal antisera for all viruses it has characterized. The basic antisera collection will increase the Unit's capacity to detect viruses that naturally infect CIAT's commodities. The VRU also plans to expand its capacity to generate radioactive and nonradioactive specific probes for viruses not readily identifiable or detected by serology. The main thrust of this effort is to develop and utilize nucleic acid hybridization techniques.

Activity 5. Implementation of molecular virology and genetic engineering techniques to produce transgenic plants possessing resistance to plant viruses.

The recently developed technique of introducing useful foreign genes into plants by ballistic methods has allowed scientists to genetically transform many species, such as beans, and circumvent the difficult regeneration of certain species by tissue culture techniques.

The incorporation into plants of foreign genes shown to confer virus resistance has been demonstrated for various virus-plant systems. The VRU will continue to work on the genetic transformation of bean and, later, cassava plants to test different virus-induced plant resistance mechanisms such as coat protein, satellite, and lethal mutant-mediated plant resistance. Other vectors of genetic material, such as *Agrobacterium* spp., can also be tested with tobacco systems amenable to plant transformation. Through the use of these techniques, breakthroughs in the area of plant regeneration are anticipated.

Activity 6. ***Training.***

The VRU reached full operational capacity in 1992, when training of junior staff in molecular virology was completed. The Unit will then be in a position to transfer information and appropriate technology to scientists in national programs, who are responsible for handling similar virus problems in their countries. Emphasis will be placed on demonstrating modern virus-detection techniques, such as cDNA probes, as practical tools for field researchers who need diagnostic capacity in the absence of adequate local virology facilities.

Other virus-detection techniques, such as immunosorbent serological methods (ELISA), using polyclonal or monoclonal antibodies, will be demonstrated to promote scientists' awareness of the availability of backup centralized tests, which can greatly assist breeding for virus resistance in isolated regions.

Another major training area for national program virologists is screening for virus resistance and selection of virus-resistant germplasm.

Resource Requirements

Table 17 shows the resources allocated for the Virology Research Unit in terms of Senior Staff positions.

Visiting Scientists and Postdoctorals

Visiting scientists from institutions of developed countries are expected to be financed through non-CIAT resources. However, CIAT budgets for limited financial resources to cover, if necessary, part of the sustenance costs of such visiting scientists. CIAT also maintains a program to invite cooperating, senior scientists from national programs to conduct research at the Center for periods of 6 to 12 months. On the average, CIAT can host 2 to 3 such scientists at a cost approximately equal to that of one postdoctoral fellow.

The Center budgets core resources for postdoctoral fellows on a yearly basis at an equivalence of 7-8 person-years. Postdoctoral fellows are recruited to engage in high-priority, often exploratory, research and are placed directly with the research programs or the research support units. While these young scientists make considerable contributions to the research programs, the postdoctoral program also provides them with experience in an international research setting that prepares them for careers in tropical agriculture.

Research Services

Centralization of services ensures economies of scale and reduces capital costs by providing an efficient mechanism for sharing the use of expensive advanced research equipment. Research Services at CIAT are organized to provide centralized services to all programs and units in the following areas: soil and plant analytical services, plant growth facilities (screenhouses, greenhouses, growth rooms, and growth chambers), mass spectrophotometry laboratory, and mycorrhizae laboratory. The central microscope laboratory now has updated equipment and will expand its services. The small-animal colony will be transferred to Research Services.

As advanced research equipment is purchased, these resources are placed under the administration of Research Services, supervised by a committee of users.

Research Stations

CIAT maintains research stations in Colombia for experimental use by all its programs, with commercial production only on land that is in excess of program needs. CIAT-Palmira (404 ha of cultivable land), CIAT-Quilichao (177 ha cultivated), CIAT-Santa Rosa (29 ha cultivated), CIAT-Popayán (19 ha cultivated), and ICA's Centro Nacional de Investigaciones at Carimagua (CNI-Carimagua; co-managed by CIAT) are key elements in CIAT's strategy for commodity programs and for expanding needs in natural resource management research.

CIAT-Palmira

This fully irrigated station has reached maturity, but appropriate equipment replacement remains a key element in efficient management. All programs and units use the station, with heaviest emphasis on beans and rice research; about 20% of the cultivated area is devoted to commercial production, contributing an average of US$120,000 per year to CIAT's income.

CIAT Substations

These stations are directly managed and provide a set of environments for research not available at headquarters, e.g., at Popayán (1800 m altitude), there are acid soils and a humid, cool tropical climate for beans and cassava; at Quilichao (1000 m), acid soils and a subhumid mid-altitude climate for tropical forages, cassava, beans, maize (CIMMYT), and sorghum (INTSORMIL); and at Santa Rosa (300 m), moderately acid soils with a humid lowland tropical climate for rice. The substations are managed by Station Operations as a service to all programs. The facilities are relatively modest, and, apart from the essential replacement of capital, significant capital investments are not expected in the future. On-station research by resource management programs will expand in some key areas, and this will be accommodated on existing stations with present resources.

Diagnostic work now being carried out by the resource management group will identify two further locations for on-station research over the planning period. In both cases, the research to be conducted would be in collaboration with national programs at existing stations. Modest funds have been allocated for the additional capital needed at those stations to provide appropriate office and field laboratory space for CIAT. The actual locations of these two sites should be determined by early 1993. Modest amounts of funding have been included for this purpose in the capital requests for 1993 and 1994.

In addition to the above, there will be a need to develop a mid-altitude (approximately 1500 m) screening site for the Tropical Forages Program's work on MFPTS, as well as in grasses and legumes. This site is not envisaged as a full substation. It is expected that resources for this site will be derived from normal capital allocations in 1993 or 1994.

CNI-Carimagua and Llanos-based Research

On-station and on-farm research by the Rice and Tropical Forages Programs in the Llanos Orientales (Eastern Plains) of Colombia has expanded greatly in recent years. The new Savannas Program will have a major set of activities in the Colombian Llanos, incorporating the existing rice-pasture activities within a systems context. The Rice and Tropical Forages Programs will continue to carry out germplasm development work (rice at Santa Rosa, and in collaboration with ICA at nearby "La Libertad," and on-farm in the area; and tropical forages at Carimagua and on-farm). In addition, the Cassava Program will continue to develop germplasm for the acid lowland humid tropics in collaboration with ICA at "La Libertad."

All these activities will place increasing logistic demands on CIAT's Station Operations. The administrative base now in place at Villavicencio and Santa Rosa will need to grow to provide local support for these far-flung activities. The total resources required for the Llanos-based station operations and logistic support will be accommodated within the present budget allocated to existing activities in the region. The working budget of the new Savannas Program will help to complement the centrally funded logistic services.

Information Management

To develop its information functions, CIAT has opted for decentralized hardware, software, and personnel resources within so-called "information domains" relevant to the new CIAT strategy, combined with a centralized policy, coordination, and technical support.

The information domains identified within CIAT are:

Geographic and Land Use Information;

Socioeconomic Information;

Germplasm Development Information;

Soil/Plant Information;

Bibliographic/Documentation Information;

Institutional Development Information;

Financial/Administrative Information.

Each domain develops information input, processing, storage, and analysis procedures to support its unique information needs.

The Information Management Committee (IMC) considers and recommends CIAT policy and coordinates activities, services, and resources to guarantee efficient management of CIAT's information resources. It is chaired by a DDG and includes as members both technical personnel in the areas of information management and analysis, and users representative of the different information domains. In particular, the IMC assumes the following responsibilities:

Long-term policy and strategies for information management within CIAT and between CIAT and its partner institutions.

Components and standards of the various information systems.

CIAT policy on hardware and software acquisition, maintenance, and growth.

A central group of specialists in the areas of information management and analysis forms the Information Management Unit. The Unit provides technical advice and support to CIAT research Programs and Units within the information domains in databases and information systems development. Additionally, it is responsible for maintaining the principal mainframe installation. The budget shown in Table 17 for this Unit reflects the costs of all the above functions.

Databases/Information Systems Development

Depending of the nature of the information domain, the effective conceptualization, design, implementation, and maintenance of databases or information systems require a specifically composed "database team." For CIAT germplasm development databases, soil/plant relations databases, and some types of socioeconomic databases, for example, whose body is constituted by experimental results, the database team requires a clear understanding of the biological nature of the crop(s), their multiple components, and the meaning of experimental data. Therefore, members of these database teams are (a) the systems analyst, who is the software expert and designer of the efficient storage of data with minimal redundancy and with the most effective interactive access to end-users; (b) the researcher(s), who have a clear understanding of the problem, purpose, and audience of the database; and (c) the biometrician, who has a clear understanding of the data and the most suitable statistical summaries with which to characterize a given research process. For other types of applications, such as bibliographic and documentation databases, the database team would include people with a different mix of abilities.

Specific responsibilities of the Databases/ Information Systems Development group include:

Assisting CIAT to develop standards for database management software for mainframe, micros, and LAN environments, and methodology for applications development.

Supporting the different domains in database development.

Designing, implementing, and maintaining institutional research and research-related databases in close collaboration with CIAT research Programs and Units.

