External Program and Management Review

October 2-9, 1994
Cali, Colombia

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

[Programs]

PROGRAM FOR THE EXTERNAL PROGRAM AND MANAGEMENT REVIEW
2-9 October 1994
CIAT, Cali, Colombia

Sunday, 02 October 1994

EPMR PANEL AGENDA

Monday, 03 October 1994

AM	I	Overview - Chair: R. Havener
08:00		Welcome & Introduction L. Vaccaro
08:15		CIAT Overview R. Havener
08:45		Management Overview F. Kramer
09:15		Research Overview W. Scowcroft
10:15		Coffee
10:45		Institutional Relations G. Häbich
11:15		Impact Assessment D. Pachico
11:45		Open Discussion
12:30		Lunch
PM	II	Research Presentations Moderator: W. Scowcroft
14:00		Genetic Diversity SRG - W. Roca -GRU (Rigoberto Hidalgo)

15:00		Germplasm Development SRG - W. Scowcroft -BRU (W. Roca)
16:00		Coffee
16:30		Pest and Diseases SRG - A. Bellotti -VRU (F. Morales)
17:30		Adjourn

Tuesday, 04 October 1994

AM	III	Research Presentations Moderator: R. Vera
08:00		Tropical Forages P. Kerridge
09:20		Overview Resource Management Research R. Vera
09:50		Coffee
10:20		Hillsides J. Ashby
11:40		Production Systems and Soil Management SRG R. Thomas
12:30		Lunch
PM	IV	Research Presentations
14:00		Tropical Lowlands R. Thomas
15:20		Coffee
15:50		Land Management SRG - G. Gallopin GIS (W. Bell/ P. Jones)

17:00		Adjourn

Wednesday, 5 October 1994

AM	V	Research Presentations Moderator - W. Scowcroft
08:00		Beans J. Kornegay
09:20		Rice M. Winslow/ L. Sanint
10:40		Coffee
11:10		Cassava R. Best
12:30		Lunch
14:00		Site Tour
15:30		Coffee
16:00		EPMR PANEL AGENDA

Thursday, 6 October 1994

VI EPMR PANEL AGENDA
All day

VII AM

ROOTS AND TUBERS REVIEW PANEL MEMBER(S)
-To meet with Cassava Program and related Units if desirable/possible.

VIII BOT PROGRAM COMMITTEE
All day

-Discussion with Directors and/or Programs, SRGs/Units.

Friday, 7 October 1994

IX EPMR PANEL AGENDA - ALL DAY

14:00-15:30 CIAT suggests a review discussion with Directors, Research Leaders and BOT Members

X BOT PROGRAM COMMITTEE (OPTIONAL)
- Interaction with Programs, SRGs and Units.

Saturday, 8 October 1994 (DETAILS TO BE PROVIDED)

Field trip to Carimagua - EPMR, BOT Program Committee, Staff

CIAT BOT EX-COM meeting

Sunday, 9 October 1994 (DETAILS TO BE PROVIDED)

Field trip to Villavicencio
Return to Bogotá and/or Cali late afternoon

ATTENDEES FOR CIAT
EXTERNAL PROGRAM AND MANAGEMENT REVIEW

EPMR MEMBERS

Grant Scobie	- Chairman
Juan Comerma	
Peter J. Dart	
Evert Jacobsen *	
Marilyn Mason	
Mgbanu Emchebe (consultant)	
Joan Joshi (consultant)	
Miguel Cahuêpê (consultant)	
Mike Collinson (Resource Person)	
Pammi Sachdeva (Resource Person)	
Vivian Timon (Panel Secretary)	

* Member of the Roots and Tubers Review Panel

BOARD OF TRUSTEES

Lucia de Vaccaro	- Chairman
Sam Jutzi	- Program Committee Chairman
Wallace Beversdorf	
Masashi Kobayashi	
Paul Vleck	
Fernando Homem de Melo (Ex Com meeting only)	

DIRECTORS

Robert Havener	- DG
Fritz Kramer	- DDG, F&A
William Scowcroft	- DDG, Research
Gerardo Häbich	- Ass. Dir, Inst. Relations
Raúl Vera	- Ass. Dir, RMR

RESEARCH LEADERS

Jaqueline Ashby	- Hillsides
Rupert Best	- Cassava
Peter Kerridge	- Tropical Forages
Julia Kornegay	- Beans
Mark Winslow/Luis Sanint	- Rice
Richard Thomas	- Tropical Lowlands

SCIENTIFIC RESOURCES GROUP & UNITS

Douglas Pachico	-Impact Assessment
William Roca GRU	-Genetic Diversity -Rigoberto Hidalgo
William Scowcroft BRU	-Germplasm Development -William Roca
Anthony Bellotti VRU	-Pest & Diseases -Francisco Morales
Richard Thomas	-Production Systems & Soil Management
Gilberto Gallopin GIS	-Land Management -William Bell\Peter Jones

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RECENT EVOLUTION OF CIAT AND PERSPECTIVES

FOR THE FUTURE

Background Paper Prepared for the

External Program and Management Review

September 1994

CIAT

Cali, Colombia

DRAFT

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RECENT EVOLUTION OF CIAT AND PERSPECTIVES FOR THE FUTURE

As an input to the 1994-95 External Program and Management Review of CIAT, this paper provides a brief overview of the development of CIAT's mission, strategy, mandate, and organization in the period 1989-94; followed by consideration of some of the principal trends in the external environment that are expected to significantly influence CIAT over the mid to long term; next, recent achievements at CIAT are reviewed to set a context for the future; and finally it concludes with a summary of CIAT's current strategy for the future.

PART I: CIAT EVOLUTION 1989-94

The 1990's has been a period of great dynamism during which CIAT has coevolved rapidly with its environment. This evolution has required several reappraisals of the principles that orient CIAT's thinking and actions. These principles, expressed in CIAT's mission statement, mandate, and strategy, and embodied in its organization, are ideally altered infrequently in order to provide an underlying consistency to daily, annual or even multi-year decisions. Changes in these principles are thus important signals that indicate shifts in CIAT's fundamental course.

Mission Statement

CIAT's Mission Statement for the 1990's reformulates its guiding principles.

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.(CIAT Strategic Plan, 1991 p 19)

Although this new statement conserves much of the essence of the previous version for the 1980's it also introduces significant modifications. First, a more prominent emphasis is given to overcoming hunger and poverty. This emphasis is consistent with CIAT's long term commitment to increasing production of foods consumed or produced primarily by the poor, thereby improving both food availability as well as incomes of the poor. This has been a major rationale for CIAT' commodity improvement efforts.

However, the statement for the 90's implies a broader view of technology generation that is not limited solely to "specific food commodities" as in the 1980's statement. Moreover, there is new mention of the "resource base" and "lasting increases" in output that reflect an enhanced awareness of the need to tackle a set of environmental problems that extend beyond the concern to achieve immediate increases in food production.

The new mission statement reaffirms technology generation as a key objective of CIAT, but makes more explicit the central role of science in its achievement. This underlines a heightened commitment by CIAT to advance the frontiers of knowledge rather than only concentrating narrowly on technology development. Finally, in recognition of the potential contribution of CIAT germplasm in Africa and Asia, the new statement deletes the earlier focus on "principally countries in Latin America and the Caribbean".

Research Strategy

CIAT's strategy for the 1990's and beyond flows naturally from its mission statement. The Center is fundamentally concerned with human welfare. It sees hunger and environmental degradation as two of the most serious threats to sustained human welfare. Germplasm development and resource management are inseparable and essential components for successfully achieving food security and environmental sustainability. They therefore constitute the key strategic elements of CIAT's research strategy.

CIAT has chosen to focus on adapting cultivated species to stressed environments and on the management of the resource base in these environments. There are three reasons for this choice. First, because of the vast increase in food production required to meet growing populations, favored lands alone will not be able to satisfy demand, particularly because over intensive exploitation of favored environments is already leading to significant problems of resource degradation. Second, stressed environments today provide food and incomes for large numbers of people whose welfare is tied to those environments. Third, considerable research attention is being given to favored lands both by other IARCs and by national systems.

Acid soils are a severe constraint limiting productivity over a large area of the tropics and sub-tropics. Developing acid tolerant germplasm and managing acid soils is a key part of the work agenda in all CIAT programs. Adaptation to drought is another crucial constraint that demands attention particularly in beans and cassava, but seasonal water deficits are also a critical constraint throughout the hillsides and in savanna grazing systems. A strategy that includes both natural resource management and germplasm research is essential to overcome major constraints like acid soils and water deficits.

Germplasm development research is directed at improving crop productivity through better understanding and utilization of the genetic resources of selected tropical species. This work has a direct impact on overcoming hunger by increasing food availability and security while also having an effect both on poverty and economic growth.

Germplasm research is very much a continuation of an ongoing effort for two decades, but nonetheless represents a departure from what previously had been commodity research. The germplasm approach is intended to more fully exploit CIAT's international comparative advantage by focussing its efforts more sharply on strategic genetic research while deemphasizing crop management or production systems research in a commodity context.

Responding to a greater awareness of the problems of environmental degradation, resource management research is basically a new initiative even though it also builds upon earlier work at CIAT. While many of the outputs of commodity research in the late 1980's were contributing to sustainable agriculture, and while genetic improvement of crops is an essential component of sustainable agricultural systems, nonetheless a land use systems approach is also required in order to achieve stability and productivity at the ecosystem level.

Resource management research focuses on important tropical American agroecosystems that are threatened by natural resource degradation largely associated with increasing land use intensity. CIAT also focuses on agroecosystems that have the potential for relieving such pressure. The aim of this research is to make agricultural production more sustainable by understanding the basic bio-physical and socio-economic processes within these agroecosystems. For resource management research to successfully preserve or enhance the environment, it must contribute to poverty alleviation and sustainable economic growth.

Both resource management and germplasm research are pursued within a strategy for cooperation with institutions in developing countries at the regional and national levels as well as links with other international centers and advanced research institutes in high income countries.

Mandate

Just as CIAT's mission statement and strategy have evolved since the late 1980's, so also has its mandate. In contrast to some other IARCs which are inherently identified with specific commodities, CIAT's germplasm research depends first on an explicit choice of commodity to be improved. This choice was subject of an intense scrutiny. Nineteen commodities were appraised for their contribution in Latin America in terms of the three criteria that emerge from the CIAT mission statement: poverty alleviation; productivity or economic growth; and sustainability of natural resources. CIAT's existing comparative advantage was also taken into account.

This analysis concluded that CIAT's existing commodity portfolio of beef and milk (through tropical forages), beans, cassava, and rice is highly relevant, especially when the potential impact of beans and cassava in Africa and Asia are also considered. In addition, CIAT decided to assume a secondary responsibility for sorghum and soybean improvement in the Americas, particularly for the acid infertile soils of the savannas.

This new operational mandate for the 1990's was tailored to fit in the context of the CGIAR system. The mandates for beans, cassava, and tropical forages adapted to lowland acid soils, are all global, but in Africa CIAT works through IITA in the case of cassava, and ILRI (then ILCA) for forages. Conversely, CIAT's responsibilities for rice, sorghum, and soybeans were strictly for Latin America and the Caribbean in coordination with IRRI, ICRISAT, and IITA respectively. Eventually CIAT opted not to engage in genetic improvement of sorghum and soybeans, but rather to link its ecoregional work on production systems in priority tropical American agroecosystems with germplasm provided by sister centers, including CIMMYT for maize and multipurpose forage trees and shrubs from ICRAF.

CIAT's new land resource mandate for the 1990's emerged in part out of its established comparative advantages in the late 1980's. Attention was drawn to the forest margins and savannas due to prior work in acid tolerant rice, cassava, and forage legumes and grasses, as well prior work on crop-pasture systems. Similarly, attention was drawn to the tropical American hillsides due to prior work on erosion control in cassava and bean cropping systems as well as the potential for using CIAT forages in this environment.

A subsequent GIS study to assess resource preservation problems in Latin America and the Caribbean as well as the feasibility of overcoming these problems, both confirmed the importance of the previously proposed agroecosystems as well as provided a rigorous quantitative identification of them. The seasonally dry areas and other agroecological zones were also observed to experience serious resource degradation, but CIAT chose to limit its attention in these other zones to analysis of land use policies and strategies and provision of adapted germplasm for specific commodities.

Organization

CIAT's initial strategic plan for the 1990's foresaw the continuation of four commodity programs (beans, cassava, rice, and tropical pastures) supported by a Training and Communication Support Program and six research support units (genetic resources, biotechnology, virology, agroecological studies, and data services). This essentially preserved the then existing structure. It was also anticipated that a new ecosystems program might be created to deal with sustainability.

The bold vision of the revised strategic plan for the 1990's and beyond, aimed to create an effective critical mass to deal with natural resource problems at the level of production systems in three agroecosystems as well as at the level of land use strategy across agroecosystems. This led to the formation of four new programs: forest margins, hillsides, savannas and land use (the latter absorbing the previous agroecological studies unit).

The existing commodity programs were recast as germplasm programs. This resulted in the transformation of the Tropical Pastures Program into the Tropical Forages Program focussing more strictly on improvement of the germplasm of key species while responsibility for the deployment of these species in production systems was transferred to the agroecosystem programs. This led ultimately to the transfer of 25% of the international personnel and resources of the Pastures Program to the new Savannas Program. At the same time the Forage Program expanded its mandate to include higher elevations to support the new Hillsides Program; global responsibility for forage development in tropical acid soils; and woody trees and shrubs of forage value for selected agroecosystems.

A new Institutional Development Support Program emerged to provide a broader range of services to strengthen national capacity than the prior Training and Communication Support Program. The new Program absorbed the Seed Unit, which in a few years completed its mission and was phased out.

These dramatic changes were seen in a dynamic context particularly in terms of resource allocation. It was projected that over the period 1991-2001 Core resources actually allocated to the Bean Program would decline 35%; cassava would fall 7%; rice would drop 17%; and tropical forages would decrease 38%. Simultaneously it was anticipated that the natural resource programs would grow steadily over the period, climbing from 2% of CIAT core research resources in 1991 to 42% in 2001.

The vigorous commitment to resource management research along with the new associated organization of eight essentially self sufficient interdisciplinary research programs, was predicated on obtaining at least some additional resources. However, in current US Dollars there was little change from actual 1989 core expenditures of $26.6

million to the 1994 estimate of $27.5 million. This means that actual Senior Staff research positions has held constant at 64 and anticipated expansion in the natural resource programs has not kept pace with plans. This shortfall in anticipated resources is inextricably associated with further organizational changes discussed below.

Other factors have also pressed for modification of the organizational structure implemented in 1992. There has been a long running concern to foster effective integration between the germplasm and natural resource programs. Moreover, since the last EPMR CIAT has been keenly aware of the need to foster greater intradisciplinary cooperation even among germplasm or natural resource management programs. Such interchange is seen as promoting the quality of science in CIAT and can help achieve economies of scale.

Throughout the CGIAR system there has also been a drive to seek greater accountability in IARC operations, with clear outputs, milestones, and terminal points for activities. These factors along with financial constraints that undermined the viability of the structure of eight essentially free standing programs, led CIAT to reorganize itself in the 1993 Action Plan.