Training end-users in the use of existing databases, using the Microcomputer Training Laboratory facilities.

CIAT's standard database management software, across all hardware platforms (mainframe, micros, and LANs), is ORACLE from Oracle Corporation. All major research and research-related databases--Genetic Resources Database, Bean Breeding Database, Cassava Breeding Database, Tropical Forages Evaluation Database, and Interinstitutional Relations Database--are implemented in ORACLE, and interactive access to them is provided to end-users within CIAT Headquarters. Databases are distributed to CIAT regional programs in other countries and partner NARDIs by diskette, making use of ORACLE interfaces with Dbase and Lotus. However, because CIAT was recently accepted as member of the scientific WAN (wide area network), BITNET, electronic information flow from and to CIAT is technically feasible.

Biometry Support

As a science-based institution, CIAT relies heavily on statistical and mathematical sciences and on tools for research design and analysis of results. The Center's research Programs and Units receive biometric support in the following areas:

Statistical and mathematical orientation in experimental design, data analysis methodology, interpretation of results and their forecasting ability, and final presentation.

Statistical analysis of experimental results to be stored in research databases, and selection of relevant statistical summaries.

Collaborative methodological studies and data analysis projects with CIAT scientists.

Training in statistical and mathematical methods and data analysis for CIAT research staff and collaborating national program researchers, using the Microcomputer Training Laboratory facilities.

Assistance to CIAT in defining standards for statistical and mathematical software for mainframe, micros, and LAN environments.

CIAT standards for statistical and data analysis software for the mainframe computer include SAS/BASICS, SAS/STATS, SAS/GRAPH, SAS/FSP, SAS/ETS, SAS/IML, and SAS/OR from SAS Institute Inc., Raleigh, North Carolina, USA; and GENSTAT, GLIM, and Fortran Library from the NAG Algorithm Group, London, England. Microcomputer statistical and data analysis software include MSTAT from Michigan State University; GLMM from Louisiana State University; SYSTAT from SYSTAT Inc., Chicago, Illinois; AGROBASE/4 from Agronomix Software Inc., Manitoba, Canada; Lotus 1-2-3; and Dbase III.

Impact Assessment

The shift toward increased emphasis on strategic germplasm development as described in this Operational Plan is accompanied by an important reduction in agricultural economics work in the germplasm development programs. At the same time, however, there is a continuing, even increasing, need for CIAT to monitor the agricultural economics situation surrounding the production of the Center's mandate commodities. Such research assists in the continuous setting of priorities through *ex ante* impact assessment.

Similarly, with the initiation of the Agroecosystems Programs, methodologies for impact assessment in the area of resource management research need to be developed or adapted. While actual fieldwork will be carried out by the respective programs, this work needs to be integrated into the Center's overall impact assessment processes.

Additionally, CIAT must be able to assess and monitor the impact of its work, as well as to respond to requests for special economic analyses from the CGIAR, the Board, and Management. To partly fill the gap opened by the reduced number of agricultural economist positions, and to fulfill the needs for trends analysis, impact assessment, and special economic studies, the section of Impact Assessment is proposed, to be initiated in 1993. The Unit will report to the Director General. It will be staffed by a senior economist and a small professional support staff. Also assigned to the office are financial resources that allow the senior economist to contract selected data collection and field studies work and coordinate the Center's working group on impact assessment research.

The resource requirements for Impact Assessment in the 1993-1998 period are shown in Table 17.

MANAGEMENT, ADMINISTRATION, AND CENTRAL SERVICES

In 1992, after an important restructuring of administrative and services areas, CIAT devoted 7.4% of its core resources to management and administration, and 12% to central services. Together, the two areas accounted for US$5,680,000 or 19.4% of the core budget. For the forthcoming operational period, 1993-1998, CIAT projects general operating expenditures to remain at approximately the same proportion.

CIAT is aware that the more complex organization described by this operational plan and the addition of resource management research will significantly increase demands on management, administration, and central services. However, the center will continue to selectively decentralize management and administration and to increase the systematization of operations and cost reduction measures, thus making it feasible to meet the demand of the expected ripple effect with minimal additional resources.

Table 20. Management and Administration. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
Senior Staff Position	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Board of Trustees	–	200	–	200	–	200	–	200	–	200	–	200	–	200
Central administration														
Office of Director General	2	422	2	422	2	422	2	422	2	422	2	422	2	422
Office of DDG for Finance and Administration	1	236	1	236	1	236	1	236	1	236	1	236	1	236
Off. of the Executive Officer	1	378	1	378	1	378	1	378	1	378	1	378	1	378
Financial administration	1	580	1	580	1	580	1	580	1	580	1	580	1	580
Human resources	–	223	–	223	–	223	–	223	–	223	–	223	–	223
Internal audit	–	122	–	122	–	122	–	122	–	122	–	122	–	122
Central services														
Purchasing/Warehouse	–	270	–	260	–	260	–	260	–	260	–	260	–	260
Administrative systems	–	327	–	327	–	327	–	327	–	327	–	327	–	327
Central services	–	1,193	–	1,193	–	1,193	–	1,193	–	1,193	–	1,193	–	1,193
Physical plant	–	639	–	639	–	639	–	639	–	639	–	639	–	639
Motor pool	–	492	–	492	–	492	–	492	–	492	–	492	–	492
General expenses	–	598	–	608	–	608	–	608	–	608	–	608	–	608
Total	5	5,680	5	5,680	5	5,680	5	5,680	5	5,680	5	5,680	5	5,680

Senior Staff positions for management and administration were reduced from six in 1991 to five in 1992 (not included are two positions for research directors, which are shown in the respective research divisions [see Table 23]). The internationally recruited position of Projects Officer was transferred from the Projects Administration Office to the Institutional Development Support, as Project Design Specialist. Replacing the position is a locally recruited position for Administration.

Table 20 shows the projected Senior Staff positions and resource requirements in the areas of management, administration, and central services.

CAPITAL REQUIREMENTS

The present value of CIAT's fixed assets is US$20.4 million. To keep its capital infrastructure at present levels, CIAT calculates that an annual allocation of US$2.0 million is required.[1] With the influx of these financial resources, CIAT can guarantee the donor community that its capital infrastructure is maintained at optimal levels and that all its research, laboratory, machinery, and computer equipment will be in good operating order and will be replaced with state-of-the-art equipment at reasonable intervals. However, the constant pressure on CIAT to maximize its research output by availing itself of advanced research equipment requires capital resources beyond the current levels at which CIAT keeps up its present fixed assets. To replace outdated research equipment with new and enhanced equipment, and to acquire new research implements, machinery, and other equipment, CIAT projects an additional annual capital allocation of US$300,000. This amount is reflected in the corresponding asset category shown in Table 21.

[1]The amount mentioned here is the result of applying the straight-line depreciation formula to CIAT's assets valued at original acquisition costs. This formula was introduced in the 1991 financial year as per guidelines issued by the CGIAR Secretariat. The amount closely matches CIAT's own estimates--estimates based on experience over several years--as to the resources needed to maintain the capital infrastructure (including research and laboratory equipment) up-to-date and in working order.

Table 21. Capital resources. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992	1993	1994	1995	1996	1997	1998
Assets categories	Amount	Amount	Amount	Amount	Amount	Amount	Amount
Land, buildings, and leasehold improvements	200	400	280	400	300	300	150
Operating equipment	500	500	300	420	500	500	350
Vehicles	400	420	420	450	450	450	450
Furnishing and office equipm.	30	50	30	30	50	50	50
Research equipment	690	750	690	800	800	800	700
Aircraft	–	–	400	–	–	–	400
Computer equipment	180	180	180	200	200	200	200
Total	2,000	2,300	2,300	2,300	2,300	2,300	2,300

SUMMARY AND ANALYSIS OF RESOURCE REQUIREMENTS

CIAT's proposed allocation of resources over the 1993-1998 period is summarized in Table 22. Information in this table is based on the classification of "activities" used by the CGIAR system (see Appendix II).

Table 23 shows projected resource requirements for the core program during the planning period. Details on those requirements appear in the respective program or unit description.

Table 24 gives the same information for complementary activities in the same period, while Table 25 presents the total resource requirements for core and complementary activities combined.

Table 26 shows the resource requirements by expense categories; Table 27 shows total personnel requirements by program and unit for the planning period.

Table 22. Utilization of core resources by activities for the years 1991–1998 (percent share). [a]

Activities [b]	1991	1992	1993	1994	1995	1996	1997	1998	Avg. 92–98
1. Conservation and management of natural resources, including germplasm conservation	10.0	21.0	25.0	24.5	25.0	25.0	25.5	26.0	24.5
1.1 Ecosystem conservation and management	3.0	13.0	17.5	17.0	17.5	17.5	17.5	18.0	17.0
LAC	3.0	13.0	17.5	17.0	17.5	17.5	17.5	18.0	17.0
1.2 Germplasm collection, conservation, characterization and evaluation	7.0	8.0	7.5	7.5	7.5	7.5	8.0	8.0	7.5
LAC	4.0	4.5	4.0	4.0	4.0	4.0	4.5	4.5	4.0
SSA	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Asia	1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2. Germplasm enhancement and breeding	23.5	33.5	32.0	31.0	30.5	31.5	31.5	31.0	32.0
2.1 Crops	23.5	33.5	32.0	31.0	30.5	31.5	31.5	31.0	32.0
LAC	16.5	20.0	19.0	18.5	18.0	18.5	18.5	19.0	19.0
SSA	4.5	8.5	8.0	7.5	7.5	7.5	7.5	8.0	8.0
Asia	2.5	5.0	5.0	5.0	5.0	5.5	5.5	4.0	5.0
3. Production systems development and management	27.5	16.5	14.5	15.5	15.5	15.0	14.5	14.5	15.0
3.1 Crops systems	21.0	15.0	13.0	14.0	14.0	13.5	13.0	13.0	13.5
LAC	13.5	8.5	7.5	8.0	8.0	7.5	7.5	7.5	7.5
SSA	5.0	4.0	3.0	4.0	4.0	3.5	3.0	3.0	3.5
Asia	2.5	2.5	2.5	2.0	2.0	2.5	2.5	2.5	2.5
3.2 Livestock systems	6.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LAC	6.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4. Socio–economic, public policy and public management research	6.0	9.0	11.5	12.0	12.0	12.0	12.0	12.0	11.5
4.1 Economic and social analysis	5.5	6.5	8.0	8.5	8.5	8.5	8.5	8.5	8.0
LAC	4.0	5.0	6.5	7.0	7.0	7.0	7.0	7.0	6.5
SSA	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Asia	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4.2 Policy analysis	0.5	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
LAC	0.5	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
4.3 Governance and management of public systems	–	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LAC	–	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5. Institution building	33.0	20.0	17.0	17.0	17.0	16.5	16.5	16.5	17.0
5.1 Training and conferences	17.5	7.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
LAC	13.5	4.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
SSA	3.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Asia	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5.2 Documentation, publication and dissemination of information	10.5	10.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0
LAC	8.5	6.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0
SSA	1.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Asia	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5.4 Networks	5.0	2.5	2.0	2.0	2.0	1.5	1.5	1.5	2.0
LAC	3.5	1.5	1.0	1.0	1.0	0.5	0.5	0.5	1.0
SSA	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Asia	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Summary by region:									
LAC	73.5	67.5	69.5	69.5	69.5	69.0	69.5	70.5	69.0
SSA	18.0	21.0	19.0	19.5	19.5	19.0	18.5	19.0	19.5
Asia	8.5	11.5	11.5	11.0	11.0	12.0	12.0	10.5	11.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a. LAC = Latin America and Caribbean; SSA = Sub–Saharan Africa.
b. Numbers refer to CGIAR's definitions of "activities" (see Appendix II).

Table 23. Resource requirements. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Germplasm Development														
Beans	15	3,890	14	3,390	14	3,390	13	3,240	13	3,190	13	3,190	13	3,190
Cassava	10	2,655	10	2,400	11	2,816	11	2,826	11	2,580	10	2,400	10	2,400
Rice	6	1,655	6	1,540	6	1,540	6	1,540	6	1,540	6	1,540	6	1,540
Tropical Forages	9.5	2,615	9.5	2,395	9.5	2,395	9.5	2,395	10.5	2,625	10.5	2,625	10.5	2,625
Biotechnology	3	500	3	500	3	500	3	528	3	528	3	550	3	550
Virology	2	352	2	352	2	352	2	352	2	352	2	352	2	352
Genetic resources	1	649	1	680	1	700	1	753	1	763	1	783	1	783
Strategic research initiatives	–	100	–	185	–	320	–	370	–	420	–	420	–	420
Research management	1	238	1	238	1	238	1	238	1	238	1	238	1	238
Total germplasm development	**47.5**	**12,654**	**46.5**	**11,680**	**47.5**	**12,251**	**46.5**	**12,242**	**47.5**	**12,236**	**46.5**	**12,098**	**46.5**	**12,098**
Resource Management														
Forest Margins	1	300	4	900	4	900	4	900	4	900	4	900	4	900
Hillsides	1	300	4	930	4	930	4	930	4	930	4	930	4	930
Savannas	5.5	1,400	5.5	1,500	5.5	1,500	5.5	1,500	5.5	1,500	5.5	1,500	5.5	1,500
Land Use	3	770	4	1,030	5	1,150	6	1,230	6	1,230	6	1,230	6	1,230
Strategic research initiatives	–	100	–	185	–	320	–	370	–	420	–	420	–	420
Research management	1	233	1	233	1	233	1	233	1	233	1	233	1	233
Total resource management	**11.5**	**3,103**	**18.5**	**4,778**	**19.5**	**5,033**	**20.5**	**5,163**	**20.5**	**5,213**	**20.5**	**5,213**	**20.5**	**5,213**
Research Support														
Research services	–	438	–	438	–	438	–	438	–	438	–	438	–	438
Field operations	1	871	1	773	1	773	1	773	1	773	1	773	1	773
Carimagua	[illegible]	347	–	347	–	347	–	347	–	347	–	347	–	347
Information management	–	283	–	286	–	286	–	286	–	286	–	286	–	286
Biometry support	–	224	–	224	–	224	–	224	–	224	–	224	–	224
Visiting scientists and postdoctorals	–	532	–	532	–	532	–	532	–	532	–	532	–	532
Impact assessment	–	–	1	200	1	200	1	250	1	250	1	300	1	300
Total research support	**1**	**2,695**	**2**	**2,800**	**2**	**2,800**	**2**	**2,850**	**2**	**2,850**	**2**	**2,900**	**2**	**2,900**
Institutional Development Support														
Associate Director (Institut. relations)	1	228	1	228	1	228	1	228	1	228	1	228	1	228
Professional development	–	560	–	460	–	460	–	460	–	460	–	460	–	460
Conferences	–	240	–	240	–	240	–	240	–	240	–	240	–	240
Information and documentation	1	585	1	550	1	550	1	550	1	550	1	550	1	550
Communication/Public affairs	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031
Project design [a]	1	–	1	–	1	–	1	–	1	–	1	–	1	–
Seed supply	–	268	–	–	–	–	–	–	–	–	–	–	–	–
Total institutional development	**5**	**2,912**	**5**	**2,509**	**5**	**2,509**	**5**	**2,509**	**5**	**2,509**	**5**	**2,509**	**5**	**2,509**
Management and Administration														
Board of Trustees	–	200	–	200	–	200	–	200	–	200	–	200	–	200
Central administration	5	1,961	5	1,961	5	1,961	5	1,961	5	1,961	5	1,961	5	1,961
Central services	–	3,519	–	3,519	–	3,519	–	3,519	–	3,519	–	3,519	–	3,519
Total management and administrat.	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**
Depreciation expense	–	2,000	–	2,000	–	2,000	–	2,000	–	2,000	–	2,000	–	2,000
Contingencies	–	300	–	300	–	300	–	300	–	300	–	300	–	300
Total operations	**70**	**29,344**	**77**	**29,747**	**79**	**30,573**	**79**	**30,744**	**80**	**30,788**	**79**	**30,700**	**79**	**30,700**
Capital														
New capital	–	–	–	300	–	300	–	300	–	300	–	300	–	300
Total capital	–	–	–	**300**	–	**300**	–	**300**	–	**300**	–	**300**	–	**300**
Additional operating funds	–	–	–	59	–	64	–	9	–	3	–	–	–	–
Total	**70**	**29,344**	**77**	**30,106**	**79**	**30,937**	**79**	**31,053**	**80**	**31,091**	**79**	**31,000**	**79**	**31,000**

a. Paid from indirect costs recovery.

Table 24. Resource requirements. Revised budget for 1992 and projected budgets for complementary activities for 1993–1998 (SYs = Senior Staff years). [a]
(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Germplasm Development														
Beans	8	2,964	9	3,292	7	2,660	7	2,663	6	2,351	6	2,285	6	2,285
Cassava	2	1,678	3	2,908	2	2,443	2	2,396	1	1,849	1	1,359	–	1,074
Rice	1	340	2	970	2	1,030	2	1,000	2	810	2	810	2	810
Tropical Forages	2	601	3	777	4	933	3	746	2	536	2	536	2	536
Biotechnology	–	–	1	215	1	215	1	215	1	215	1	215	1	215
Genetic resources	–	80	–	50	–	50	–	–	–	–	–	–	–	–
Total germplasm development	**13**	**5,663**	**18**	**8,212**	**16**	**7,331**	**15**	**7,020**	**12**	**5,761**	**12**	**5,205**	**11**	**4,920**
Resource Management														
Forest Margins	–	–	2	350	3	550	3	550	3	550	3	550	3	550
Hillsides	–	130	3	480	5	830	5	930	5	930	5	930	5	930
Savannas	1	65	1	65	1	215	1	250	1	250	1	250	1	250
Total resource management	**1**	**195**	**6**	**895**	**9**	**1,595**	**9**	**1,730**	**9**	**1,730**	**9**	**1,730**	**9**	**1,730**
Research Support														
Farmer participatory research	1	279	1	279	1	279	1	279	1	279	1	279	1	279
Total research support	**1**	**279**	**1**	**279**	**1**	**279**	**1**	**279**	**1**	**279**	**1**	**279**	**1**	**279**
Institutional Development Support														
Professional development	–	600	–	600	–	600	–	600	–	400	–	200	–	100
Conferences	–	–	–	300	–	300	–	300	–	300	–	300	–	300
Total institutional development	**–**	**600**	**–**	**900**	**–**	**900**	**–**	**900**	**–**	**700**	**–**	**500**	**–**	**400**
Contingencies	–	67	–	103	–	101	–	99	–	85	–	77	–	73
Total operations	**15**	**6,804**	**25**	**10,389**	**26**	**10,206**	**25**	**10,028**	**22**	**8,555**	**22**	**7,791**	**21**	**7,402**
Capital														
New capital and replacement	–	300	–	300	–	300	–	300	–	300	–	300	–	300
Total capital	**–**	**300**	**–**	**300**	**–**	**300**	**–**	**300**	**–**	**300**	**–**	**300**	**–**	**300**
Additional operating funds	–	–	–	299	–	–	–	–	–	–	–	–	–	–
Total	**15**	**7,104**	**25**	**10,988**	**26**	**10,506**	**25**	**10,328**	**22**	**8,855**	**22**	**8,091**	**21**	**7,702**