This Action Plan introduced Projects and Scientific Resource Groups as important new organizational features of CIAT while reducing the number of Programs from eight to six. CIAT has retained all its mandate areas and adhered to the essence of its Strategic Plan, but decided to assume only selected responsibilities within those areas implemented through a portfolio of 18 project areas (See Appendix). Each of these project areas is intimately associated with the mandate and activities of the historical programs.

Project organization offers more transparent accountability to stakeholders; clearer definition of responsibilities both internally and in collaborative activities with partners; more flexibility in undertaking new or in terminating completed or unsuccessful activities; and a better base from which to seek further funding. To achieve these benefits, more intensive management is required; a corporate culture that fosters cooperation; and financial accounting by projects rather than traditional Programs or Units.

CIAT needs to retain core scientific competencies in key fields of expertise in order to execute and fund planned projects as well as to have the capacity to implement new initiatives that might attract funding. These competencies are housed in Scientific Resource Groups (SRG).

The SRGs provide a critical mass of disciplinary based talents that deliver research outputs in a structure where project areas or programs do not have an adequate internal critical mass. Moreover, the SRGs will encourage innovation within various disciplines. Five SRGs have been established: Genetic Diversity; Germplasm Development; Pest and Disease Management; Production Systems and Soil Management; Land Management.

The Action Plan has also consolidated the Programs from eight to six. The Bean, Cassava, Hillsides, Forage and Rice Programs continue essentially unchanged. The Forest Margin Program, which scarcely ever became operational due to budget constraints, has been absorbed as a project area within a new Tropical Lowlands Program which also includes the full activities of the existing Savannas Program. The Land Use Program has been converted to the Land Management SRG.

PART II: FUTURE TRENDS IN THE EXTERNAL ENVIRONMENT

Having reviewed recent institutional developments at CIAT as a background for addressing its future role, trends in the external environment that are expected to have a significant influence on CIAT's future development are now considered. These external trends are grouped in four themes: trends in science and technology; developments in national and regional research in agriculture and the environment in tropical America; trends in funding for international agricultural research; and finally, new directions in the international agricultural research system.

Trends in Science and Technology

There is no doubt that scientific and technological progress has been occurring at an accelerating rate and this appears likely to continue for the foreseeable future. Advance has been especially rapid in molecular biology and genetics. The new techniques and knowledge generated by biotechnology are highly relevant to solving many of the research problems on which CIAT has been working.

Despite the explosive progress in basic biotechnology research in the high income countries, it is not yet having a significant impact on tropical agriculture for a variety of reasons. First, this research is very poorly articulated with the applied problems of tropical agriculture, particularly those of food staples in which commercial interest is limited. Second, the field is in fact quite new and there is substantial time required to move from theoretical speculation to concrete solutions. Third, there are complicated issues of biosafety and intellectual property rights that in the short run could impede the utilization of some biotechnology derived applications.

Advanced biological research demands a considerable investment, not only due to the extended time period over which sustained research expenditure is required, but also because of the need for a critical mass of highly qualified specialized scientists and laboratory equipment. Since the field is so dynamic, constant investment is essential to keep personnel and equipment up to date.

Rapid change is likewise transforming data processing and communications technologies. The costs of both are likely to continue to fall dramatically thereby opening new opportunities in access to information and also in the mathematical modeling of complex systems. Furthermore, there will be radical changes in the capacity of institutions and communities in tropical America to obtain and process information, implying opportunities for the provision of new information services to them.

Trends in Agricultural Research Systems in Tropical America

The condition of national agricultural research in Latin America and the Caribbean seems to be becoming ever more variable, with a few countries retaining the potential for effective national research systems, while many others are experiencing an aggravated decline. As part of structural reform of the economy and the state, there has been a generalized substantial cutback in public sector spending that has seriously reduced resource allocation and research capacity of many national agricultural research institutes in tropical America.

Associated with declining funds for public agricultural research in much of tropical America, moves have come to encourage increased private investment and tighter links between public research and beneficiary constituencies. Such tendencies create a more diverse and complex institutional arena for CIAT to work in.

Additionally, both support for private research and the demand for public research are more likely to come from better organized groups and for commodities with higher growth prospects. Thus, on the one hand new funding opportunities for research are appearing for some commodities and regions, on the other hand staple foods, disadvantaged regions, and more marginal farmers all risk receiving reduced research attention.

New issues of environmental sustainablity are receiving more attention in a post Rio and UNCED world. New actors are putting new demands on the agenda. Ministries or agencies responsible for environmental issues are becoming more prominent just as non-governmental organizations are also becoming increasingly active in promoting environmental concerns related to agriculture.

Funding Trends for International Agricultural Research

International agricultural research has received very strong funding support for many years, mainly from the governments of the high income countries, development banks, private foundations (especially in the early years) and, until lately, to a limited extent from tropical countries which have generally lacked the financial capacity to make large contributions.

Despite the wide recognition by traditional donors of the high payoff from international agricultural research, unrestricted core funding to the IARCs (including CIAT) peaked in the late 1980's and has since declined in real terms. Funding geared to projects has become relatively more important than formerly and funding for basic or long term strategic research has become increasingly scarce. Development assistance in general has fallen, and a larger part of remaining resources are going to disaster relief.

A major innovation in funding has been Colombia's recent decision to become a member of the CGIAR as a significant donor to CIAT. Other new approaches to funding, including debt purchase and conversion; the establishment of an endowment fund; or the tapping of new donors, have yet to yield significant results. CIAT continues to explore the potential for semi-public investment from South America in a joint initiative for irrigated rice.

As a matter of current policy, CIAT has decided not to seek income from intellectual property rights on its innovations. Ventures with the private sector are not ruled out.

It is far from clear that there will be a renaissance of core funding from traditional sources, but prospects for greater project funding are seen as quite positive. There may be some demand for contracting CIAT research services in the region linked to bilateral projects.

Trends in the International Agricultural Research System

CIAT is acutely aware of its position in an international agricultural research system, carefully adapting its strategy to the priorities of the CGIAR. As discussed above, CIAT's mandate is crafted to complement those of its sister centers. Moreover, both CIAT's natural resource research strategy and focus on germplasm improvement with strength in applied biotechnology are explicitly rooted in CGIAR priorities.

Consequently, the ongoing fundamental reappraisal of the CGIAR is of the utmost importance for CIAT. While the final shape of any restructuring of the CGIAR is still to be determined, some broad outlines can be detected. Increasing emphasis is being given to system-wide programs both global and ecoregional, with CIAT anticipating significant participation in both.

At the global level, CIAT's research on forages for acid soils is a key element in any global livestock research program as would be its cassava research in the context of a roots and tubers program, or its bean research were a global legume program to emerge. All of these species have their center of origin in the Americas giving CIAT a comparative advantage as trustee of major collections of their genetic resources, both for their conservation and utilization. This makes CIAT a natural member of a global genetic resources program.

At the ecoregional level, TAC has recommended that CIAT be the convening center for the Latin American ecoregion. CIAT is already exploring with regional partners and sister centers how best to fulfill this responsibility. CIAT could also make a useful contribution to other ecoregional initiatives, particularly in the eastern African highlands where it has a strong presence through its regional bean research.

How these system-wide global and ecoregional programs will operate in practice is thus a matter of vital interest for CIAT. Dialogue is being actively pursued with national partners, other centers, TAC, CGIAR, and donors to clarify these issues and reach an optimal working arrangement.

PART III: SOME MAJOR CIAT RESEARCH ACHIEVEMENTS 1989-94

Review of the areas in which CIAT has had significant recent achievement helps point out where existing strengths are. These serve as a sound foundation on which to build for the future. Achievements will be presented by themes: genetic diversity; germplasm improvement; pest and disease management; soils and crop management; research planning methods; institutional development support in Latin America and the Caribbean; and global projection outside Latin America.

Genetic Diversity

The preservation of plant biodiversity as well as understanding patterns of agrobiodiversity have been areas of major advance at CIAT. For example, techniques are being developed for cryopreservaton or ultrafreezing for the conservation of cassava germplasm in the form of shoot tips. This would make possible the indefinite preservation of the plant genetic material.

Distinct patterns of diversity in gene pools and races have been found in beans through statistical analysis of biochemical and morphoagronomic markers. This finding permits a better basis for a strategy for conservation of phaseolus genetic resources. It also opens greater prospects for genetic improvement in beans in the future since lack of awareness of the patterns of variability has limited progress in bean breeding which has not exploited inter-gene pool variability in the past.

A large number of genetic markers have been generated through the development of cassava DNA libraries. These markers are being assembled into a linkage map which will help define the genome structure of cassava and to tag traits of agronomic interest.

CIAT has begun to assist national governments in implementing the Biodiversity Convention. Training courses and research collaboration have been started with countries in Latin America and the Caribbean to strengthen their capacity to study and manage their agro-biodiversity.

Core collections have been developed for beans and cassava as tools for the understanding of genetic variability. The bean core collection was formed by a novel approach that included the use of GIS and genetic data.

Thus, by working on its mandate species, CIAT has developed great experience in the characterization, understanding, and conservation of agrobiodiversity. This expertise can be readily applied to assisting nations in the region in managing their agrobiodiversity resources as well as to contributing to germplasm improvement.

Germplasm Improvement

Progress in germplasm improvement has been accelerated both by greater knowledge about genetic resources and also by the utilization of new techniques for the generation and selection of useful genetic variability. Anther culture has been developed into a routine tool in CIAT rice breeding. This technique produces large numbers of homozygous plants thereby speeding up the entire breeding process. This has helped introgress early maturity and good grain quality into cold tolerant germplasm.

Molecular markers (RAPDs) have been identified that are linked to the single dominant gene that controls apomixis in *Brachiaria*, the most important forage grass in tropical America, grown on over 50 million hectares. By allowing rapid identification of apomict among progeny of crosses between apomictic and sexual types, this will greatly speed up *Brachiaria* improvement and could even have applications in other crops.

Cloning of the genes that control starch composition in cassava is well advanced as is work on devising an efficient system for cassava transformation. Finishing this research could open new markets for cassava in industrial uses of starch, as has been achieved in maize, potatoes and other crops.

Classical breeding with conventional techniques also continues to play a major role at CIAT. This generates valuable information on inheritance and breeding techniques for national programs. It also produces a large number of parental materials and finished lines that serve the diverse needs of national breeders. Numerous varieties derived from CIAT materials are now widely grown in farmers' fields.

Pest and Disease Management

New research tools are significantly improving CIAT's capacity to overcome biotic constraints through resistance breeding, which continues to be a lower input and sustainable strategy for these problems.

DNA "fingerprinting" of *Magnaporta grisea*, the fungal pathogen of blast, the most widespread and damaging disease of rice in the world, has uncovered 14 distinct lineages. By understanding how different lineages infect different rice cultivars, it should be possible to obtain durable resistance to rice blast by selecting specific combinations of genes for entire lineages rather than for individual pathotypes as has been done heretofore.

Similarly, molecular markers have been used to find that major bean diseases like anthracnose and angular leaf spot, have coevolved with the bean host. This knowledge makes possible a strategy of introgressing resistance genes across bean gene pools to achieve higher and more stable levels of resistance.

Because only low levels of resistance to anthracnose are readily accessible in the forage legume *Stylosanthes guianensis*, a transgenic approach is being used. A transformation protocol using *Agrobacterium tumefaciens* has been developed that generates transgenic plants expressing marker genes. With this it should be possible to achieve expression of the RIP resistance gene from barley in *Stylosanthes.*

The molecular characterization of the rice hoja blanca virus has led to the design of novel virus resistant strategies to genetically engineer comercially grown rice cultivars. Control of this virus by plant transformation is being successfully attempted at CIAT by following the coat protein mediated cross protection strategy.

In addition to this work on genetic resistance, CIAT has recently given much greater attention than in the past to research on improved management components and methods as part of an integrated approach to disease and pest control.

Bacteria have been isolated both from cassava and tropical forage species that inhibit the growth of fungi that cause major diseases. The potential for using these beneficial microorganisms or their antibiotic products is being assessed.

Several biocontrol agents have been developed against the cassava hornworm. These include wasp parasites of hornworm eggs and a baculovirus that infects hornworm. The virus is particularly effective since it is prepared by simply grinding infected larvae in a blender then spraying the solution on the crop.

Green manures have been found to be an effective method of control of root rot pathogens in Africa

Integrated pest management packages have been developed for irrigated rice, snap beans, and field beans where pesticide use is excessive. These packages include population studies, estimation of threshold application levels for pesticides, and a variety of cultural control methods.

Production Systems and Soil Management

In agropastoral systems litter from crops and forages may be an important mechanism for recycling nutrients that could contribute to soil organic matter and affect soil biological properties. In the Colombian savannas rates of decomposition of residues from rice and maize were found to be as high as those for forage legumes and greater than those for forage grasses. A model was also validated for simulation of litter decomposition under tropical conditions.

It was found that carbon accumulation in introduced grass-legume pastures was substantially greater than in native savanna pastures. If this were a general phenomenon, it could be of global importance in moderating the rise of atmospheric carbon dioxide and consequent global warming.

On the highly acidic Oxisols and Ultisols of the Colombian savannas, nutrient efficiency is often low in maize and rice production. Studies have shown that rice responds strongly to lime, K and Mg. Similarly, applications of phosphorus and silicon also increased rice yields while silicon also improved grain quality.

Evaluations of erosion control practices by farmers in Rio Ovejas, Colombia, showed that they ranked Vetevier grass as the least desirable species for use in erosion control barriers even though technically it is the best option. Farmers preferred cut and carry forages for incorporation into live barriers. They also chose to locate conservation barriers on relatively good soil, as opposed to poor, degraded soils. Better understanding of farmer criteria with respect to erosion control practices can aid in the design of options with higher acceptance and utilization.

The potential of legume/grass pastures was highlighted by the rapid fall in animal liveweight gain that occurred when the legume *Centrosema* did not persist. Subsequent analysis showed that K nutrition of the legume is a key factor in its survival and that the grass competes vigorously for K.

Multi-year trials have indicated that continuous rice monocropping is not sustainable in the savannas as rice yields steadily drop due to increased weed populations and apparent soil nutrient imbalances. In contrast, animal weight gains are higher in grass/legume pastures established following a rice crop. This superiority is maintained until the legume is lost from the system.

These findings again confirm the great potential for increased productivity and sustainability that can be achieved through CIAT's strategy emphasizing nutrient cycling; agropastoral systems; and the incorporation of legumes into tropical pastures.

Research Planning Methods

Research will have little impact unless it is focussed on problems and opportunities that are truly significant. Both in order to plan its own research agenda and also to assist national institutions in their planning, CIAT is involved in methods development and applied research on research. This work is carried out on a relatively aggregate level through geographical information systems analysis and economic modeling, while innovations in participatory methods have been introduced at CIAT in order to plan research at a more location specific level.

CIAT has earned a leading position in GIS analysis in Latin America through the creation of a comprehensive climate data base that is linked to other data bases on soils, crop geography, transportation infrastructure, and policy variables such as legally restricted areas. Analyses of these data have been crucial tools both in the selection of priority agroecosystems, and also in the initial characterization of research problems and opportunities within these agroecosystems.

Several years of work by the team of CIAT economists has led to the development of models for the *ex ante* assessment of efficiency and equity impacts that are more sophisticated than those used by TAC or most other Centers. These models explicitly take into account changing market conditions over time; market effects of technical change; and differences between research alternatives in terms of projected change in productivity, probability of research success, and costs in time and resources.

At a more disaggregated or local level, participatory research methods have been developed in order to more fully incorporate local farmer knowledge in the design and evaluation of prototype technologies. These methods improve research efficiency both by improving feedback from farmers to researchers and also by enabling local communities to assume greater responsibility for adaptive research, thereby offering the possibility of relieving national systems of this task which generally they have not been able to afford to undertake. Extensive training materials on participatory methods have been prepared in Spanish, English, French, Portuguese, and are available in Chinese from IRRI.

Institution Development Support

Supporting the development of agricultural research systems in Latin America and the Caribbean has always been a high priority for CIAT, but this activity has recently undergone major changes deriving from a strategy that encourages greater self reliance by institutions in the region.

Due to the buildup over the years of trained human resources in the region, CIAT has been able to devise and implement a new strategy of "training trainers". This approach takes advantage of the highly capable people that are now in the national systems, and provides them with skills and methods to enable them to meet the training needs that in the past were handled by CIAT, for example, in-country training of extensionists or on farm researchers.

Likewise a major effort has been made to foster the development of regional research networks. These networks raise research efficiency by facilitating a greater exchange of information and materials. In some cases these networks even take on joint prioritization and division of responsibilities among network members to avoid duplication and exploit comparative advantages that exist among countries.

It must be noted, though, that during the financial stringencies of recent years, institutional support activities have been particularly hard hit. Nonetheless, CIAT is making progress at developing new information services based on advances in computing and information technologies that are increasingly within the reach of many national systems.

Global Projection

While the bulk of CIAT research was initially directed to Latin America and the Caribbean, the projection of the results of CIAT research world wide has become increasingly important. Several significant advances in this regard have occurred in recent years both in Africa and Asia.

In Africa CIAT's major presence has been in the eastern and southern highlands where half of CIAT's bean researchers have been working since the mid 1980's, with a current total of eight international scientists. This effort has led to the creation of strong self governing regional bean research networks; substantial strengthening of national research capacity; and a striking broadening of the bean genetic base through the introduction of much new genetic diversity from the Americas including some 16 materials that have been released as varieties in seven countries since 1989.

Africa is also a major priority for cassava. In 1989 CIAT's first outposted cassava scientist was stationed at IITA in Nigeria. In addition, CIAT has continued a serious effort to identify in the Americas predators of major cassava pests in Africa. Another large project has linked the improvement of cassava adapted to the semi-arid northeast of Brazil to the evaluation of its performance in West Africa.

Forage germplasm from CIAT has also been extensively evaluated in West Africa. Grass, legume, and multi-purpose trees and shrubs has been tested at over 15 sites in collaboration with ILCA.

In Asia CIAT's biggest effort is in cassava where two scientists are outposted in Thailand. The genetic base of cassava in Asia is extremely narrow and varieties with CIAT germplasm which broaden the genetic base are already being grown by farmers in China and Thailand.

Since 1992 a forage scientist has been outposted at IRRI in order to foster a germplasm evaluation network. The forage legume *Stylosanthes guianensis* has been successfully adopted in southern China.

PART IV: CIAT'S VISION FOR THE FUTURE

Overview

From now through the onset of the next century the prospect is one of onrushing change: change in scientific knowledge and techniques; change in the agricultural sector and its research system, both national and international; change in the funding base for agricultural research. The direction and destiny of these changes can not be fully perceived from today's vantage point, but there is no doubting that change will be massive, relentless, and unpredictable.

An effective institution, one that makes a difference to human welfare, must have the flexibility to adjust to these cross currents of change, while still steering a steady course to a clear goal. The complex problems of attaining food security for an ever growing population without doing irremediable harm to the environment and natural resource base, can not be resolved by improvisation and requires clarity of vision and purpose.

CIAT's self image is crystal clear: it is a development oriented agricultural research institute dedicated to contributing to the development of sustainable agricultural production as a means of bringing about lasting well-being of people in tropical and sub-tropical developing countries.

CIAT is an international autonomous non-profit institute, created through an agreement between the UNDP and the IBRD. The Center's headquarters agreement is anchored under Colombian law. The Board of Trustees is responsible for setting objectives and policy, and for overseeing their implementation. Responsibility for executing policy and achieving CIAT goals is delegated to the Director General, and through the DG to the management team.

CIAT predates the CGIAR system to which it has been strongly linked since the system's creation. It is committed to the goals of the CGIAR and to making an active, positive contribution to reaching these goals.

CIAT intends to unflinchingly pursue its purpose of contributing to the alleviation of hunger and poverty in tropical developing countries by applying science to the generation of technology leading to lasting increases in food production.

To succeed in this endeavor, CIAT must have the internal capacity for change, the capacity to sustain its relevance in a dynamic world. CIAT will dare to have the vision to undertake tasks that require a long term commitment, but will have the flexibility and creativity to respond to changing circumstances.

Strategy and Organization

Currently a strategy is being implemented to coalesce CIAT's energies in five core competencies, each of which addresses a major set of opportunities or challenges, and each of which provides a focus for mobilizing and organizing CIAT's efforts.

- Genetic Diversity is concerned to conserve and understand genetic diversity in key food species and their associated agroecologies.

- Germplasm Improvement generates new useful genetic variation as well as new knowledge and methods to increase productivity of priority food species.

- Pest and Disease Management provides technology components and information to aid control of ever evolving problems while avoiding dependence on agrochemicals.

- Production Systems and Soil Management develops technology components and information to enhance and sustain the productivity of tropical soils.

- Land Management aims to understand how to modify trends and policies that degrade land resources.

Within each of these competencies CIAT will maintain a sufficient mass of intellectual strength and physical capacity to provide a basis for the delivery of high payoff outputs. The scale, composition, and specific activities of each competency will be adapted to changing circumstances, but will be consistently rooted in the framework of long term commitments within the CGIAR for global and ecoregional responsibilities.

Current long term global responsibilities for CIAT include the improvement and conservation of the genetic resources of cassava, common beans, and tropical forages adapted to acid soils. Due to its location in the center of diversity for these species, and due to the accumulated knowledge and human capital that CIAT has acquired through years of research on these species, CIAT has unique comparative advantages for working on them. The capacities of the competency areas will be harnessed to the tasks involved in meeting these global obligations of the highest priority.

At the same time, CIAT will undertake long term ecoregional activities in Latin America and the Caribbean. Initially these efforts are inspired within the context of CIAT's role in the CGIAR system, and include regional responsibilities for rice as well as for the hillsides and tropical lowland agroecologies. Ultimately, the ecoregional agenda will emerge out of a multi-institutional consensus and will be implemented in close partnership with national and regional institutions.

Projects are a key operational means of reaching these global and ecoregional objectives from a basis of strength in the competency areas. Framing CIAT's global work on cassava, common beans, and tropical forages in a project structure, provides unsurpassed transparency in accountability to the CGIAR.

Likewise, a project structure gives the flexibility essential to permit the construction of a truly responsive regional agenda. Moreover, projects are a valuable tool for implementing joint ventures with national and regional partners which require clarity in mutual commitments and resource allocations as well as visible milestones by which to measure progress.

While projects lend needed flexibility and transparency in meeting the demands of a changing world by drawing on the competencies of the Scientific Resource Groups, direction and coherence in the project portfolio are derived from the research programs.

Programs are the internal source for the expression of demand and the prioritization of projects, while the SRGs are sources of supply capacity for delivering outputs through projects. Programs foster goal orientation around a set of interrelated problems and opportunities. Programs catalyze a multidisciplinary approach to complex issues and are the internal focal point for project planning, funding, implementation, and evaluation. Programs are centered on the achievement of concrete outputs.

The scientific competency areas will be the most permanent organizational feature in the future. Programs are also enduring entities as expressions of strategic decisions to pursue a set of mid to long range objectives. Nonetheless, periodic strategic reviews will modify the suite of programs. Projects, as the most transitory operational unit, provide institutional flexibility, but even projects are generally planned and implemented over a three to five year time horizon.

Global Germplasm Research

CIAT will conduct strategic and applied research to exploit the global potential of the germplasm of common beans, cassava, and selected genera of forages adapted to tropical acid soils.

Beans are the most important grain legume in the developing world with an annual world value of production almost equal to that of the combined value of all other food legumes on which research is done in the CGIAR. Beans are the second most important source of protein and the third most important source of calories in eastern and southern Africa. They are the third leading source of protein in Latin America. The CIAT bean program is the largest food legume research program in the CGIAR.

Cassava has been ranked by TAC as the highest priority root or tuber crop in the developing world. It is the fourth most important source of calories in the tropics world wide, and the single most important in sub-Saharan Africa. Cassava is the most important root or tuber in Africa and Latin America. In many countries it is the cheapest source of calories so that consumption levels are generally highest among the poor. Diversification into new cassava products and markets can provide greater income and employment opportunities.

Poor animal nutrition is a major constraint on cattle productivity in Latin America. Beef and milk, which depend on forages in Latin America, are the most important sources of protein in the diet when taken together. These products constitute the largest items of food expenditures in Tropical America, even among the urban poor. Over 110 million hectares of acid soils in lowland tropical America are in pastures, supporting about 30% of the region's cattle stock. Pastures are the leading land use in the acid soils apart from native forest, and improved pastures can contribute to enhancing the soil resource. Africa and Asia combined have a total area of acid soils slightly larger than that of Latin America, and acid tolerant forages could play an important role there.

CIAT brings several comparative advantages which help define its role in global germplasm research on these important mandate species. Its unmatched germplasm collections give a unique capacity for characterization and utilization of the broadest range extant of genetic variability within the center or origin of the species where most major pests and diseases have also coevolved.

Work on several species also creates economies of scale in applied biotechnology that can only be equaled by a handful of the largest national programs. This strength in biotechnology enables CIAT to tap the latest advances in basic research. Situated in the tropics with a history of close collaboration with national programs throughout the world, CIAT has direct experience with, and an unparalleled wide knowledge of, tropical production conditions and problems.

Thus, CIAT is uniquely able to link advanced research techniques to the most strategic problems in its global mandate species.The combination of these strengths helps define CIAT's key roles for germplasm research in a global system.

The improvement of the germplasm of CIAT's globally mandated species depends critically on preserving and understanding their genetic diversity. This is the a very high priority activity for CIAT which has the world's largest and best collections of genetic diversity for cassava, beans, and tropical forages adapted to acid soils. Major research efforts are underway for each of these to develop improved methods of germplasm conservation and also to better understand patterns of genetic diversity.

Not only does CIAT strive to preserve this germplasm, but also to insure that its potential is more fully utilized in agriculture. This is achieved through an active effort of genetic improvement which includes a wide range of research endeavors: characterization and understanding of strategic production constraints; identification of agronomically desirable traits; studies of the genetics and heritability of these traits; development of methods for more efficient recombination of and selection for desirable traits; and generation of gene pools which combine multiple traits.
Both classical breeding techniques and biotechnology make major contributions to this work. In forages, the emphasis is on germplasm evaluation rather than breeding which is restricted to a few major traits on targeted priority species.

Significant effort is made to transfer outputs from germplasm research to national systems and adapt them to the needs of NARS. This includes strengthening NARS capacity through training and information services. Also important is linking NARS into research networks that promote information and technology exchange among them as well as joint prioritization and division of labor to optimize utilization of their scarce research resources.

The particular characteristics of the different mandate species sometimes lead to special attention to specific issues. For example, the potential for cassava to be transformed into a variety of products has resulted in research to genetically modify cassava quality traits and develop novel prototype products and processes.

Research on CIAT mandate species is concentrated on but not limited to their genetic improvement alone. For example, rhizobia are studied and selected to improve biological nitrogen fixation in beans and forage legumes. Similarly, beneficial microorganism are tested for control of pathogens of forages and cassava, while natural enemies of cassava pests are a significant research area.

Finally, research on CIAT mandate species will likely be more tightly articulated with CG systemwide programs. Genetic resource conservation and utilization definitely will be closely linked to systemwide efforts on certain issues. Likewise, divisions of responsibilities could change with the emergence of a systemwide root and tuber program, and forage research will doubtlessly play a key part in the new global livestock initiative. The precise nature of these relations is still to be established.

Ecoregional Research

Since its conception in the late 1960's, CIAT has had a special and intimate relation with the Latin America and Caribbean region. Initially CIAT priorities and mandates were defined solely in the context of the region. Only later did CIAT accept global responsibilities for crops that it had originally selected for their importance in Latin America and the Caribbean.

Research on rice, the most important calorie staple produced in the tropical Americas, is currently CIAT's oldest ecoregional responsibility. Drawing on the global strategic research conducted by IRRI, CIAT has concentrated on adapting this germplasm to the particular circumstances of the neotropics: local strains of rice blast; the hoja blanca virus, endemic to the Americas; and materials adapted to the acid soils of the savannas.

CIAT plans to continue this research in the context of a new strategic alliance with the rice sector in the region. This new partnership will empower public and semi-public institutions in the region in setting the regional research agenda. This will become, over time, a regional responsibility for implementation and funding, with CIAT playing a highly selective strategic support role.

Agroecosystem based research that addresses major natural resource management problems or opportunities has become the principle focus of CIAT's ecoregional efforts in recent years.

This work is concentrated on the savannas and forest margins agroecosystems of the lowland tropics, and the mid-altitude hills of Central America and the Andes.

The savannas of South America are an immense land resource of 240,000,000 hectares where frontier expansion has more than tripled crop and pastures area over the last two decades. Still, over half of the land is unutilized. Thus, the savannas are a huge untapped resource that could make a major contribution to food production. This potential, though, is limited by a lack of technology adapted to the acid infertile soils of the savannas. Moreover, current management practices are already incurring deterioration of the resource base.

Frontier expansion has also been devastating the tropical lowland forests. Expansion of crops and pastures has been occurring at a rate similar to that of the savannas, resulting in massive deforestation and degradation of the land resource. This expansion continues in part because the performance of existing production systems degenerates rapidly. CIAT concentrates on developing ecologically and economically sound production systems for the over 40,000,000 hectares of already cleared forest. More sustainable use of already cleared land could greatly reduce pressures for further deforestation.

Hillsides cover 95,000,000 hectares of land, much of which is already intensively used and 25,000,000 hectares of which is already highly degraded. This agroecosystem supports over 20,000,000 people, most of whom depend on low incomes from small farms. Widespread poverty drives many of them to overexploit their scarce resources, thereby not only undermining the sustainability of their own livelihoods, but also causing degradation of the downstream environment.

In order to insure the sustainability of the resources of these agroecosystems, economically viable production systems tied to ecologically sound natural resource management systems have to be introduced. For this to happen a supportive policy regime must be in place. Consequently, CIAT research focuses on technology generation and evaluation; understanding the ecology of critical natural resource processes; and developing policy options that promote sustainable land management practices.