a. Not shown are the expected complementary activities, carried out in close collaboration with CIAT, by other international centers and international or regional research organizations. Many of these collaborative or joint activities will be hosted at CIAT headquarters or will be jointly based at research sites.

Table 25. Resource requirements. Revised budget for 1992 and projected budgets for core and complementary activities for 1993–1998 (SYs = Senior Staff years).

(Constant 1992 US$'000)

	1992		1993		1994		1995		1996		1997		1998	
	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount	SYs	Amount
Germplasm Development														
Beans	23	6,854	23	6,682	21	6,050	20	5,903	19	5,541	19	5,475	19	5,475
Cassava	12	4,333	13	5,308	13	5,259	13	5,222	12	4,429	11	3,759	10	3,474
Rice	7	1,995	8	2,510	8	2,570	8	2,540	8	2,350	8	2,350	8	2,350
Tropical Forages	11.5	3,216	12.5	3,172	13.5	3,328	12.5	3,141	12.5	3,161	12.5	3,161	12.5	3,161
Biotechnology	3	500	4	715	4	715	4	743	4	743	4	765	4	765
Virology	2	352	2	352	2	352	2	352	2	352	2	352	2	352
Genetic resources	1	729	1	730	1	750	1	753	1	763	1	783	1	783
Strategic research initiatives	–	100	–	185	–	320	–	370	–	420	–	420	–	420
Research management	1	238	1	238	1	238	1	238	1	238	1	238	1	238
Total germplasm development	**60.5**	**18,317**	**64.5**	**19,892**	**63.5**	**19,582**	**61.5**	**19,262**	**59.5**	**17,997**	**58.5**	**17,303**	**57.5**	**17,018**
Resource Management														
Forest Margins	1	300	6	1,250	7	1,450	7	1,450	7	1,450	7	1,450	7	1,450
Hillsides	1	430	7	1,410	9	1,760	9	1,860	9	1,860	9	1,860	9	1,860
Savannas	6.5	1,465	6.5	1,565	6.5	1,715	6.5	1,750	6.5	1,750	6.5	1,750	6.5	1,750
Land Use	3	770	4	1,030	5	1,150	6	1,230	6	1,230	6	1,230	6	1,230
Strategic research initiatives	–	100	–	185	–	320	–	370	–	420	–	420	–	420
Research management	1	233	1	233	1	233	1	233	1	233	1	233	1	233
Total resource management	**12.5**	**3,298**	**24.5**	**5,673**	**28.5**	**6,628**	**29.5**	**6,893**	**29.5**	**6,943**	**29.5**	**6,943**	**29.5**	**6,943**
Research Support														
Research services	–	438	–	438	–	438	–	438	–	438	–	438	–	438
Field operations	1	871	1	773	1	773	1	773	1	773	1	773	1	773
Carimagua	–	347	–	347	–	347	–	347	–	347	–	347	–	347
Information management	–	283	–	286	–	286	–	286	–	286	–	286	–	286
Biometry support	–	224	–	224	–	224	–	224	–	224	–	224	–	224
Visiting scientists and postdoctorals	–	532	–	532	–	532	–	532	–	532	–	532	–	532
Impact assessment	–	–	1	200	1	200	1	250	1	250	1	300	1	300
Farmer participatory research	1	279	1	279	1	279	1	279	1	279	1	279	1	279
Total research support	**2**	**2,974**	**3**	**3,079**	**3**	**3,079**	**3**	**3,129**	**3**	**3,129**	**3**	**3,179**	**3**	**3,179**
Institutional Development Support														
Associate Director (Institut. relations)	1	228	1	228	1	228	1	228	1	228	1	228	1	228
Professional development	–	1,160	–	1,060	–	1,060	–	1,060	–	860	–	660	–	560
Conferences	–	240	–	540	–	540	–	540	–	540	–	540	–	540
Information and documentation	1	585	1	550	1	550	1	550	1	550	1	550	1	550
Communication/Public affairs	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031	2	1,031
Project design [a]	1	–	1	–	1	–	1	–	1	–	1	–	1	–
Seed supply	–	268	–	–	–	–	–	–	–	–	–	–	–	–
Total institutional development	**5**	**3,512**	**5**	**3,409**	**5**	**3,409**	**5**	**3,409**	**5**	**3,209**	**5**	**3,009**	**5**	**2,909**
Management and Administration														
Board of Trustees	–	200	–	200	–	200	–	200	–	200	–	200	–	200
Central administration	5	1,961	5	1,961	5	1,961	5	1,961	5	1,961	5	1,961	5	1,961
Central services	–	3,519	–	3,519	–	3,519	–	3,519	–	3,519	–	3,519	–	3,519
Total management and administrat.	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**	**5**	**5,680**
Depreciation expense	–	2,000	–	2,000	–	2,000	–	2,000	–	2,000	–	2,000	–	2,000
Contingencies	–	367	–	403	–	401	–	399	–	385	–	377	–	373
Total operations	**85**	**36,148**	**102**	**40,136**	**105**	**40,779**	**104**	**40,772**	**102**	**39,343**	**101**	**38,491**	**100**	**38,102**
Capital														
New capital	–	300	–	600	–	600	–	600	–	600	–	600	0	600
Total capital	–	**300**	–	**600**	–	**600**	–	**600**	–	**600**	–	**600**	–	**600**
Additional operating funds	–	–	–	358	–	64	–	9	–	3	–	–	–	–
Total	**85**	**36,448**	**102**	**41,094**	**105**	**41,443**	**104**	**41,381**	**102**	**39,946**	**101**	**39,091**	**100**	**38,702**

a. Paid from indirect costs recovery.

Table 26. Budget by categories of expenses. Revised budget for 1992 and projected budgets for core activities for 1993–1998 (SYs = Senior Staff years).
(Constant 1992 US$'000)

	1992	1993	1994	1995	1996	1997	1998
Categories of expenses	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**
Personnel	18,148	18,113	18,372	18,338	18,445	18,319	18,319
Training	692	692	692	692	692	692	692
Supplies and services	4,991	4,846	4,956	4,976	4,977	4,983	4,983
Travel	1,600	1,633	1,690	1,701	1,687	1,697	1,697
Other expenses	1,613	1,693	2,023	2,164	2,114	2,136	2,136
Depreciation expense	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Contingency	300	300	300	300	300	300	300
Capital	–	300	300	300	300	300	300
Working capital adjustment	–	19	61	6	3	–	–
Total	**29,344**	**29,596**	**30,394**	**30,477**	**30,518**	**30,427**	**30,427**

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Table 27. Actual positions for 1992, and projected core positions for 1993–1998.