The aim of developing prototype technologies is to allow lasting improvement in the efficiency of resource use while controlling or reversing soil and water degradation. To achieve this, component technologies are evaluated in a systems context through trials conducted on farm. Farmer evaluation of technologies is an especially high priority in the hillsides and forest margins where conditions are highly heterogenous. CIAT germplasm research, as well as that of other IARCs, will be important sources of component technology.

Construction of models to understand complex interactions between soil chemical, physical, and biological processes in sequential and agropastoral systems provide crucial understanding of the long term consequences of alternative management systems that typically can not be observed in the short run in on farm trials. Identification of easily observable indicators of subtle and gradual processes is an important objective.

Many negative outcomes of unsustainable practices occur either off farm or at a landscape rather than at the farm or field level. Thus, studies are conducted on spatial and intertemporal dynamics of land use, including socioeconomic aspects, in order to understand these off farm and landscape effects. Such studies are also a valuable tool for extrapolation and are linked to policy research. In the hillsides, where farm sizes are particularly small, community based participatory approaches to resource management decision making is vital.

CIAT can produce crucial strategic outputs relevant to a variety of ecoregional problems. However, the range of ecoregional issues is so vast, and many of problems so complex, that CIAT's contribution can only be a part of the solution. Vigorous participation and significant contributions from a gamut of national and regional institutions is vital to achieving success. Consequently, CIAT is keenly aware of the need to act as a player in regional multi-institutional consortia.

Ultimately, institutions from the region are the major partners in these consortia, undertaking most responsibilities and supplying most of the resources. Institutions from the region must also have a strong voice in the setting of the ecoregional agenda. CIAT's ecoregional activities will be carefully crafted to respond to the demand expressed in this agenda.

CIAT's will play a dual role response to this ecoregional agenda: one technical, the other institutional. Its technical role will be as a supplier of strategic research outputs consistent with its strengths and comparative advantages. The Center's institutional role will be that of a convener in the CGIAR system.

Initially the latter entails a major effort with national and regional institutions, including IICA, IDB, and CATIE, to lay a foundation on which regional and sub-regional consensus can be erected. CIAT will provide institutional neutrality and a technical perspective to these priority decisions that rest, in the final analysis, with institutions from the region. In addition to participating in this process, CIAT will also serve as a mechanism to articulate this regional agenda with the global activities of the CGIAR, insuring complementarily and facilitating the operations of other Centers in the region.

To survive, an ecoregional approach must ultimately be adapted to regional conditions. It will emerge from an evolutionary process subjected to the selection pressures endemic to the region. No doubt some characters with clear descent from CIAT's past and present will be expressed, but a fully evolved ecoregional mechanism will be much more, and perhaps significantly different, from current CIAT or CGIAR activities in the region.

Synergies Between Global Germplasm and Ecoregional Research

Insuring adequate food supplies while preserving the natural resource base is a complex challenge which does not have a simple, one dimensional solution. Crop productivity can not be sustained if the resource base is degraded, and the number of poor and hungry will be multiplied many fold if sufficient food is not produced. Hence, crop productivity must be raised and the management of natural resources must be sustainable.

CIAT strategy accepts that these interrelated problems can only be attacked in a integrated fashion: combining genetic improvement of crops with management of natural resources; and combining local action with a global perspective.

Cognizant of the complexity of this task; of its own assets and limitations; and of the contributions of other IARCs; CIAT concentrates its efforts on improving the productivity of species cultivated in stressed environments and on maintaining the productivity of the resource base in stressed environments. Thus, to a very significant degree there will be correspondence between the constraints on the crops, and the constraints on the management of the resource base.

Adaptation to acid soils is a major focus of germplasm improvement for forages, upland rice and to a lesser extent, for beans and cassava. Management of acid soils is a crucial issue for the tropical lowlands of the Americas, and also for the hillsides. Thus, there are clear synergies between several lines of research at CIAT.

Similarly, water deficit is a major constraint for cassava and bean production; for savanna grazing systems; in the hillsides; and for upland rice. Moreover, drought is a more severe problem when soils are acid. Hence, again there are great synergies between several lines of research at CIAT. Further examples could be cited, and CIAT's strategy will be to exploit such synergies.

In the mid 1980's CIAT was attacking problems principally through germplasm improvement. This continues to be a major effort, but it is now complemented by research on priority natural resource problems.

CIAT focuses its natural resource research on Latin America and the Caribbean, where its mandate crops have their origin and remain important, and where it has established invaluable working relationships through a long experience of collaboration with national systems.

While thus able to act locally, CIAT will also think globally as part of the CGIAR system, serving as an ecoregional convener to facilitate the activities of other centers in the region.

Likewise, CIAT germplasm improvement will address local needs in Latin America and the Caribbean, and will also be relevant to problems world wide. Thus, germplasm developed in one region will be distributed and utilized globally.

Operating as a center with dual global and ecoregional concerns creates exceptional opportunities for the delivery of high payoff outputs, but is a demanding challenge. To meet this challenge CIAT has had to reorganize itself internally into a more complex structure consisting of programs, competency areas, and projects. This new structure is vital to be effective both globally and regionally, both in germplasm improvement and resource management.

For the future, then, CIAT will proceed with fixity of purpose: to use science to generate agricultural technology that contributes to poverty alleviation, economic growth, and sustainability. To reach this goal both globally and regionally, CIAT will have to display the creativity and flexibility to evolve in response to the demands of a changing external environment. Current strategy and organization are designed to achieve these end

Appendix: Project Areas

Beans: *Phaseolus* Diversity

Beans: Yield Stability

Beans: Sustaining Productivity in Latin America and the Caribbean

Beans: Sustaining Productivity in Sub-Saharan Africa

Cassava: *Manihot* Diversity

Cassava: Improved Gene Pools

Cassava: Integrated Crop Management

Cassava: Markets

Rice: Lowland Rice Improvement

Rice: Upland rice Improvement

Forages: Diversity

Forages: Adaptation to Acid Soils

Forages: Improvement

Hillsides: Andean

Hillsides: Central America

Tropical Lowlands: Brazilian Cerrados

Tropical Lowlands: Colombian Llanos

Tropical Lowlands: Forest Margins

Programs

BEAN PROGRAM
1989-1994 EXECUTIVE SUMMARY

The Bean Program underwent two intensive reviews in the last five years. In both reviews the Program was commended for the impact of its germplasm on production, the quality of its science, and the organization and management of its regional networks. We are proud of our achievements: More than 135 CIAT-based bean varieties have been released in over 40 countries and are grown on more than 700,000 ha; nearly 40% of the total bean production area in Central America is planted with BGMV resistant varieties, sustaining bean production in this region; the multi-disease resistance CIAT line, EMGOPA Ouro, is now the second most recommended variety in Brazil; improved climbing beans in Rwanda were being grown by 43% of the bean farmers prior to the outbreak of civil war; the Bean Program has also been a pioneer in the development of five regional research networks which have been successful in strengthening research capacity of national programs. In 1993, our oldest network, PROFRIJOL, in Central America, was devolved to local coordination; two other networks will be devolved in the next two years. The productivity and quality of our research is also reflected in over 110 research papers that have been published in international journals since 1989.

Yet, because of a 35% reduction in Program scientific positions and operational funds in recent years, the ability of the Bean Program to execute its global mandate is now in question. Most alarming is the reduction of headquarter plant breeders from 3 to 1.3 positions and the near absence of outposted staff in Latin America. By 1996, the stream of new bean technologies going to NARS will be reduced by nearly 50%. Our ability to support the newly devolved networks will be limited and their future may be jeopardized. The CGIAR needs to address the long term implications of a much reduced Bean Program upon global bean research and third-world bean productivity.

Research Outlook: The overall goal of the Bean Program--to develop technologies that are amenable to the needs of resource poor farmers--has not changed since the Program's inception in 1974. Where possible we look for genetic solutions to production constraints. For intractable problems, we develop integrated control practices, such as IPM for whitefly in Latin America and soil fertility management for root rot control in Africa. Farmers are an integral part of the research process. Our anthropologists and sociologists have been key players in developing methodologies to increase farmer input into technology testing.

There has been a significant evolution within the Bean Program research agenda since 1989. A complete description of our research activities can be found in the Bean Program Annual Reports. Five examples have been chosen to illustrate some of the program's activities and outputs of the last five years.

1.) The Program has assumed greater responsibility for characterization of the *Phaseolus* germplasm collection housed at CIAT. In 1992, we created a research position specifically for germplasm characterization. Through implementation of the *core collection* concept and the analysis of passport data using GIS data, valuable new sources of bean germplasm with greater resistance/tolerance to difficult constraints, such a low soil phosphorus, have been identified and incorporated into breeding programs.

2.) Molecular techniques are being used to understand host\pathogen interactions, race diversity, evolution and distribution analyses. We will soon be able to target tailored gene combinations for specific pathogen populations with greater accuracy and longer durability.

3.) Significant genetic variation for low soil phosphorus tolerance has been found in germplasm from southern Mexico, Colombia, Ecuador, Peru and southern Africa. Collaborative work with several advanced institutions and regional networks is providing a greater understanding of specific traits responsible for efficient P uptake and internal use. Plant and rhizobial traits responsible for improved BNF in low P soils are also being identified, and rhizobial population dynamics in different soil environments are being studied.

4.) Major advances in understanding and increasing yield potential in Mesoamerican bean types were obtained by maximizing genetic variability through inter-racial and inter-gene pool crosses. Large-seeded Andean types are not as amenable to inter-gene pool crosses, but yield gains within this group have been achieved through modification of growth habits and phenology. Yield breeding strategies for both gene pools have been developed.

5.) The regional networks have pioneered the development of new methodologies to involve farmers in research. In addition to on-farm testing of breeding lines, expert farmers are also being brought to research stations to evaluate large numbers of genotypes. Farmer participation in research is extending to other areas such as: the development of disease control practices, management of soil fertility and erosion control, and novel seed multiplication and distribution methods.

Strategy for Research in the Future: To keep up with future bean production demands in Latin America and Africa, new technologies, some obtained through breakthrough-science, are needed. Strong collaboration with national programs will be required to adapt and test new technologies with farmers. Our research agenda has been organized into a series of 13 projects within four *mega* project areas. Most on-going activities will continue within the new project structure. The first two projects concentrate on strategic research to improve bean productivity. These are: 1.) Understanding *Phaseolus* genetic diversity, and 2.) Improving yield stability in beans. The last two projects are important for adaptive and ecoregional research, and to provide support to the research networks: 3.) Sustaining bean productivity in Latin America, and 4.) Sustaining bean productivity in Africa. More detail concerning the projects is available in CIAT's Action Plan, (Supplement A).

Several new research initiatives are being developed. A fact finding visit to several Eastern European countries has recently been undertaken to explore the possibility of establishing a regional research network in Eastern Europe. The Seeds of Hope project will help restock genetic variability of traditional food crops in war-ravaged Rwanda. The Bean program aims to produce and distribute over 200 tons of seed of 200 different Rwandan bean varieties. The Andean Integrated Pest Management Project, Phase II, was recently approved by IDRC to evaluate the adoption and impact of IPM technologies with small scale bean farmers.

INTRODUCTION

Goal and Objectives of the Bean Program
The Bean Program has the CGIAR global mandate *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.* We fulfill our mission using a two pronged approach: 1.) Strategic research to understand and exploit *Phaseolus* genetic resources for germplasm improvement and 2.) Strengthening of national program capacity to improve bean productivity through participation in research networks. The Bean Program operates as a multidisciplinary team with scientists based in Latin America and Africa.

Importance of Beans
Nearly 10 million tons of dry beans are produced annually worldwide, of which 80% occurs in the developing world. The total value of production is US $6.2 billion. Beans are the most important food legume for over 500 million people in Latin America and in Eastern and Southern Africa. Beans are the second most important source of protein after maize in Africa (and thus critical for amino acid complementation), and a significant source of calories. In Latin America, beans are the forth major source of protein, closely following milk and beef in per capita daily consumption. Beans are often considered the poor man's meat; a unit of bean protein costs about one-fourth that of beef protein. Like other legumes, beans are also an important source of dietary iron and folic acid, especially important for childbearing women with limited access to animal products. Nearly twice as many beans are produced in Latin America as in Africa, but the demand for beans is growing faster in Africa where production growth lags behind population increase.

History and Impact of the Bean Program (1989 - 1994)
The Bean Program underwent two major reviews of its activities in 1989 and 1992. During the first review, the Program developed a five-year strategic plan to respond constructively to new challenges of the 1990's. The second review looked at how the Bean Program had adapted to these challenges and to changes in the global and donor environments. In both reviews, the Bean Program was commended for the impact of its germplasm on production, the quality of its science, and for the highly effective management of its research networks.

More than 135 CIAT-based bean varieties have been released by NARS in more than 40 countries. These varieties are being grown on more than 700,000 ha, primarily in Latin America, where the Program has been operating longest. In Central America, nearly 40% of the total bean production area is planted with CIAT-based varieties that are resistant to Bean Golden Mosaic Virus. Without BGMV resistance, bean production in Central America would have declined significantly in the last decade, malnutrition would have increased, and the economic well-being of millions of small farmers would have been jeopardized. In Brazil, the largest bean producer country, more than 25 CIAT-based varieties are being grown on 25% of the total bean area in the states of Espirito Santo, Goias, Minas Gerais, and Rio de Janeiro. The most successful CIAT line in Brazil is EMGOPA 201 Ouro. The advantages of Ouro over other Brazilian varieties is its multiple disease resistance (bean common mosaic virus, rust, angular leafspot, and anthracnose) and stable yield. The release of Ouro gave rise to a new market class of beans in Brazil and increased genetic diversity. Ouro is now the second most recommended variety in nearly 20 bean growing states; only Carioca, which was released in 1971 is more widely grown. The impact of CIAT-bean varieties in Africa is more recent. In Rwanda, before civil war erupted, 43% of bean farmers were cultivating 17,000 ha with improved climbing bean varieties introduced by CIAT and ISAR, the national program. These new varieties were providing Rwanda, a country with desperate nutritional deficiencies, an additional annual production of 45 thousand tons of beans . The total global value of additional bean production attributed to farmer adoption of CIAT-based bean varieties is US $86.5 million per annum, with an internal rate of return to the CGIAR investment in bean research of 24.5%. Besides impact on bean production and productivity, the Bean Program has also made a significant contribution to science. Since 1989, over 110 research papers have been published in international refereed journals.

The Bean Program has been a pioneer in the development of regional research networks. Five regional bean networks were fully operational by 1989. Two regional networks (PROFRIJOL and PROFRIZA) are located in Latin America, and three networks (EABRN, RESAPAC, and SADC) are in Eastern and Southern Africa. All five networks are funded through complementary or highly restricted core funds donated by the SDC, CIDA, and USAID. The network model of the Bean Program has been successful in empowering and strengthening national programs. We see our long term role in the networks as providers of technological support, not as network managers. In 1993, CIAT devolved its longest running network, PROFRIJOL, to local coordination. We support PROFRIJOL through constraint-specific breeding activities at headquarters, frequent visits to Central America and the Caribbean, and collaborative research projects. The Bean Program Leader participates as a nonvoting adviser to PROFRIJOL's steering committee. Two other networks, RESAPAC and PROFRIZA, are scheduled to be devolved during 1995 and 1996, respectively. In addition to the regional networks, a four-year bilateral project between CIAT and Malawi was funded by ODA, England in 1994.