	Senior Staff							Support Staff: Scientific and supervisory							Support Staff: Clerical and Other staff							Total Staff						
	92	93	94	95	96	97	98	92	93	94	95	96	97	98	92	93	94	95	96	97	98	92	93	94	95	96	97	98
Germplasm Development																												
Beans	15	14	14	13	13	13	13	31	29	29	26	26	26	26	121	116	116	111	111	111	111	167	159	159	150	150	150	150
Cassava	10	10	11	11	11	10	10	25	25	29	29	28	25	25	91	91	91	91	91	91	91	126	126	131	131	130	126	126
Rice	6	6	6	6	6	6	6	19	19	19	19	19	19	19	66	66	66	66	66	66	66	91	91	91	91	91	91	91
Tropical Forages	9.5	9.5	9.5	9.5	10.5	10.5	10.5	26	26	26	26	27	27	27	107	107	107	107	112	112	112	143	143	143	143	150	150	150
Biotechnology	3	3	3	3	3	3	3	8	8	8	9	9	9	9	7	7	7	7	8	8	8	18	18	18	19	20	20	20
Virology	2	2	2	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14	14	14
Genetic resources	1	1	1	1	1	1	1	8	8	8	9	9	9	9	40	40	42	42	42	42	42	49	49	51	52	52	52	52
Research management	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	4	4	4	4	4	4	4
Total germplasm development	47.5	46.5	47.5	46.5	47.5	46.5	46.5	124	122	126	125	125	122	122	440	435	437	432	438	438	438	611.5	603.5	610.5	603.5	610.5	606.5	606.5
Resource Management																												
Forest Margins	1	4	4	4	4	4	4	2	8	8	8	8	8	8	2	16	16	16	16	16	16	5	28	28	28	28	28	28
Hillsides	1	4	4	4	4	4	4	2	8	8	8	8	8	8	2	16	16	16	16	16	16	5	28	28	28	28	28	28
Savannas	5.5	5.5	5.5	5.5	5.5	5.5	5.5	15	15	15	15	15	15	15	41	41	41	41	41	41	41	62	62	62	62	62	62	62
Land Use	3	4	5	6	6	6	6	11	15	18	22	22	22	22	8	10	11	12	12	12	12	22	29	34	40	40	40	40
Research management	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Total resource management	11.5	16.5	19.5	20.5	20.5	20.5	20.5	31	47	50	54	54	54	54	54	86	85	86	86	86	86	96.5	149.5	154.5	160.5	160.5	160.5	160.5
Research Support																												
Research services	–	–	–	–	–	–	–	10	10	10	10	10	10	10	15	15	15	15	15	15	15	25	25	25	25	25	25	25
Field operations	1	1	1	1	1	1	1	4	4	4	4	4	4	4	72	72	72	72	72	72	72	77	77	77	77	77	77	77
Canmagua	–	–	–	–	–	–	–	3	3	3	3	3	3	3	8	8	8	8	8	8	8	11	11	11	11	11	11	11
Information management	–	–	–	–	–	–	–	4	4	4	4	4	4	4	8	8	8	8	8	8	8	12	12	12	12	12	12	12
Biometry support	–	–	–	–	–	–	–	6	6	6	6	6	6	6	3	3	3	3	3	3	3	9	9	9	9	9	9	9
Impact assessment	–	1	1	1	1	1	1	–	1	2	2	2	3	3	–	1	2	2	2	2	2	0	3	5	5	5	6	6
Total research support	1	2	2	2	2	2	2	27	28	29	29	29	30	30	106	107	108	108	108	108	108	134	137	139	139	139	140	140
Institutional Development Support																												
Associate Director	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	7	7	7	7	7	7	7
Professional development	–	–	–	–	–	–	–	5	5	5	5	5	5	5	4	4	4	4	4	4	4	9	9	9	9	9	9	9
Conferences	–	–	–	–	–	–	–	1	1	1	1	1	1	1	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Information and documentation	1	1	1	1	1	1	1	8	8	8	8	8	8	8	15	15	15	15	15	15	15	24	24	24	24	24	24	24
Communication/Public Affairs	2	2	2	2	2	2	2	15	15	15	15	15	15	15	27	27	27	27	27	27	27	44	44	44	44	44	44	44
Project design	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Total institutional development	5	5	5	5	5	5	5	33	33	33	33	33	33	33	53	53	53	53	53	53	53	91	91	91	91	91	91	91
Management and Administration																												
Central administration	5	5	5	5	5	5	5	32	32	32	32	32	32	32	49	49	49	49	49	49	49	86	86	86	86	86	86	86
Central services	–	–	–	–	–	–	–	26	26	26	26	26	26	26	216	216	216	216	216	216	216	242	242	242	242	242	242	242
Total management and admin.	5	5	5	5	5	5	5	58	58	58	58	58	58	58	265	265	265	265	265	265	265	328	328	328	328	328	328	328
Self–supporting and income – generating activities	–	–	–	–	–	–	–	9	9	9	9	9	9	9	91	91	91	91	91	91	91	100	100	100	100	100	100	100
Grand total	70	77	79	79	80	79	79	282	297	305	308	308	306	306	1,009	1,035	1,039	1,035	1,041	1,041	1,041	1,361	1,409	1,423	1,422	1,429	1,426	1,426

MANAGING THE IMPLEMENTATION OF THE PLAN

The medium-term plan, as introduced in the foregoing chapters, is not business as usual; rather, it calls for a transformation of the center in line with the aims of the Strategic Plan. This transformation will coincide with a relative scarcity of resources. At the same time, very high expectations have been placed on CIAT to have a major impact in terms of sustainable agricultural production in the regions it serves. There are real problems to be solved, which will require innovative and effective management of the center.

As evidenced in its Strategic Plan, CIAT is willing to refocus; in carrying out its mission, the center is determined to proceed with a lean, results-oriented action program. The guiding features in accomplishing the implementation of the strategic and operational plans are:

Sharp definitions of work plans;

Choice of an appropriate modus operandi;

Design of conducive organizational structures;

Transfer of selected activities;

Maintenance of maximum flexibility;

Management of the organizational culture.

Work Plans

Through its Strategic Plan and the present Operational Plan, CIAT has undertaken the basic steps to indicate clearly the directions in which the institution is headed. CIAT is committed to take the necessary additional steps to focus the work of all research and administrative units so that staff throughout the organization understand the importance of their work for the institution's new mission, and the standards required for its accomplishment. Included in this endeavor of continuous planning and definition of what is expected from each program, unit, or project are provisions for sharp definitions of work plans, and provisions for performance planning and monitoring, annual program reviews, and documentation of impact and results. The Director General's office will establish the necessary organizational features to ensure coordination of all activities designed to (1) obtain systematic feedback on the results of CIAT's work in the respective environments for which this work is designed, and (2) obtain and analyze information on the changing environments, which may require adjustments in research and management.

Modus Operandi

CIAT is involved in large and complex tasks. Clearly, no single institution will be able to accomplish these tasks on its own. CIAT's strategy is to integrate germplasm development and resource management research within the ecoregional model adopted. Central to the strategy is the need for an interinstitutional modus operandi. CIAT is committed to identifying innovative ways of arranging for multi-institutional linkages. These linkages should ensure sharing a common research agenda based on a common platform that provides for the free interchange of information, technologies, and materials.

The center is committed to developing simple but effective multi-institutional linkages that provide for:

Joint planning and effective coordination in the implementation of work plans;

Sharp definition of institutional and staff responsibilities for execution of activities; and

Definition of effective oversight mechanisms for monitoring outputs and impact.

This modus operandi calls for an open organization that designs its work on a cooperative level; is willing to subsume recognition for work performed to the achievement of results per se; and is as concerned about the effectiveness of the contributions of others as it is about the effectiveness of its own work.

Organizational Structures

While scientific progress is the result of creative, intelligent, persistent, and largely individual efforts of the scientific staff, CIAT's success in accomplishing its mission is a function of the degree to which multidisciplinary teams of scientists achieve integrated solutions. The challenge for CIAT as a research organization is to blend individual research efforts with the objectives of the programs in germplasm development and resource management research. Superimposed is the challenge to permit scientists to pursue selected research endeavors that require intradisciplinary work (e.g., plant protectionists working on plant protection models involving multiple commodities within an ecosystem, economists working on impact assessment, soil scientists working on nutrient processes), or that require the ad hoc formation--external to the organizational program structure--of research teams composed of various disciplinary specialists.

This Operational Plan makes it evident that CIAT will continue pursuing its research work largely along multidisciplinary program structures conducting interdisciplinary research. Nevertheless, CIAT is committed to create an open internal organizational model that allows for a high degree of intercommunication among programs and units, and facilitates the creation of temporary work teams to resolve specific problems. The key mechanism to achieve this openness is a continuing process of defining medium- and short-term objectives as they arise in pursuing the center's mission, and then assembling and reallocating the resources required to achieve these dynamic objectives on a project-by-project basis. Furthermore, CIAT is committed to participatory management, whereby individual work teams and units have a major say in how they wish to organize and staff themselves in bringing about specific outcomes under their responsibility.

Fostering Integration

The chosen "program structure" implies budgeting by programs. The advantages of "project budgeting" are captured through the sharp definition of objectives, outputs, expected impact, and assumptions within each program that facilitate performance planning and monitoring. Budget provisions for inter- and intradisciplinary activities across programs are made within each program, as well as through special budget line items for strategic research in both the Germplasm Development Division and the Resource Management Research Division and in the various support units and programs. For this purpose, internal, temporary budget reallocations will be made on a project-by-project basis. This project orientation is seen as a major factor contributing to integration of program efforts within and across the two research divisions.

Another organizational mechanism to further integration is the Management Committee whose members are all directors and program leaders. This committee is charged with the tasks of coordinating the sharing of common resources, and guiding and overseeing the overall integration of research efforts within the Center and with research partners in the region and around the globe.

Administratively, CIAT will continue to emphasize on the principle that, when it comes to processes, fewer are better. The center will work to reduce administrative procedures to the minimal amount needed for the organization to run smoothly.

Transfer of Selected Activities

The new CIAT strategy implies that the center's various programs will need to design mechanisms for others to carry out important activities currently carried out by them. These activities include production training, predevelopment activities, technical assistance, and implementation and replication of pilot projects (e.g., cassava drying plants). The new Project Design Office in the Institutional Development Support Program (funded through indirect cost recovery) will assist CIAT's various programs in the development of well-designed, accountable special projects to carry out such activities and to be executed by others. If and when such projects need continued technical support from CIAT programs, the respective budgets will include provisions for such support so not to unduly tax the center's core program.

Maximum Flexibility

CIAT cannot, and will not, invest its operational resources in more or less fixed organizational units and processes. While the center recognizes the pitfalls and limitations of continuous zero-based budgeting, it will insist that every work aspect be reviewed and justified periodically. The organization will seek to have maximum flexibility in assigning and reassigning its resources so as to be in a position to take advantage of new opportunities, embark on new initiatives, and phase out or modify processes that have outlived their usefulness or are of relatively lower priority. CIAT is aware of the fact that increased flexibility will require increased management and resource administration time; however, considering the alternative of large fixed-cost patterns and the inability to adjust to new situations expeditiously, the investment is well worth the effort.

Organizational Culture

For CIAT to excel, it not only requires focused research and administrative units but it also needs a staff that is dedicated to the center's mission and values, understands its work, and is committed to do its utmost to contribute to the center's success and to observe the standards for accomplishing its work. Management is keenly aware of the importance that organizational values, attitudes, and processes--that is, organizational culture--have on the ultimate success of CIAT. It will assign great importance to the identification of factors that have positive or negative effects on CIAT's organizational culture, with the aim of reinforcing supportive traits and eliminating or de-emphasizing those that are negative.

> It is clear that the implementation of the strategic and operational plans requires effective and creative management. CIAT is a strong institution that has responded very positively to leadership; the challenges of the future require the redoubling of the center's efforts to refocus and streamline its actions under effective management at all levels with a clear and shared vision of the future external environment of the Center.

Organizational Structure

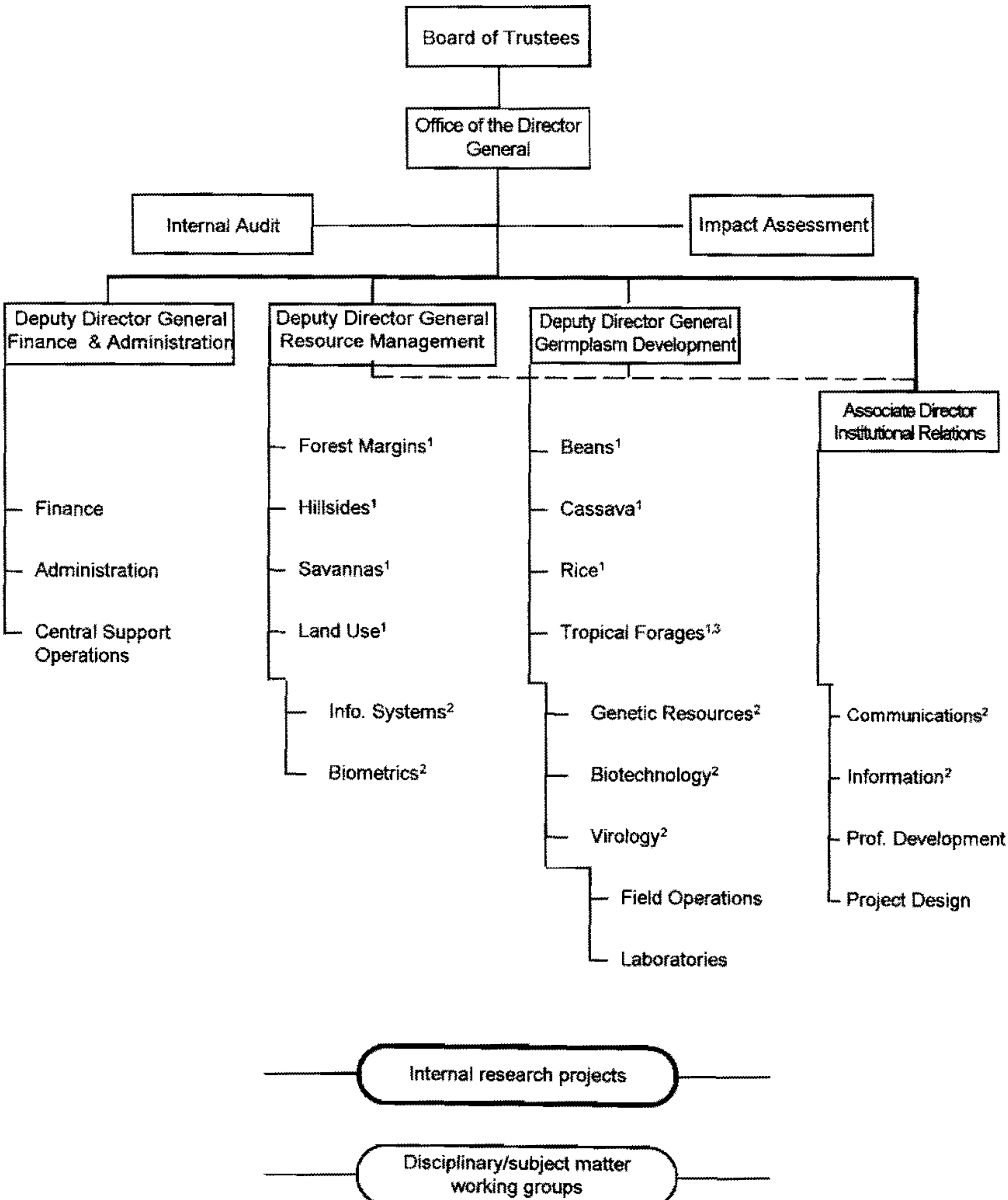
As pointed out in the Strategic Plan, CIAT has concluded that the operationalization of the Strategic Plan can best be pursued in the context of two research divisions: one emphasizing germplasm development research (and comprising the four germplasm research programs); and one primarily concerned with resource management research (and consisting of the three Agroecosystems Programs and the Land Use Program. Figure 1 shows the organizational structure for the planning period (1993-1998). It shows three divisions (Germplasm Development; Resource Management; and Finance and Administration), each headed by a Deputy Director General reporting to the

Director General. A position of Associate Director for Institutional Relations provides support in terms of interinstitutional relations, and also assumes responsibilities for support activities in training and professional development, and for communication and information services.

The research programs in the two research divisions (Germplasm Development and Resource Management) are headed by Program Leaders who assume a dual responsibility: to contribute to the research objectives of their programs in the area of their expertise; and to lead and coordinate the respective research teams.

Research support activities are assigned to the two research divisions, while central support operations are placed in the of Finance and Administration Division.

Figure 1. CIAT Organization Chart (1993-1998)



[1]Programs.

[2]Units.

[3]For organizational and technical reasons this program will be assigned to the RMRD until the end of 1993.

Appendix I

Outputs and Expected Impact of CIAT's Programs

Summaries of Outputs and Expected Impacts of the CIAT Programs over the period of the Strategic Plan, are given in the tables. These tables are based on the output tables in CIAT's Strategic Plan.

- I-A Bean Program
- I-B Cassava Program
- I-C Rice Program
- I-D Tropical Forages Program
- I-E Land Use Program
- I-F Agroecosystem Programs
- I-G Institutional Development

Table 1-A. Outputs and expected impact of the Bean Program

Objective	Output	Expected Impact	Assumptions
1. Generate advanced methods for gene identification and transfer.	- Less expensive, faster genetic improvement; - access to genes in 'exotic' material.	- Lower research costs; - earlier adoption; - solution of previously intractable problems of BGMV, ascochyta, *Empoasca*	- Continued progress in basic research at advanced laboratories; - continued public access to desirable genes; - effective national programs to utilize new genes as parental materials.
2. Increase yield potential.	- New, higher yielding ideotypes.	- Increased yields at farm level; - relief of pressure on fragile lands as beans move to higher productivity environments.	- Existence of useful genetic variability; - effective seed systems.
3. Improve microbial symbiosis.	- Better bean genotypes for nitrogen fixation; - improved strains for better symbiosis.	- Reduced production costs; - enriched soil biosphere; - more sustainable production.	- Effective inoculation/ distribution systems.
4. Improve nutrient and water efficiency.	- Parental material adapted to edaphic systems and tolerant to abiotic stresses.	- Improved productivity under stress conditions.	- Effective seed systems; - genetic variability.
5. Achieve stable resistance to diseases and pests.	- Diverse parental materials with multiple resistances.	- Stabilized and improved productivity; - reduced pesticide use.	- Effective seed systems; - genetic variability.
6. Strengthen national programs.	- Trained national scientists.	- More effective adaptive and applied research, leading to higher on-farm productivity.	- Greater national commitment to agricultural research; - improved stability of scientists in national programs.
7. Form regional networks for horizontal technology transfer.	- More efficient resource utilization through specialization and coordination; - more rapid diffusion of new technology.	- Lower research costs; - broader, more rapid productivity increases.	- National willingness to exchange results.