In spite of the Bean Program's successful execution of its global mandate, during 1989-1994 the internal and external environments were not favorable for bean research, and the program faced a serious erosion of resources. The number of senior scientists and operational funds was reduced by more than 35%. At headquarters, scientific staff dropped from 12 to 8 positions; most significantly, the number of plant breeders went from 3 to 1.3. Latin America outreach staff went from 4 to 1. In Africa, 3 regional positions were cut. There has been a gradual decline in research activities. The amount of land planted in experimental bean plots at CIAT went from 134 ha in 1989 to 40 ha in 1994. The impact of these reductions may not be felt immediately as there are enough new bean technologies in the pipeline to support national programs and regional networks for one to two more years. By 1996, however, if the genetic improvement efforts of the Program are not strengthened, the stream of new bean technologies going to NARS will be reduced by nearly 50%. In addition, the ability of CIAT headquarter staff to provide technical support to Latin American NARS will be limited and the future of the newly devolved regional networks may be in jeopardy. The long term implications of a much reduced and restricted bean program upon global bean research and third-world bean productivity is of great concern to us. We believe this concern should be addressed by the CGIAR.

Research Agenda

By 1989 significant progress had been made in breeding for disease resistance and many sources of resistance genes were available to NARS. Since then, the pathology work shifted its emphasis towards understanding host/pathogen interactions, race diversity, evolution, and distribution analyses. These results are being used to develop broader and more stable resistance combinations and to target genes in international germplasm exchanges. That many of CIAT's breeding lines have multiple disease and insect resistance made it possible for the Program to begin work on other constraints and new frontiers, such as: breeding for low soil P tolerance, improved BNF, studies of rhizobium dynamics within different soil constraints, drought tolerance, photoperiod/temperature interactions and their effects on adaptation, integrated pest management, and yield potential, to name a few. New germplasm with different gene combinations was needed for this work. The core-collection concept was implemented to more efficiently evaluate the world bean germplasm collection at CIAT. Molecular fingerprinting and analysis of pathogen, pest, and bean genomes is beginning to give us a greater understanding of the genetic diversity of the crop and its biotic constraints. Within the regional networks, pioneering work on farmer assisted selections in breeding programs, crop management practices for soil-borne disease control, germplasm screening for low soil fertility, novel seed production systems, and inter-Center collaborative activities were developed. For the sake of brevity only a few research themes are outlined below. More complete information is available in Bean Program Annual Reports and published research papers.

1.) Genetic Diversity in *Phaseolus vulgaris*

History: CIAT was assigned the world mandate for the conservation of genetic resources of domesticated *Phaseolus* species and their wild ancestors in 1976. Since then the collection of *P. vulgaris* has grown to include nearly 25,000 accessions. The CIAT Bean Team has been the most consistent client of the gene bank and has systematically evaluated over 20,000 accessions for 4 important production constraints. Lesser numbers of accessions have been evaluated for at least 8 other constraints. As is the case with most large gene banks, however, the great numbers of accessions has impeded detailed studies of the germplasm. Furthermore, in recent years we have become more aware of the importance of understanding the structure and pattern of genetic diversity as a tool for effective utilization. Recognizing that the potential of genetic resources was not being fully exploited, in 1992 a research position was created specifically for germplasm characterization, to promote the effective conservation and utilization of bean germplasm.

Results and achievements: Initial efforts at classification of genetic diversity were based essentially on morphological and agronomic data, together with evaluation of phaseolin seed proteins. Empirical evidence indicated that certain groups of accessions also shared similar adaptation ranges. From these studies, 6 races of common bean were proposed, 3 within each of the two major Andean and Mesoamerican gene pools. These races may reflect different evolutionary lines.

More detailed studies on genetic structure as well as more effective utilization of the collection required a different approach to researching genetic resources. A preliminary effort to investigate the distribution of low phosphorus tolerance in the germplasm demonstrated the potential of working with a representative sample of accessions from the gene bank. A broad sample of 364 accessions from primary and secondary centers was selected and evaluated in high and low P conditions. Results indicated that low P tolerant germplasm was concentrated in southern and western Mexico and in the northern Andes. These regions were targeted for further germplasm evaluation. Elite germplasm of widely divergent origins was identified and provided to breeders by evaluating less than 20% of the reserve collection. The methodology employed in this study was essentially an application of the concept of a *core collection*, and the success with this trial demonstrates that a core collection can serve to identify useful germplasm more efficiently.

The bean core collection itself was selected in a more systematic manner and with the use of Geographical Information System (GIS) data. The passport data on collection sites were analyzed to classify accessions based on soils, daylength, rainfall and length of growing season at the sites of origin. Within such a classification, morphological data on seed characteristics and growth habit were utilized to seek the broadest variability possible. About 1,450 cultivated beans were selected, and 105 wild accessions. This was our first large scale application of GIS to the science of genetic resources. Contrary to some cases in which GIS has been applied, this usage is a quantitative description of collection sites which lends itself to much broader applications. We are currently validating the effectiveness of the selection method, by comparing the variability of RAPD molecular markers in a sample of 90 Mexican accessions in the core versus 90 Mexican accessions taken at random from the reserve collection. We expect that the core accessions will be at least as variable as the reserve accessions.

The core has already been evaluated for percent seed protein and for protein fractions such as phaseolin, lectins, alpha-amylase and trypsin inhibitors. Morphotype and quantity of protein fractions may have nutritional consequences. Complete morphological data has also been taken on the core. Molecular analysis of DNA is advancing, and AFLP classification of the wild core will soon be done. This should give us a benchmark classification of the wild *P. vulgaris* with which to respond to many questions about the relationship of wild and cultivated populations.

The core should be an important tool for the introduction of variability to secondary centers. About half of the core accessions (those for which clean seed was immediately available) have been shipped to Africa and are being increased for distribution and evaluation. An immediate priority is the evaluation for tolerance to the bean stem maggot, *Ophiomyia* sp, a pest not found in the Americas.

Another application of GIS to genetic resources is being explored, that of predicting regions where the wild ancestors of common bean may be collected. Climatological data of wild bean collection sites were analyzed by Principal Components Analysis (PCA) and compared to all other environments in Colombia and western Venezuela. Relative probabilities of finding wild beans within each 18 km square pixel were mapped. Results appeared to be in agreement with logic and with independent reports of the presence of wild beans. In years past, wild beans were reported in two municipalities in the department of Santander del Norte, Colombia. However, we do not have seed from these sites in the bank and they therefore did not figure in the PCA of collection sites. Yet the model pinpointed these sites as areas of high probability, thus tending to validate the methodology. The model also indicated some previously reported and extensive areas in Venezuela as having high probability, as well as identifying other regions that apparently have not been explored. No collections of wild beans are available from Venezuela at present. Explorations are planned to test the predictive ability of the model. We believe that if such a methodology is validated, it could be of great use in mapping genetic resources of many species. It would also demonstrate the power of using a quantitative GIS database to study genetic resources.

Impact: We have seen in recent years that as our own consciousness of genetic resources grows, so does that of our colleagues in NARS. It is now common for bean researchers to refer to gene pools and races. Some are beginning to apply these concepts in their breeding programs, attempting to broaden their genetic base. While difficult to quantify, the long-term importance of these concepts cannot be overestimated. A more quantitative classification of diversity, based on molecular markers, should extend this trend by refining our understanding of the structure of gene pools, and aiding us to identify potentially useful variability. The core concept has already provided breeding programs with important variability for low phosphorus tolerance.

2.) Genetic Diversity and Evolution of Anthracnose and Angular Leaf spot Pathogens

Introduction

The Bean program does research on fungal and bacterial diseases of strategic importance such as anthracnose, angular leaf spot, and common bacterial blight. These diseases are widespread and endemic and cause economic losses in both Latin America and Africa. To manage these and other bean diseases, host plant resistance is our principal strategy. In many bean producing regions of Latin America and Africa, host resistance is often the only reliable method available to control disease. Several bean pathogens such as anthracnose, angular leaf spot, halo blight, rust, and others are known to have races. Consequently, a variety that is resistant to a population of pathogens in one location or year may be susceptible in another. Detailed information on race (virulence) diversity of these pathogens in space and time is a requisite for understanding their dynamics and evolution and for the formulation of successful disease resistance breeding strategies.

Results and Achievements

Research on the diversity and evolution of the anthracnose (*Colletotrichum lindemuthianum*) and angular leaf spot (ALS) (*Phaeoisariopsis griseola*) pathogens began in the late 1980s and it is an ongoing activity. Significant progress has been made in 1.) monitoring and characterizing pathogen virulence and diversity, 2.) identification of new disease resistance sources, 3.) incorporation of new resistance sources in breeding programs, and 4.) use of molecular markers to study pathogen variation. This work is done as a multidisciplinary effort involving NARS scientists, the BRU and GRU, and Bean Program staff at headquarters and in networks.

Some information on the genetic diversity of the anthracnose and ALS pathogens was available from Europe, the USA, and Canada prior to 1989, but only meager information existed for Latin America. During the last five years the Bean Program and NARS have been collecting isolates of *C. lindemuthianum* and *P. griseola* from many locations in Latin America. Monoconidial cultures are used to insure the genetic purity of each isolate. The virulence diversity (race characterization) is resolved by inoculating separately each isolate on a set of 12 bean differential cultivars; one set for anthracnose and a different set for ALS. Each set of differential cultivars includes representatives of the major bean gene pools and races.

To date, 675 isolates of *C. lindemuthianum* from 13 countries have been characterized into 99 different races. Similarly, 55 ALS isolates from 9 countries were characterized into 32 races. The virulence diversity of anthracnose and ALS pathogens is extensive and much broader than that reported for the USA, Canada, and Europe. Many races of anthracnose from Latin America attack some or all of anthracnose resistance sources identified and extensively used in Europe, the USA and Canada.

The broad racial diversity of anthracnose and ALS pathogens prompted the search for new and better sources of disease resistance. Based on the virulence diversity studies, representative isolates of both pathogens were used to inoculate thousands of bean germplasm accessions under greenhouse and field conditions. New resistance sources were identified for both pathogens. Some anthracnose resistance sources have maintained their high levels of resistance under field conditions throughout many locations of the world.

Among the pathogen isolates tested, patterns of virulence diversity were observed. The great majority of races are unique to a particular location; they occur in one region, country, or greater geographical division (such as South America or Central America/ Mexico), and not in another. More importantly, the isolates obtained from large-seeded bean cultivars from the Andean domestication center, are different in their virulence characteristics from those obtained from small or medium-seeded bean cultivars from the Mesoamerican domestication center. Isolates from Andean cultivars attack preferentially, and often exclusively, Andean bean differential cultivars. These are denominated as Andean races. Isolates from Mesoamerican cultivars are denominated as Mesoamerican races. An additional characteristic of the Andean races was their narrower differential cultivar range compared to Mesoamerican isolates. Races from small-seeded cultivars from Central America attacked most of the differential cultivars, while races from large-seeded Andean cultivars attacked only a few differential cultivars.

Pathogen specialization for bean cultivars from the same location suggests that the evolution of virulence diversity is largely determined by the diversity of bean cultivars grown in a given location. We are now using biochemical (isozymes) and molecular tools (mostly RFLPs and RAPDs) to further understand the genetic diversity and evolution of several bean pathogens. For ALS, the results from molecular analyses are analogous to those found in the race virulence studies; two groups were found corresponding to Andean and Mesoamerican virulence groups. With the anthracnose pathogen, RAPDs have been used to study isolates from Colombia, Central America, and Mexico. Isolates obtained from the same varieties or location have similar RAPD patterns.

Impact: The information obtained on pathogen diversity and evolution is being used by the Bean Program to formulate a better disease resistance strategy. New and better sources of resistance are used to broadening the genetic base of beans in disease resistance breeding. A gene pyramiding strategy, that would have been impossible without this information, is now being employed.

3.) Bean Tolerance to Soil Edaphic Stress

PHOSPHORUS

Introduction: Soils of most bean-growing regions in the tropics or subtropics are either weathered and highly oxidized or volcanic in origin. More than 60% of beans grown in Latin America and Africa are on P-deficient soils; plant growth is severely affected. Within the tropics, and especially in Africa, fertilizers are often not available or affordable to farmers. As an alternative or complement to fertilization, genetic improvement of P efficiency in beans was proposed. Initial breeding work was begun in the 1980's but it was not very successful. The problem was thought to be insufficient genetic variation.

Results and Achievements: Our work on low P tolerance intensified in 1989 with the evaluation of a large and diverse group of germplasm. These initial screenings were made at Popayan, and later in Quilichao and Darien. From the 364 genotypes evaluated in P stressed and non-stressed field and greenhouse trials, germplasm from specific geographical regions were identified with a higher likelihood of tolerance to low soil P. Further evaluation of local varieties from promising regions of southern Mexico, highlands of Peru, Colombia, Ecuador, Zambia, and Malawi confirmed the significance of the geographical selections for low P tolerance and yielded a diverse range of promising lines for further evaluation. A similar set of germplasm was evaluated for several soil nutritional factors in a series of pan-African trials.

Although the Bean Phytonutritionist position was vacant in the program from 1989 - April 1993, the work was moved forward by the breeders at headquarters, regional agronomists in Africa, and a visiting Chinese Ph.D. student, whose in-depth evaluation of 16 selected lines at CIAT revealed 1.) large genetic variability for P uptake efficiency; 2.) that variation was due to general adaptation to low P availability rather than interaction with specific soil types or mycorrhiza; and 3.) large-seeded germplasm may have superior P efficiency. Initial results indicate that different mechanisms of low P tolerance may be operating in common bean that could be combined to increase P efficiency in adapted germplasm. Some promising genotypes have been incorporated into the low soil fertility breeding programs for Mesoamerican and Andean types. Screening continues at the three research sites in Colombia and four sites in Africa. Some bred materials now show a marked improvement in P efficiency, measured by yield, over traditional checks.

Current work in the bean phytonutrition section, in collaboration with advanced institutes and NARS scientists, is focused on identification of specific traits responsible for efficient P uptake and internal use. We are involved in a large cooperative effort with Penn State University, ICRISAT, and IITA to elucidate relationships between various root traits, P uptake efficiency, and response plasticity in *Phaseolus*, *Glycine*, and *Vigna*. Genetic studies to determine the heritability of root traits that correlate well with P efficiency, including fractal dimension (complexity) and rooting angle, are also being conducted. Once responsible root traits are identified and their mode of inheritance understood, selection methodologies for breeding will be developed. Finally, we hope to use molecular techniques to tag genes associated with root traits correlated with P efficiency. The estimated impact of breeding greater P efficiency into popular bean genotypes is tremendous and the potential of success high.

NITROGEN FIXATION

Introduction: An important attribute of bean, justifying its inclusion in low input systems, is the ability to fix atmospheric N and thereby reduce depletion of soil resources. Yet, N_2 fixation in common bean cultivars is generally low when compared with many other grain legumes. Although poor nodulation is frequently observed, soils in most bean growing areas contain large numbers of compatible and effective rhizobia. Poor nodulation is not due to an intrinsic inability of bean to nodulate, as profuse nodulation normally occurs in many genotypes under controlled conditions and in some soils. Inoculation with improved rhizobium strains rarely provides a solution to the problem. These observations indicate that environmental constraint(s) limit nitrogen fixation in the field. Phosphorus deficiency is considered to be the main factor limiting fixation.

Results and achievements: Specific research into P x BNF interactions in beans were begun in 1992 in cooperation with INRA-France. Screening methods were refined based on hydroponic systems and in-situ acetylene reduction assays. Genotypes identified with varying N_2 fixation capabilities are being evaluated in P stressed and nonstressed field trials. The results from the P x BNF studies may have high potential impact for improved bean production in infertile soils.

Clear N_2 fixation selection criteria are essential for a breeding program. During 1989-1992 investigation into host plant characteristics conferring improved N_2 fixation focused on nodulation traits. Characteristics such as early nodulation or late nodule senescence were found to be correlated with yield and plant N content under specific environmental conditions. Recent evaluations, however, indicate that these characters are more closely linked to phenology than fixation ability per se. Total N accumulation, a good indicator of the total amount of N_2 fixed where soil N is limited, is now being used as the primary criteria for selection of potentially high-fixing lines. From a backcrossing program using the non-nodulating mutant NOD125, 12 genotypes of varying growth habits and adaptation ranges, expressing the non-nod phenotype, have been developed and are in final stages of evaluation for use as non-fixing reference crops. Wide-scale African screening trials are in progress using natural abundance 15N techniques to identify germplasm that consistently expresses improved fixation under conditions of low soil fertility.

A collaborative program between CIAT and NARS to select bean rhizobia strains adapted to specific areas and cultivars has been successful in Cuba and Cajamarca, Peru. The most productive strains are now produced commercially and used by farmers in these two countries. In the majority of cases, however, successful inoculation response trials in Latin America and Africa have been sporadic at best, and this line of work was discontinued in 1992, although the *Rhizobia* strain collection and data base are maintained. Current research on rhizobium is focused in two activities: 1.) evaluation of strain N_2 fixation effectiveness and strain X cultivar interactions, and 2.) evaluation of factors affecting rhizobial competitiveness. The latter is being approached through development of strains genetically transformed to express glucuronidase in nodules, enabling easy wide scale analysis of inoculation events. The objective of this work is to identify strains capable of high levels of N_2 fixation across a broad range of cultivars and a high degree of competitiveness under prevailing environmental constraints. Presently, a group of 20 strains transformed with the *gus* gene, but maintaining the symbiotic and competitive characteristics of the wildtype, have been developed and are in the early stages of competition X environment evaluations.

Impact: Although work on phosphorus and nitrogen fixation has been going on for more than a decade, the research emphasis changed considerably in recent years. With the identification of new bean genotypes with greater low soil P tolerance and new field screening techniques, more rapid progress is now being made in increasing low P tolerance levels in common bean. Phosphorus is also considered to be the main limitation in nitrogen fixation. Consequently, much of our research is now focused on understanding the interactions between P and the nitrogen fixation process, including rhizobia. Already, cultivars and strains that fix N more efficiently in low P soils have been identified. The selection criteria in breeding for improved nitrogen fixation has shifted from host plant characteristics to total N accumulation. Regional scientists and NARS in Africa are important partners in our work on soil edaphic stresses.

4.) Advances in Yield Potential

Introduction: The primary objective in increasing yield potential is to develop more efficient, higher yielding plants. In the case of beans, however, yield potential is strongly associated with bean type. The differences between one bean type or another can be very wide, as exemplified in the following comparison of bean agronomic characters:

-range of maturity: 65 to 250 days
-range of growth habits: from upright bush (type I) to support-needing climbers (type IV)
-range of seed size: 17 to 70 g/100 seeds
-evolutionary origin: Andean and Mesoamerican gene pools

As a consequence of these differences, yield potential in beans varies from 3000 to 6000 kg/ha. Within germplasm of the same origin, growth habit, seed size and maturity, yield differences are often small unless they are caused by differential responses to biotic and abiotic stresses.

The primary breeding objective for high input bean production systems is increased yield potential. Breeding is constrained by maturity, growth habit and seed quality characteristics of the predominant commercial varieties. Breeding for absolute yield outside these constraints would produce a late maturing (>150 days), climbing bean (type IV), with small seeds (<25 g/100 seeds) of no or little agronomic or market potential. Yet, bean types with yield potentials of 6000 kg/ha already exist. These bean types (late climbers) are used by subsistence farmers in marginal production areas, but their yield potential is not realized due to inter-cropping practices, limited inputs, and susceptibility to certain stresses. The advantage of these varieties is their long maturity season which allows the farm family to have food (green pods, green shelled beans and dry beans) for a long period, and to have another crop (usually corn) in the same land occupied by beans.

The above considerations are intended to illustrate that the quest for improved yield potential in beans at CIAT is not directed to attaining high levels of productivity in absolute numbers but focused to reach the yield ceilings of each bean type according to their possibilities within a production system. This includes separate strategies by plant type, maturity class and grain type.

Results and Achievements: The Bean Program has used two broad approaches to increasing yield potential. One is to seek novel gene action and selection strategies to increase yield. The other approach is to identify yield maximizing options for physiological traits, including photoperiod/temperature adaptation, canopy morphology, and patterns of N uptake and partition.

Breeding for yield potential per se started with the strategy to select for morphological traits (e.g. plant height, node and leaf number, and branching patterns) positively correlated yield. Although reported effective in some instances in temperate zones, this approach did not increase seed yield in tropical environments. We ended this line of research in 1989. Yield, in spite of its moderately low heritability, was found to be the best selection criterion and selection for yield in early generation populations proved to be effective. The choice of parents for hybridization was the key component for successful yield breeding.

Parental selection became increasingly important once studies on the patterns of variation in common bean indicated there were three distinct races within each of the Mesoamerican and Andean gene pools. Progress in breeding for yield potential in the past was slow precisely because it had been based on hybridization and selection within races and gene pools. While this may have facilitated easy recovery of desirable seed, plant and adaptation traits, the limited genetic variation for yield in intra-racial crosses did not lead to significant and large yield gains. To maximize yield potential, favorable genes with complementary and additive gene effects have been sought across races and gene pools. A series of studies conducted since 1989 have shown that inter-racial crosses exhibit useful genetic variation within and between populations and offer the maximum opportunity for larger selection gains. Moreover, a positive association exists among the yield of parents, population bulks, and advanced-generation lines derived from them. Thus, high-and stable-yielding parents belonging to different races, and with positive general combining ability for yield, should be hybridized. But owing to its low to moderate heritability (0.21 to 0.51), seed yield from replicated trials across contrasting environments must be the main criterion for selecting among and within populations in early generations. Selection gains (at 20% selection pressure) from early generation population bulks ranged from 5.6% to 19.3% over the mean of all the populations.

Results for yield improvement of Andean races are just becoming available. From single-cross, inter-gene pool populations of Andean x Mesoamerican germplasm, it is difficult to recover high-yielding recombinants with desirable seed types. The use of Mesoamerican germplasm to improve Andean yield potential is proving to be a challenge. Andean germplasm is lower yielding, physiologically inefficient, and less stable when tested across varying environments, than Mesoamerican germplasm. Moreover, in some Andean x Mesoamerican crosses, F_1 hybrid dwarfism, recombinants with virus-like symptoms, and segregation distortion occur. Several strategies are showing promise to overcome these problems: the use of bridging parents, reducing the genetic contribution of the Mesoamerican parents in multiple crosses to less than 25%, and recurrent selection breeding strategies. Also, the use of parents from different races but showing some affinity for seed, plant, and adaptation traits may increase the frequency of desirable recombinants in inter-racial populations. Alternative strategies for seeking yield improvement in Andean types are through modification of growth habits from determinate to increasing indeterminacy and delaying maturity.

Yield potential appears to be source-limited in common bean. The simplest way to increase source capacity is to lengthen the growth cycle. Unfortunately, genetic variation permitting selection of high-yielding, late maturity lines within specific gene pools has not been found. Harvest index and yield components do not show promise as selection criteria as harvest index values of 0.55-0.6 are normal for beans; similar or higher to that of other legumes or cereal crops. The possibility of increasing source capacity through increased photosynthesis or decreased respiration is thought to merit attention. Rather than seek ways to increase maximum leaf photosynthetic rate, mechanisms for prolonging effective leaf life or improving canopy structure are being sought. Studies of N metabolism have confirmed that remobilization of N from leaves to pods is associated with a rapid decline in photosynthetic capacity. Simple selection for late senescing leaves results in plants with reduced pod set. Work on canopy structure has shown that a well managed bean crop often achieves a Leaf Area Index over 6 although optimal LAI is 3.5-4.5. Excessive leaf growth seems to reflect an inherent tendency toward uncontrolled weedy grow in bean germplasm. Such a response is adaptive in conditions of weed competition, low plant rates and other management deficiencies, but is probably counterproductive when seeking maximum yields. One method being explored to lengthen plant maturity without going to climbing types is through manipulation of photoperiod sensitivity and its interaction with temperature. Beans are characteristically long daylength sensitive, but insensitivity to long photoperiods is fairly common in the Mesoamerican gene pool which may explain its greater yield stability and adaptation range. The inheritance of photoperiod response was shown to be controlled by two genes; neutrality is conditioned primarily by one recessive gene which is epistatic over the second. Additional genes for earliness show strong dominance. Neutral, intermediate, and sensitive photoperiod responses are being incorporated into a series of random inbred lines to test the effect of these genes on yield potential and stability.

Impact: The basis for improving yield potential through greater exploitation of genetic diversity has now been laid within the Bean Program. The breeders are actively recombining gene pools and overcoming initial genetic barriers. Breeding strategies promoting novel recombinations are being designed. National program breeders are cognizant of the importance of inter-racial and inter-gene pool crosses. Recombinant inbred lines (RILS) are being developed to tag genes associated with adaptation and yield. Simulation modeling is being used to study the effect of different combinations of major genes controlling morphology, phenology, and adaptation on yield potential and genotype X environment interactions.

5.) Bean Research Networks

History: The Bean Program has pioneered the creation and implementation of five regional research networks to increase bean productivity in Africa and Latin America. These networks are funded by different donors and are in different stages of evolution.

NETWORK	REGION	INITIATION*	DEVOLUTION*	DONOR
PROFRIJOL	Central America, Caribbean	1978 (3)	1993 (0)	SDC
RESAPAC	Great Lakes Region, Africa	1984 (4)	1995 (1)	SDC
EABRN	Eastern Africa	1985 (4)	(4)	USAID,CIDA
SADC	Southern Africa	1986 (4)	(1)	CIDA
PROFRIZA	Andean Zone, South America	1987 (2)	1996 (0)	SDC

* (Number of scientists)

The networks function as a voluntary association among NARS and with CIAT, and have a common objective to increase bean productivity in a particular agro-ecological zone and/or socio-economic region. All decisions on technical priories, annual planning, resource allocations, and assessment of research progress are the responsibility of a regional Steering Committee comprised of national bean research coordinators and a CIAT representative. Policy decisions concerning network activities are determined by regional committees of NARS Directors.

The primary planning tools used in all bean networks is the participatory project planning by objectives (PPO/GOPP/ZOPP etc). Essential participants in the PPO are the steering committee members, key NARS scientists from all relevant disciplines (selected on merit and not to represent a country), some national extension/NGO staff, and the relevant Bean Program staff working in the region. Our experience shows that this bottom-up approach to network management leads to a real sense of ownership and identification with the network by national program scientists, and a continuing improvement in planning and management skills.

The core set of activities within a network is collaborative research, organized as regional sub-projects led by selected NARS scientists from institutions offering comparative advantages. Sub-project funds (approx. US $2000/project/year) are awarded by the Steering Committee on a competitive basis. Multidisciplinary workshops are held regularly to share results.

Results and Achievements: The network operational model has facilitated the rapid introduction and successful adoption of new technologies in some of the most poorest regions of the world. Variety development and adoption of new technologies by farmers is the most evident output of regional collaboration and has received the greatest attention. (Refer to the Introduction chapter for specific examples of impact). Much of the success of the new varieties also depended on the development of complementary management practices such as: use and production of organic manures for soil fertility and management of soil borne pathogens, production of staking materials for climbers and promotion of agro-forestry practices, development of small scale seed production and distribution methodologies, and innovative methods for involving farmers in all aspect of research and technology evaluation. While most research efforts are spearheaded by the regional networks, many other partners such as local and international NGOs, development projects, extension specialists, and farmers actively participate in technology development and diffusion.

The Bean Program depends on the regional networks as much as the NARS do. The networks provide an essential two way flow of materials and communication between CIAT and our partner countries. The networks are a conduit for the transfer of information and improved genetic materials to NARS, and they are also one of the main sources of information and results on which the Bean Program depends for strategic germplasm development and planning. The advantages to CIAT in catalyzing strong networks include: 1.) improved sustainability of national programs by giving scientists the forum to address issues and to obtain the attention of national research directors; 2.) ready access and exchange of new technologies that go across national boundaries; 3.) broader scope of research activities not just focused on genetic improvement; and 4.) releasing Bean Program staff from management responsibilities to research.

The number of training activities at CIAT and in the regional networks decreased during the last five years. This was primarily due to a significant reduction in training funds and to a change in training strategy. Training events at CIAT are now targeted towards senior researchers, while in-country courses focus on new NARS scientists and extension personnel. The training associate model for senior African researchers has been particularly successful. About 6-10 national scientists come to CIAT for one to three months intensive training. The training events are tailored to meet the individual needs of the researchers, and in many instances, joint research projects are developed. All visiting researchers are expected to develop a research project for submitting to their respective steering committees upon returning home. In addition, the training-of-trainers program at CIAT, particularly for Latin America, provided a cadre of trainers who are increasing assuming general training responsibilities within their regions. Regional Bean Program scientists in Africa offered the first Pan-Africa Bean Research Methods Course in May this year. Both CIAT and national program scientists shared in the preparation of lectures and practicals.

Considerations: The Bean Program staff in the networks, as well as the networks themselves, are dependent on special project funding. During 1992 a sudden reduction in funding by CIDA for the SADC region caused the abrupt lay off of three senior staff positions. When PROFRIJOL devolved, the number of CIAT scientists in Central America was reduced to zero. The SDC, in anticipation of the devolution of PROFRIZA in the Andean Zone cut back the number of senior positions from two to one--the remaining position to be eliminated in mid-1996 when the local coordinator takes over. RESAPAC started out with four senior positions in the Great Lakes project in 1984 and by 1995 will have only one. We are proud the networks are successful and that the steering committees and regional directors are beginning to function more independently of CIAT. Yet, during the last three years a paradox situation has developed: the rapid pace of network devolution to local management has coincided with a significant reduction of the Bean Program and its resources, not only in the networks, but at headquarters as well. Our ability to provide technical support to several devolved networks at the same time is severely limited. The newly independent networks will need nurturing and constant support. Inadequate support may mean their failure.