Table 1-B. Outputs and impact of the Cassava Program

Objective	Output	Impact	Assumption
1. Genetically improve productivity and yield stability of cassava. 2. Develop crop management practices for sustainable cassava production in selected ecosystems. 3. Improve cassava quality for diverse end uses.	- High-yielding parental materials tolerant of biotic and abiotic stresses and with desirable quality characteristics for specific end uses; technology for the commercial production of cassava, using true seed; principles and technology components for the design of cassava-based cropping systems, emphasizing: . soil fertility maintenance . soil conservation . integrated pest and disease management; consumer-acceptable cassava-based products.	- Increased overall cassava production, stability and quality; economically and environmentally sustainable cassava production, especially under adverse edaphoclimatic conditions; increased incomes of the rural population in cassava-growing regions; increased market potential for cassava and cassava-based products; cheaper cassava for direct and indirect human consumption in urban areas.	- Continued and increasing interest in cassava research by advanced laboratories; adequate funding for cassava research at the international level; commitment of national governments to invest in the development of martginal areas where cassava is a principal crop; government policies that are not biased in favor of competing carbohydrate sources.
4. Strengthen national cassava research and development systems.	- Trained NARDS personnel; - regional cassava research and development networks; - integrated cassava production, processing and marketing projects.	- More effective and integrated national systems.	- Minimum investment in cassava research and development at the national level.

Table 1-C. Outputs and expected impact of the Rice Program.

Objective	Output	Expected Impact	Assumptions
1. Achieve a fuller expression of the yield potential and broaden the genetic base of the upland rice germplasm adapted to the savannas.	- Well adapted, high-yielding germplasm for upland conditions; - Better understanding of plant genetics/physiology components affecting yield potential; - Better understanding of root physiology.	- Additional 2.5 million tons/year by 1998.	- Variety release and adoptions by 1994/1995.
2. Broaden the genetic resource base for irrigated rice to increase yield potential and production stability.	- Populations with disease resistance background; - Parental material for crossing programs at national level; - Irrigated lines with upland root systems; - Evaluation methodologies for NARDS; -Understanding of biotic/abiotic constraints and germplasm interactions.	- Stabilized high productivity levels; - Expanded area of rice lines with higher efficiency of water use; - Reduced production costs; - Reduced prices for urban consumers.	- Continued support for national rice improvement programs; - Continued INGER/IRRI support for germplasm exchange.
3. Reinforce and promote regional information exchange among national programs.	- Information in usable form; - Books, pamphlets, newsletters; - CD-ROM (including germplasm databases).	- Availability of knowledge to enable broad implementation of objectives 1-2 at NARDS.	- CIAT support for information exchange mechanisms, and capability to develop them.

Table 1-D. Outputs and expected impact of the Tropical Forages Program.

Objective	Output	Expected Impact	Assumptions
1. Generate herbaceous and woody species adapted to acid soils.	- Improved grasses and legumes for poor acid-soil lands, from 0 to 1800 m.a.s.l.	- Improved ruminant production and fertility in low-fertility acid soil lands.	- Resources for continued acquisition of germplasm and support by GRU; - effective feedback from agroecosystems programs.
2. Improve efficiency of germplasm development through the understanding of ecological compatibility mechanisms.	- Knowledge of acid-soil adaptation mechanisms; - knowledge of mechanisms of plant resistance to pests and diseases; - quality and antiquality factors affecting ruminant nutrition; - identification of genes.	- New pastures and MPFTS components that are efficient in contributing to animal production and to soil enhancement.	- Effective links with advanced institutions, and support by BRU and VRU.
3. Strengthen national and regional capabilities.	- NARDS and networks (RIEPT, AFRNET and SEAFRAD) capable of developing germplasm and pastures and deploying multipurpose forage trees and shrubs (MPFTS).	- Broad adoption of new adapted pastures and MPFTS to low-fertility acid soils.	- National commitment to forage research; - adequate support by CIAT's IDS program, especially in seed supply systems.

Table 1-G. Outputs and expected impact of the Institutional Development Support.

Objective	Output	Expected Impact	Assumptions
1. Strengthen the capacity of national research institutions.	- Human resources and teams with appropriate knowledge, skills and information for applied and strategic research.	- Increased generation of relevant technology by NARS; - increased efficiency of research through national programs/CIAT complementarity.	- Continuity of alumni in mother institutions and in their field of specialization, and availability of resources.
2. Increase the efficiency of national research systems and facilitate their interfacing with agricultural development.	- Mechanisms for interinstitutional complementary research; - tightly designed projects.	- Increased efficiency of research through interinstitutional collaboration.	- Political support and institutional willingness to cooperate and fulfill commitments.
3. Develop seed supply systems suitable for small farms' circumstances.	- New organizational mechanisms and enterprises for seed supply; - new seed production and processing technologies for small seed enterprises.	- Adoption of improved crop varieties and of pastures and MPFTS for resource conservation.	- Support from national research and development programs, and donor financial support to initiate pilot projects.
4. Enhance national/regional training in commodity production and adaptive research.	- Institutionalized national and regional training programs for commodity production and adaptive research.	- Increased effectiveness of CIAT/regional/national research and technology transfer systems; therefore, more efficient technology generation and adoption.	- Political decision to institutionalize training at national/subregional levels, and ongoing political and financial support.

Appendix I

Appendix II

TAC RESEARCH ACTIVITY STRUCTURE

The Technical Advisory Committee (TAC) of the CGIAR has developed a list of definitions to describe activities carried out by the chain of international agricultural research centers, to which CIAT belongs. CIAT's activities, as described in the text and tables, are listed in this appendix, together with their corresponding TAC definitions.

Activity	Sub-Activity	Sub-Activity Specific
1. Conservation and Management of natural resources, including Germplasm conservation (Biodiversity)	1.1 Ecosystem conservation and Management	(1) Eco-system analysis, ecological characterizatior and environmental concerns -- the characterization, classification, mapping and analysis of aquatic and terrestrial ecosystems, especially in relation to the functioning and use of ecosystems, climate hydrology, soil and land reform. (2) Biology and ecology of useful organisms and pests -- study of the distribution, production and dynamics of economically important plants, animals and fish and of the weeds, insect pests and diseases which affect them. (3) Land resources conservation and management research on the maintenance or improvement o the potential productivity of the land resource base and its components especially the edaphic climatic, hydrological and biological resources. (3.a) Soil and landform - research on monitorin maintaining or improving the physical, biological and chemical fertility of soils. (3.b) Water - research on the conservation anc management of rainfall and/or irrigation water. (3.c) Plants and animals - research on the factors affecting the productivity and conservation of natural vegetation including forests and rangelands, and research to monito natural populations of wildlife. (4) Aquatic Resources Conservation and Management - research on the maintenance or improvement of the potential productivity of the aquatic resource base, including research on the population dynamics of aquatic resources and their exploitation.
	1.2 Germplams Collection, Conservation, Characterization and Evaluation	(5) Collection, conservation, characterization and evaluation of germplasm - collection and maintenance of in vitro (and in situ) germplasm collections and the ditribution, characterization and documentation of collections.
2. Germplasm Enhancement and Breeding	2.1 Crops	(1) Crop germplasm enhancement and breeding - incorporating primitive and novel germplasm intc useful material for breeding purposes, as well as germplasm evaluation and conventional breedin
	2.2 Livestock	(2) Breed improvement including livestock and fish - breeding of improved livestock and fish.

Activity	Sub-Activity	Sub-Activity Specific
	2.3 Trees	(3) Tree germplasm improvement - breeding of improved trees including multipurpose trees and shrubs.
	2.4 Fish	(4) Breed improvement including livestock and fish - breeding of improved livestock and fish.
	(Generic)	(5) Techniques in molecular biology - development and application of modern methods in molecular biology such as genetic mapping and genetic markers to assist genetic enhancement and breeding programmes.
3. Production Systems Development and Management	3.1 Cropping Systems	(1) Plant protection (diseases, insect pests and weeds) - the economic control of disease, insect pests and weeds of crop and pasture species including systems for integrated pest management. (2) Seed production - increase of seed of elite materials, its certification and release. (3) Plant nutrition - crop, pasture and nutrient requirements, the availability, cycling and uptake of nutrients (including the role of mycorrhiza and other symbionts), and fertilizer management. (4) Post harvest technology - the development of ways of treating commodities to reduce losses in the storage and marketing system and improve the quality and value of foods through processing.
	3.2 Livestock Systems	(5) Animal health (including fish pests and diseases) - epidemiology, biology, immunology and genetics of animal and fish pests. (6) Livestock reproduction - reproductive biology of livestock and the reduction of reproductive wastage from reproductive diseases and other causes. (7) Livestock nutrition including studies on feeds, pastures and fodder - assessment of the nutritional status of livestock in relation to the availability of feed resources.
	3.3 Tree systems	(8) Silviculture and tree production - the management of trees in agroforestry, plantation and natural forest systems to enhance and sustain productivity.