FUTURE RESEARCH STRATEGY

In 1994 the Bean Program restructured all its research activities within projects. Details on the projects, outputs, activities, and milestones are outlined in CIAT's Action Plan (Supplement A). The Program now consists of four major project areas, and within these, thirteen projects have been developed. Nearly all on-going activities have been maintained in the new project structure. We have also tried to maintain a multidisciplinary approach to problem solving within each project area. The projects encompass not only core, but special project activities as well. Within the Program are 14 special projects which provide more than US $2.1 million (1993) to our total program budget. The majority of these funds are earmarked to support regional activities, including 9 outposted staff positions. In 1995, 7 of the 9 regional staff positions will be reclassified as core-like activities, but will continue to depend upon special project funding for their existence. CGIAR core funds support 8 positions at headquarters. The basic outline of the Bean Program Projects are as follows:

PHASEOLUS DIVERSITY: ***Improve the productivity of common beans and enhance biodiversity by acquiring , assessing , maintaining, and deploying genetic resources.***

Activities:
Phaseolus Conservation
Phaseolus Genetic Structure
Wild and Cultivated *Phaseolus* Species
Bean Utilization

YIELD STABILITY: ***Improve yield stability in beans by developing gene pools with resistance to major pests and diseases, tolerance to abiotic stresses, and enhance yield potential.***

Activities:
Biotic Stress Resistance
Abiotic Stress Tolerance
Improved Yield Potential

SUSTAINING BEAN PRODUCTIVITY IN LATIN AMERICA AND THE CARIBBEAN: ***Improve and sustain bean productivity in this region by deploying gene pools that help solve major production constraints and by supporting networks for applied research.***

Activities:
Germplasm Improvement
Network Development
Integrated Bean Production Systems

SUSTAINING BEAN PRODUCTIVITY IN SUB-SAHARAN AFRICA: ***Improve and sustain bean productivity in this region by deploying gene pools that help solve major production constraints and by supporting networks for applied research.***

Activities:
Germplasm Development
Network Development
Seed Distribution and Farmer Participation

Because of the global nature of the Program, most of our research activities are strictly defined in terms of our projects and do not cut widely across programs at CIAT, except in specific ecosystems where beans are important. Within the regional networks, however, we actively collaborate with other IARC and networks especially in the area of training and natural resource management. Increasingly, we are developing stronger research ties with advanced institutions.

COLLABORATIVE PROJECTS - New and Pipeline:

1.) Inter- IARC projects involving the Bean Program:

- The Eastern Africa Highlands Initiative (ICRAF, CIAT, CIMMYT, IITA) - **new**
- Seeds of Hope: seed relief initiative for Rwanda (CIAT, IITA, CIP, CIMMYT, IPGRI) - **new**
- Genetic potential to improve iron, zinc, and methione concentration in common bean and their bioavailability (CIAT, CIMMYT, IFPRI) - **pipeline**
- Genetic Manipulation within Cropping Systems to enhance Integrated Nutrient Management (CIAT, ICARDA, ICRISAT, IITA) - **pipeline**

2.) Collaborative Projects with Advanced Institutions:

- Adaptation of food legumes to low phosphorus soils in tropical and subtropical China. McKnight pre-proposal accepted.(South China Univ. , Penn State Univ, CIAT) - **new**
- Effect of Phosphorus availability on efficiency of nitrogen fixation (INRA, France and CIAT) - **pipeline**
- Improvement of common bean cultivars to higher latitudes (Univ. of Saskatchewan, Univ. of Colorado, CIAT) - **new**

NEW BEAN PROGRAM INITIATIVES
Looking beyond the present portfolio of projects, the Bean Program is activity exploring and developing new research initiatives. Just a few of these are listed here. Others new project ideas are developed in a series of Project Profiles available within the program.

1.) *Improving Bean Productivity in Eastern Europe.* Nearly 1 million ha of bean are grown in eastern Europe, with the largest producing country being Rumania (>500,000 ha). A fact finding visit to countries in Eastern Europe was recently made by one member of the Bean Program. A project proposal profile has also been distributed to three potential donors.

2.) *Pan Africa Bean Research Network: Revised Strategy for the Consolidation of Sub-Saharan Africa Bean Research Activities.* There is a strong push by CIDA to merge the three bean regional networks into one Pan-Africa network in 1995. Steps are already underway to merge RESAPAC and EABRN. Existing research networks would continue to function as sub-regions in the new project.

3.) *Development of IPM Systems for Small Bean Farmers in the Andean Zone. Phase II.* The second phase would look at farmer participation in the design of IPM practices, and their adoption by resource poor farmers in the Andean zone. (Funded Sept. 1994, IDRC)

4.) *Improved Adaptation to water Deficit and Low Soil Phosphorus in Mexico and Brazil.* Promote collaborative inter-regional research among strong NARS and CIAT by awarding small research grants to national program scientists in Mexico and Brazil. CIAT would participate as a collaborating institute.

Cassava Program

Achievements, constraints and impact

1989 - 1994

September, 1994

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Executive Summary

Cassava cultivation and processing provide household food security, income and employment for over 500 million people in Africa, Asia and the Americas. The crop is tolerant of low soil fertility and drought, and recovers from the damage caused by most pests and diseases. The roots can be stored for long periods in the ground and have multiple end uses. These attributes have contributed to the crop's important role in alleviating hunger and in providing opportunities for economic development in less favored rural areas.

The goal of CIAT's Cassava Program is to enhance the crop's contribution to the wellbeing of cassava farmers, processors and consumers. Its specific purpose is to generate knowledge, research methods and technology components whose deployment will lead to a sustainable improvement in the level, stability and quality of cassava production and to a diversification in the end uses of the crop. The relevance of the Program's work depends on the establishment of strong links with partner institutions in both developed and developing countries.

The Program has adopted an interdisciplinary, commodity system philosophy which seeks to integrate research on germplasm improvement with research on crop management and process, product and market development. The products of this research and the most recent advances include:

- Conserved and characterized *Manihot* genetic resources. CIAT holds the largest, most comprehensively characterized *Manihot* germplasm collection, freely available to researchers around the world. The definition of a core collection, a model for identifying duplicates and the assembling of a molecular linkage map are among recent achievements. Diagnostic methods are now available for the detection of all viruses of quarantine significance. Cryopreservation of cassava shoot tips will become an alternative method for germplasm conservation within the next 5 years.

- Improved cassava gene pools, with adaptation to the principle biotic and abiotic constraints and appropriate quality characteristics. A total of 17 varieties, derived directly from CIAT's gene pools or having CIAT's materials as one of the parents, have been released since 1989. A model has been developed for the participatory evaluation of cassava varieties with farmers and successfully implemented in Colombia and Brazil. Marker-assisted selection and the opportunity for genetic manipulation of cassava will provide additional tools for solving a number of breeding challenges, among them the modification of certain root quality characteristics, resistance to stress with mechanisms for protecting fragile environments and the development of true seed propagated cassava.

- Crop management practices for economically and environmentally sustainable cassava production. Natural enemies for biological control of mites, mealybugs, burrowing bugs and the cassava hornworm have been identified and studied. Ten species of predatory mites have been introduced into Africa via IITA. Recommendations for the integrated control of root rot pathogens, cassava bacterial blight, superelongation and the witches' broom disease have been implemented in Brazil and Colombia. Technologies for maintaining soil fertility and arresting soil loss have been developed in Asia and for hillside and subhumid agroecologies in Colombia. The development of farmer participatory methods for selecting and adapting appropriate technological solutions to biotic and abiotic stresses will receive emphasis over the next five years.

- Cassava agroindustrial processes that strengthen links between small-scale farmers and markets. Processes for the primary transformation of cassava into dry chips, flour and starch have been developed and adopted commercially in Latin America. Technology for the conservation of fresh cassava for human consumption has been pilot tested both in Latin America and Africa. Collaborative interinstitutional projects in the future will focus on the extension to Africa of an integrated approach to process product and market development and the identification of opportunities for the development of second generation products.

In addition to research in the above areas, the Program seeks to enhance the effectiveness of cassava research and development at national, regional and global levels through the provision of needs assessment methodologies for priority setting, information services and training. A global Cassava Biotechnology Network has been established and regional research networks have been consolidated.

CASSAVA PROGRAM

Achievements, constraints and impact 1989-1994

1. INTRODUCTION

Total world cassava production has risen from 132 million t in 1984 to 154 million t in 1993, a growth rate of 1.8% per annum. Growth in production has been fastest in Subsaharan Africa (3.3%) followed by Asia (1.0%), while production in Latin America has stabilized (0.0%) after experiencing negative growth during the previous decade. On all continents, cassava area is increasing at a faster rate than cassava yields. This trend is attributed to the movement of cassava production from relatively fertile environments, where it is being replaced by higher value crops, to regions with poorer soils and/or lower rainfall.

Cassava has maintained its critical importance as a household food security crop in Subsaharan Africa where it is also increasingly a major source of cash income. Product and market diversification has continued rapidly in S.E. Asia and is starting to occur in several Latin American countries. Production and transformation of the crop remains concentrated in the hands of small-scale farmers and processors.

The environment within which cassava research and development (R and D) takes place has evolved over the past ten years. There is now a much greater governmental and donor awareness of the contribution that cassava, and roots and tubers in general, can make in meeting development goals, especially those associated with marginal rural areas, such as food security and income and employment generation. However, since 1989, economic policies of developing countries have changed significantly with an almost universal trend towards trade liberalization and the concern for environmental conservation has grown. Both these factors have important implications with respect to the research and development agenda for cassava. The strengthening of market links and improved cost and quality competitiveness of cassava products will be of paramount importance. However, gains in productivity will need to be environmentally sustainable.

In parallel with these socioeconomic and political changes, there has been a progressive consolidation of the institutional environment, with closer links between international, regional and national institutions involved in cassava R and D. Cassava has often been termed an "orphan crop" in terms of research investment. There is still considerable need for basic knowledge generating research on the crop. The creation of the Cassava Biotechnology Network (CBN) has been instrumental in promoting relevant advanced research and enhancing communication between institutions involved in this work. Of particular importance has been the evolving relationship between CIAT's Cassava Program and the Brazilian and Thai national cassava programs which are now sharing with CIAT international responsibilities for certain areas of cassava R and D. The last five years have also seen a major renewal of CIAT's collaboration with IITA.

At the applied research level, national cassava programs face budgetary difficulties similar to those faced by all government financed agricultural research institutions. However, progress has been made in understanding better the institutional constraints to the development of technologies that, through client (farmer, processor, consumer) involvement in the R and D process, have a greater probability of adoption. In Latin America, an institutional model known as "Integrated Cassava Research and Development Projects" (ICRDP) has been successfully tested in a number of countries. These projects have proven to provide effective links between research and development institutions, including farmer organizations, and the integration of production, processing and marketing components.

Over the past five years, the mission of CIAT's Cassava Program has not altered substantially. The Program's continuing concern is to enhance cassava's contribution to the wellbeing of cassava farmers, processors and consumers. Its specific role is to generate knowledge, research methods and technology components whose subsequent deployment by our national partners will lead to a sustainable improvement in the level, stability and quality of cassava production and to a diversification in the end uses of the crop.

The considerable financial restrictions imposed on the CG system since 1990 has required a constant process of examining priorities and an appraisal of CIAT's advantage in undertaking certain types of research compared with either advanced laboratories or national cassava research programs. There has been a reallocation of core resources to strengthen the Program's competence in the area of genetic resources. This resource reallocation, together with the budgetary reduction experienced in 1992 and 1994, have had repercussions on our capacity (a) to link with our national program partners in collaborative research on the validation and adaptation of technology components and their subsequent integration into cropping systems at the farm level in Latin America and (b) to provide leadership in integrating product, process and market research. The acquisition of special project funds and the development of collaborative links with other international institutions has only partially offset these gaps.

The internal reorganization of the Program around "Project Areas" has been an important step towards reaffirming the Program's interdisciplinary commodity system philosophy in which research on germplasm improvement must be integrated with research on crop management and process, product and market development. Resource allocation across Project Areas reflects the fact that CIAT's most important asset is the World *Manihot* germplasm collection which bestows on the Program a comparative advantage in characterizing and using genetic diversity to enhance cassava production and utilization. A competency and an ability, albeit reduced, to link with other R and D institutions in collaborative projects has been maintained in crop management and in process, product and market development research, both vital aspects if CIAT is to fulfil its global cassava mandate and provide intellectual leadership to our partners while act as a real bridge between advanced labs and national cassava R and D systems.

This document presents an historical assessment of the activities and outputs of the Program over the period 1989-1994 and a summary of the strategy that will be pursued by the Program in the following five-year period.

2. HISTORICAL ASSESSMENT AND FUTURE STRATEGY

(1) Manihot genetic diversity

Historical Assessment

The project area *Manihot* Genetic Diversity has developed relatively recently to house the Cassava Program's activities in optimizing opportunities and strategies for the conservation and use of genetic diversity. Activities in collection, conservation and evaluation are multidisciplinary efforts; concepts of ecological adaptation/ geographic distribution (GIS mapping) and tools of biotechnology (cryopreservation and molecular markers) have been incorporated into the research strategy.

The World cassava collection has increased its holding from 4344 to 5491 accessions during the past five years, largely through national or international collecting missions, or germplasm exchange, with Brazil, Argentina, Paraguay, Cuba, China and Thailand. Collaborative collecting efforts have proven to be very efficient in terms of describing germplasm (as preliminary data taken at site helps to minimize duplication), and establishment of the accessions both in the country of origin and in the world collection. Morphological and isozyme characterization of the base collection has been completed, but will continue to be required for new acquisitions. The cassava collection is maintained at CIAT both in a field collection, and *in vitro*. Approximately 300 accessions of wild *Manihot* species, and a progeny of 150 individuals selected for molecular mapping are also held *in vitro* and analysed in the field.

The definition of a core collection for cassava, accomplished since 1991, took advantage of extensive characterization data collected on accessions of the world collection. The definition of the core was based on the parameters of geographic origin (passport data), diversity of morphological characters, diversity of ää esterase banding patterns, and *a priori* considerations in favor of particular genotypes. The consideration of geographic origin accounted for the importance of the accessions' origin as a center of diversity for the crop, and representation of diverse ecosystems. The core collection of 630 accessions is a manageable size which is actively used to assess genetic diversity in cassava for characters which require specific, expensive evaluations and may be difficult to apply to the base collection.

A model for the identification of duplicates in the collection has been developed and implemented in the past five years. The procedure consists of three steps in which the data base of morphological and isozyme characteristics is first consulted to identify accessions with identical descriptors. Next, putative duplicates are observed side by side in the same year, and compared morphologically. Accessions still appearing as duplicates are then subject to molecular fingerprinting using an *M13* DNA probe. To date, 35 groups of putative duplicates at the morphological and isozyme level have been evaluated with *M13*. Enhanced resolution provided by DNA fingerprinting showed 17% of the groups to contain unique individuals, while the remaining 83% were confirmed as duplicates. Accessions which are identical at this resolution are reported to the source country and eliminated from the field collection at CIAT, but at present they are still being maintained *in vitro*.

Research on the methodology of cryopreservation of cassava shoot tips has continued toward the application of this conservation method to a broad range of genotypes. Adjustments to pre-culture conditions, and freezing and thawing profiles have extended the range of genotypes that can successfully be recovered from cryopreservation.