Activity	Sub-Activity	Sub-Activity Specific
		(9) Tree nutrition - tree nutrients requirements, the availability, cycling and uptake of nutrients (including the role of mycorrhiza and other symbionts), and fertilizer management. (10) Tree protection (diseases, insect pests and weeds) - the economic control of disease, insec pests and weeds of tree species including systems for integrated pest management.
	3.4 Aquatic Systems	(11) Fish reproduction - reproductive biology of fish and the reduction of reproductive wastage from reproductive diseases and other causes. (12) Fish nutrition including studies on feeds - assessment of the nutritional status of fish in relation to the availability of feed resources.
	(Generic)	(13) Baseline studies of production systems (including constraint analysis and monitoring of sustainability) - characterization of the socio-economic and agricultural aspects of farming systems including analysis of constraints of production and sustainability. (14) Development and management of farming systems - design and testing of farming system and components for more productive and sustainable systems listed. (14.a) Cropping systems (14.b) Livestock sytems (14.c) Tree systems (14.d) Aquatic systems
4. Socio-economic, Public Policy and Public Management Research	4.1 Economic and Social Analysis	(1) Human nutrition - study of the relationship between such factors as nutritional compositior of commodities, food quality, income, price, socio-economic characteristics and the nutritional status of people. (2) Gender, human health and socio-cultural organization - analysis of gender, health and socio-cultural organization in agricultural communities. (3) Micro-economic and social analysis - research to determine the economic and social effects and implications of technologies or policies as they affect people, by examining farm, household or village data.

Activity	Sub-Activity	Sub-Activity Specific
		(4) Market and trade analysis - research to determine the market level economic conditions that may result from various technologies, institutions or policies and to analyze the impact of trade and macro-economic policy on markets. (5) Impact assessment and priority setting - research to assess the impact of research including cost/benefit analysis and to improve the analytical bases on which research priorities are set.
	4.2 Policy Analysis	(6) Policy analysis - research to determine the desirability of alternative policies from the viewpoint of society, taking into consideration productivity, equity , sustainability, and environmental concerns.
	4.3 Governance and Management of Public Systems	(7) Governance and management of public systems (including irrigation systems) - analysis of organizations for the management of public systems (including irrigation systems) and the development of innovations to improve their performance.
5.Institution Building	5.1Training and Conferences	(1) Training - human resource enhancement including specialized training courses, post graduate research, study tours, etc. (2) Conferences and seminars - to foster the build-up of NARS capacities and the effective functioning of international research collaboration; fora for discussion of scientific cooperation among the partners in the global System (IARCs, NARS, specialized institutions); stimulating horizontal transfer ofinformation and technology among NARS.
	5.2 Documentation, Publication, and Dissemination of Information	(3) Documentation, publication and dissemination of information - efforts to use systematically the global knowledge base in areas and disciplines of relevance to Centre's research programmes and to make available to NARS relevant information on progress and output of Centre's research programmes, making available relevant information through newsletters, publications, electronic media, and abstracting services.

Activity	Sub-Activity	Sub-Activity Specific
	5.3 Organization and Management Counselling	(4) Research on organization and management of institutes - analysis of research and research management processes aimed at the development/enhancement of approaches, methodologies and tools for conducting these processes. The procedures generated relate to: biological/technological research, i.e., technolog generation efforts and organization and management of NARS. (5) Institution building/advice to NARS - assisting NARS through the provision of advise and counsel. This covers a range of subjects/topics and includes the biological sciences (conduct of research) and the organization and managemen field (organization and management of NARS). Primary objective: build up of NARS capacities (institution building).
	5.4 Networks	(6) Networks - organizing, coordinating, managing or backstopping of collaborative research efforts among various partners in the global research systems to build up national capacities; the objectives cover a broad range and include: research/technology generation, global/regional/ topic specific information exchange, etc.

ACRONYMS AND ABBREVIATIONS

AEP	Agroecosystems Program
AFRNET	Pan-African Livestock Feed Resources Network, ILCA
BCMV	bean common mosaic virus
BGMV	bean golden mosaic virus
BNF	biological nitrogen fixation
BRU	Biotechnology Research Unit, CIAT
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CBN	Cassava Biotechnology Network
cDNA	complementary DNA
CD-ROM	compact disc-read only memory
CEEMAT	Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropical, France
CENARGEN	Centro Nacional de Recursos Genéticos, Brazil
CGIAR	Consultative Group on International Agricultural Research
CGM	cassava green spider mite
CGPRT	ESCAP Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots, and Tuber Crops in the Humid Tropics of Asia and the Pacific, Indonesia
CIDA	Canadian International Development Agency
CIFOR	Centre for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico
CIP	Centro Internacional de la Papa, Peru
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CLAIS	Comisión Latinoamericana de Investigación en Sorgo
CNI	Centro Nacional de Investigaciones, ICA, Colombia
CNPGC	Centro Nacional de Pesquisa de Gado de Corte, EMBRAPA, Brazil
CNPMF	Centro Nacional de Pesquisa de Mandioca e Fruticultura, EMBRAPA, Brazil

CPAC	Centro de Pesquisa Agropecuária dos Cerrados, EMBRAPA, Brazil
CRIN	Caribbean Rice Improvement Network, Dominican Republic
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
CVC	Corporación Autónoma Regional del Valle del Cauca, Colombia
DDG	Deputy Director General, CIAT
DNA	deoxyribonucleic acid (fundamental genetic material)
DSU	Data Services Unit, CIAT
ELISA	enzyme-linked immunosorbent assay
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária, Brazil
EMPASC	Empresa de Pesquisa Agropecuária de Santa Catarina, Brazil
EPR/EMR	External Program Review/External Management Review, CIAT
FAO	Food and Agriculture Organization of the United Nations, Italy
FUNDAEC	Fundación para la Aplicación y Enseñanza de la Ciencia, Colombia
FUNDAGRO	Fundación para el Desarrollo Agropecuario, Ecuador
GAS	General Administrative Services, CIAT
GDP	Germplasm Development Programs, CIAT
GIS	geographic information systems
GRU	Germplasm Resources Unit, CIAT
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit [German Agency for Technical Cooperation], Germany
HCN	hydrogen cyanide
HQ	headquarters
HPLC	high-performance liquid chromatography
IBPGR	International Board for Plant Genetic Resources (now IPGRI), Rome
IBSRAM	International Board of Soil Resources and Management, Bangkok
ICA	Instituto Colombiano Agropecuario, Colombia
ICM	integrated crop management
ICRAF	International Center for Research in Agroforestry, Nairobi, Kenya
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

IDB	Inter-American Development Bank, Washington D.C.
IDRC	International Development Research Centre, Canada
IDS	Institutional Development Support, CIAT
IEMVT	Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux, France
IFAD	International Fund for Agricultural Development, Italy
IFDC	International Fertilizer Development Center, Muscle Shoals
IFPRI	International Food Policy Research Institute, Washington D.C.
IICA	Instituto Interamericano de Cooperación para la Agricultura, San José, Costa Rica
IITA	International Institute of Tropical Agriculture, Ibadan, Nigeria
ILCA	International Livestock Center for Africa, Addis Ababa, Ethiopia
IMC	Information Management Committee, CIAT
IMSU	Information Management Systems Unit, CIAT
INGER	International Network for Genetic Enhancement of Rice, IRRI
INTSORMIL	International Sorghum and Millet Program, USA
IPDM	integrated pest and disease management
IPGRI	International Plant Genetic Resources Institute (formerly IBPGR), Rome
IPM	integrated pest management
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières, France
IRRI	International Rice Research Institute, Los Baños, Philippines
IUCN	International Union for Conservation of Nature and Natural Resources, Switzerland
IVDMD	in vitro dry-matter digestibility
IVITA	Institute Veterinario de Investigaciones Tropicales y de Altura, Peru
JICA	Japan International Cooperation Agency
LAN	local-area networks (computer networking)
LUP	Land Use Program, CIAT
m.a.s.l.	meters above sea level
MPFTS	multipurpose forage trees and shrubs
NARDIs	national agricultural research and development institutions

NARDS	national agricultural research and development systems
NARIs	national agricultural research institutions
NARS	national agricultural research systems
NFTA	Nitrogen Fixing Tree Association, USA
NGOs	nongovernmental organizations
NifTAL	Nitrogen Fixation by Tropical Agricultural Legumes, USA
NRI	National Resources Institute, England
OFI	Oxford Forestry Institute, United Kingdom
PCR	polymerase chain reaction
QTL	quantitative trait loci
R & D	research and development
RABAOC	Réseau d'Alimentation du Bétail d'Afrique de l'Ouest et Centrale, Ethiopia
RAPD	random amplified polymorphic DNA
RFLP	restriction fragment length polymorphism
RHBV	rice "hoja blanca" virus
RIEPT	Red Internacional de Evaluación de Pastos Tropicales
RMRD	Resource Management Research Division, CIAT
RMRP	Resource Management Research Programs, CIAT
RWW	rice water weevil
SDC	Swiss Development Cooperation, Switzerland
SEAFRAD	Southeast Asian Forages Research and Development Network
SP	Savannas Program, CIAT
TFP	Tropical Forages Program, CIAT
TPP	Tropical Pastures Program, CIAT
UNDP	United Nations Development Programme, New York
USAID	United States Agency for International Development, USA
VAM	vesicular-arbuscular mycorrhizae
VRU	Virology Research Unit, CIAT
WAN	widea-area networks (computer networking)
WARDA	West Africa Rice Development Association, Côte d'Ivoire