A large number of genetic markers have been generated through the development at CIAT of cassava DNA libraries. These markers are currently being assembled into a linkage map, which will help to define the genome structure of cassava and to monitor and 'tag' traits of agronomic interest. Collaborative research with US Universities has been established to strengthen mapping efforts and ensure that appropriate analytical methods are applied to understanding the phylogeny of *Manihot* species.

International workshops/conferences have helped to set research and support priorities in *Manihot* genetic resources. A conference held in Rome in 1991, under the auspices of the FAO, determined that post harvest deterioration is a significant constraint to cassava utilization, and that sufficient knowledge of the biological processes involved in the phenomenon are at hand to justify research toward extending the storage life of cassava. An international workshop held at CIAT in 1992 to address needs in the area of cassava genetic resources, recommended the establishment of a *Manihot* Genetic Resources Network. Working groups developed recommendations for 1) the development of a global conservation strategy for cassava genetic resources, 2) the development of a global data base, and 3) the utilization of genetic resources for germplasm enhancement. Participants represented national programs, IPGRI, IITA and CIAT. An international workshop was held at IITA in 1994 to clarify aspects surrounding the issue of the safety of cassava as a cyanogenic food crop. As results of these conferences, a comprehensive proposal has been developed for collaborative research on post harvest deterioration, and responsibilities have been assigned for researching and resolving constraints and issues, such as safety standards, surrounding cassava cyanogenesis. Training in the area of germplasm maintenance has contributed to NAR ability to conserve and utilize cassava genetic resources. The formation and subsequent operation of the Cassava Biotechnology Network (CBN) have also stimulated communication and research in the area of *Manihot* genetic diversity.

While the workshop held for the formation of the *Manihot* Genetic Resources Network helped to prioritize needs of various institutions concerned with germplasm and genetic diversity, staffing at CIAT in the area of genetic resources has not been adequate to meet our commitment as network Secretariat. The recent appointment of a Cassava Curator will strengthen our networking capacity. The lack of a Head of the GRU during CIAT's adjustment to global expectations following the Convention on Biodiversity has further handicapped our positioning with respect to the evolution of our role in the area of genetic diversity.

Germplasm screening under field and controlled conditions has identified outstanding sources of desirable traits such as resistance to white fly, mites, root rots and bacterial blight, and high photosynthetic capacity and water use efficiency, which have been made available to improved gene pools. A search for resistance to cassava frogskin disease is also underway. Screening of the wild species collection for resistance to pests and diseases and for root quality characteristics has been intensified in the past two years, indicating potential new sources of desirable traits. Approximately 2,500 *in vitro* plantlets, representing several hundred genotypes from the cassava and wild species collections have been shipped to programs outside of CIAT in the past five years, requested either for their specific adaptation or for particular desirable traits.

The presence of virus and "virus-like" diseases of cassava has greatly hindered the introduction and distribution of promising cassava germplasm in Latin America, Asia and Africa. The "frogskin" and "Caribbean mosaic" diseases of cassava in Colombia and cassava vein mosaic virus, which is widespread throughout the semi-arid region of Brazil, are the diseases considered to be of quarantine significance. The distribution and causal pathogens have been identified and diagnostic methods are now available. These methods are used at CIAT but have yet to be adapted for use by national programs; exchange of *in vitro* germplasm among continents is still a bottleneck due to lack of quarantine facilities.

Future Research Strategy

In the past, conservation and evaluation efforts have concentrated on cassava, with limited attention being paid to *ex-situ* conservation and characterization of the crop's wild relatives. A broader conservation strategy is now envisioned, considering thoroughly both the genetic diversity of the primary gene pool, and valuable genes and gene complexes in other *Manihot* species as targets of conservation. Molecular markers are being incorporated into the germplasm evaluation process to obtain objective measures of genetic diversity. Through molecular mapping, we hope to develop markers for genes of interest which can be used to simplify the selection process. As mapping may reveal the genetic basis of quantitative traits, it is also likely that breeding methods may be refined according to the resulting knowledge. We may apply this strategy to the introgression of genes from wild species. Another facility of biotechnological research is the modification of the expression of existing genes in cultivated germplasm, or the introduction of foreign or synthetic genes. For this approach, basic understanding of specific biochemical processes critical to cassava development are essential.

Future research will stress improved understanding of the distribution and structure of genetic diversity among cassava's genetic resources, toward the development of sound conservation and use strategies. An important component will be improved global communication around germplasm issues among curators and disciplinary scientists, geographers and biotechnologists to accomplish this large task efficiently. In collaboration with IITA and the Genetic Resources Network, more attention will be given to the conservation of African germplasm and assessment of the genetic base of cassava in Africa.

The culmination of several years of germplasm screening by the Cassava Program and our partners have identified specific useful genetic variability in important quality characteristics and for adaptation to biotic and abiotic constraints. Biochemical and molecular techniques and specially constructed genetic stocks will be used to generate knowledge on the mechanistic and/or genetic control of essential traits for practical use in cassava improvement. Resistance to white flies, African cassava mosaic virus, cyanogenesis, and photosynthetic efficiency under conditions of drought or temperature stress are among traits in the best position to utilize these approaches. Collaborative research will be undertaken with ORSTOM, France, toward studying the genetic diversity of the bacterial blight pathogen, *Xanthomonas campestris* pv. *Manihotis* in the center of diversity of cassava. This will relate to the effective development and deployment of resistant germplasm.

Integration across programs at CIAT is promising in the areas of genetic diversity and molecular biology, where concepts and research technologies are not commodity specific, and may in fact cross-feed each other. Integration across Centers may also be beneficial, particularly in devising strategies for germplasm conservation. Relatives of various crop plants may share eco-geographical sites of origin, rendering them conducive to coordinated, collaborative study; and crops with similar mating strategies (such as vegetatively propagated roots and tubers) may share biological principles relevant to conservation strategies.

During the next five years the cassava collection will be expanded to fill gaps in current eco-geographic representation, and it will be safely conserved in two additional institutes and under cryopreservation. Better *ex-situ* representation of cassava's wild relatives will be sought, with accompanying knowledge of their ecological provenances and particular adaptive features. Changes in genetic diversity at the field level will be documented, and *in situ* conservation considered. The molecular map of cassava is the first to be constructed at a CG Center, its use will be a short term milestone for CIAT.

(2) Gene pool development

Historical Assessment

The Program's selection scheme has been based on the subdivision of the cassava growing environments into different agro-ecological zones: Sub-humid tropics, acid soil savannas, humid tropics, mid-altitude tropics, highland tropics, sub-tropics and semi-arid tropics. Gene-pools for each of these ecozones are enhanced by the recombination of selected parental material after the evaluation in representative environments where the principal traits of interest are consistently expressed at levels appropriate for selection. Recognizing that wide variation for edaphoclimatic conditions and end product uses exist within each zone, the enhanced genetic variability is taken by national programs and selected and adapted to local needs.

During the last five-year period, gene pool development activities for different agro-ecological zones has resulted in considerable gains when comparing selected genotypes with the best local and/or released cassava varieties. The percentage gain in terms of dry matter production per hectare was: 45% for sub-humid lowland tropics, 40% for acid soil savannas, 70% for mid-altitude tropics, 90% for highland tropics, 12% for the sub-tropics and 46% for the semi-arid tropics. Considering the relative importance of the different ecosystems and that the heritability of the trait is estimated at 40% on average, the selected material could potentially increase the productivity of cassava across ecosystems by 19%.

These gains have been achieved by evaluating 3,000 germplasm accessions and 150,000 hybrid clones for all the ecosystems. From these evaluations, 112 elite clones have been selected and used as parents to generate segregating progenies from which to initiate a new selection cycle. The elite materials have also been placed *in vitro* for their transfer to homologous ecosystems in Latin America and Asia. A total of 600,000 recombinant seeds were introduced to different cassava producing countries on the three continents. This infusion of germplasm represents an increase in the existing genetic base beyond the genetic diversity already existing in Africa and Asia.

A total of 17 varieties, derived directly from CIAT's gene pools or having CIAT's materials as one of the parents, have been released in Asia and Latin America since 1989. These new varieties are covering an area close to 200,000 hectares in Asia and

40,000 in Latin America. The impact from these new varieties is probably at the beginning of the exponential phase. Slow multiplication rate and the almost total absence, particularly in Latin America, of well organized cassava multiplication systems hinders the rapid diffusion of improved varieties. It is expected that measurable impact will be significant during the coming 5-year period.

A total of 251,744 recombinant seeds have been introduced to IITA for evaluation and selection in different agro-ecosystems, expanding significantly the genetic base for cassava breeding for the semiarid tropics, highland tropics, humid tropics and the sub-tropics of Africa. The joint evaluation by IITA and CIAT of this germplasm has resulted in the selection of 33 clones with good adaptation to African semiarid conditions.

One of the major constraints to adaptative breeding and cassava varietal diffusion is the lack of appropriate mechanisms for understanding farmer, processor and consumer perceptions regarding the acceptability of new cultivars. During the last 5 years, major emphasis has been placed on the development of a model for the evaluation of cassava varieties with the participation of farmers. Important feed-back from farmers has been gained in Colombia and Brazil using this methodology. It also resulted in improved opportunities for varietal diffusion. This work is now concentrating on training national program researchers in the use of the model and its adaptation to differing conditions.

Reduced personnel and operational resources have limited the study and implementation of alternative breeding methodologies that could boost the genetic progress and the efficiency of cassava breeding programs throughout the world, and at the same time complement the efforts being made on the development and application of new tools.

During this period, the support for implementing different methodologies for planting material multiplication at national program level was discontinued when CIAT's Seed Unit was phased out in 1992. Although the Program itself took the responsibility to continue that support, that activity was cancelled in 1994 as a result of budgetary restrictions.

Greater emphasis is being given to gene pool development for semi-arid and sub-tropical agro-ecosystems through a special project being implemented together with the Brazilian national program and funded by IFAD, Rome. For the semi-arid, drought and mite resistance materials have been evaluated. Additional criteria have been incorporated into the selection scheme following basic studies conducted on the physiological basis of drought tolerance and nutrient use efficiency. Breeding activities for the humid tropics, sub-humid (including savannas) and highlands (including mid-altitude) have been maintained. For all ecosystems, greater attention is now placed on the enhancement of starch content and the reduction of cyanogenic potential.

During the last 5-year period, the Latin American and Asian breeders networks have been consolidated as the most important mechanism for germplasm and information exchange with national program counterparts. Network activities have been important for the strengthening of the relatively weaker Latin American national programs. In Asia, China and Vietnam, two countries with which we had little prior experience of cooperation, have received priority attention.

Future Research Strategy

The process of developing broad based gene pools from which national programs will select varieties for release to farmers is a long term endeavor. A breeding cycle at CIAT takes 8 years, and once the recombinant seeds or elite materials are introduced to national programs, it can take up to 10 years to select and release a cassava variety to cover an area of 1000 ha. Although major shifts in the ongoing process are not anticipated for the next five years, there will be refinements to further stratify and target the gene pools to the particular needs of the intermediate and end users of that germplasm. The available genetic diversity, the representative sites where the germplasm is evaluated and selected, and the recombination process will ensure that a 25% increase over the most elite germplasm available today, could be realized under farmer's conditions by the end of the next 5-year period. In order to improve the efficiency of gene pool development, a cycle of inbreeding will be implemented in between two cycles of recombination. This method ensures an extensive elimination of deleterious recessive alleles, normally carried in heterozygous condition.

Marker-assisted selection of parents and segregating progenies will be implemented particularly for those traits that require expensive, destructive and time-consuming screening methodologies, and for those needing particular conditions for their expressions (i.e. selection of resistant germplasm to ACMV carried out at CIAT without the need to introduce the virus to Latin America).

The improvement of micro-nutrient content (particularly vitamin A) and the extension of storage life for cassava roots are research lines recently initiated and could bring global benefits for the people who grow and consume cassava.

Conventional approaches to cassava improvement have not yet been exhausted in bringing the crop to its potential in terms of adaptation, productivity and tapping existing and future markets. However, there are challenges that go beyond what the conventional approaches are able to handle, and if successfully achieved, would have global significance in terms of how the crop is grown, processed and consumed. These challenges will require a major investment and dedication from a network of collaborators. During the next 5-year period it is expected that a reliable protocol for cassava transformation will be available. This will be an important component of an integrated approach to solving some of those breeding challenges. The following appear to be the most important challenges where biotechnology can make its greatest contribution: a) acyanogenic cassava and its biological and utilization consequences; b) qualitative improvement in the potential for post-harvest storage; c) modification of starch characteristics for specialized markets; d) coupling an increase in tolerance to stress with mechanisms for protecting fragile environments; and e) overcoming several of the constraints associated with vegetative propagation, through the development of a seed-propagated cassava crop, preferably through apomixis.

(3) Integrated crop management

Historical Assessment

Small-scale farmers grow most of the world's cassava crop over a broad range of tropical environments, often on fragile or poor soils, under rainfed conditions, and in areas where resources are limited. The Cassava Program, since its inception, has addressed this situation by continual strategic and applied research in crop management, including pest and disease management. Crop management technologies and recommendations are continually being designed for the major agroecological zones, previously described in this document. Research has shown that each ecological zone often requires a unique package of management practices to obtain optimal yield. Crop management technologies generated include the production, selection and treatment of planting material, proper land preparation, the adequate use of fertilizers, the use of mixed cropping, rotations, and cover crops, biological control of pests and diseases, the use of ecosystem adapted varieties, with resistance to major biotic and abiotic stresses, and soil conservation and fertility maintenance practices.

Extensive and continued research over two decades have identified the most important biotic constraints associated with cassava in the major ecosystems where the crop is grown. A constraint assessment exercise carried out by the Cassava Program in 1993, based on field and research data, indicate that average yields could be increased by 25% globally through the effective control of arthropod pests and diseases.

Arthropods are primarily pests of cassava in seasonally dry or semi-arid agroecosystems. Major pests include mites, mealybugs, whiteflies, lacebugs, the cassava hornworm and burrowing bugs. During the last five years, natural enemies for biological control of mites, mealybugs, burrowing bugs, and the cassava hornworm have been identified and many have been extensively studied in the laboratory and field. The mealybug parasite *Aenasius vexans* was found in Venezuela and has been released in Colombia where it has become established and has decreased mealybug populations in the Llanos. Three key parasite species are being introduced into N.E. Brazil for mealybug control. The collaborative effort between CIAT and IITA for mealybug control continues and a predator form Colombia was released recently into cassava fields in Africa.

Extensive surveys for natural enemies of the cassava green mite in 12 countries have been achieved. Methodologies for culture, packing and shipping have been developed; ecological and biological characterization of predatory mites, coleopteran predators, and the fungal pathogen, *Neozygites* sp. is being advanced. Ten species of predatory mites have been introduced into Africa via IITA, and three species from Brazil have become established.

Effective biological control of the cassava hornworm, a migratory lepidopteran, is based on a hornworm-specific baculovirus, which can be formulated into a spray by very simple technology. The timing, application frequency, optimal concentration, effects of prolonged storage, and field duration of the virus spray have been determined. Successful field application of the virus has been achieved in Brazil, Colombia and Venezuela, where in one large plantation pesticide costs were reduced by US$50,000 per year. In Southern Brazil it is estimated that virus application reduces pesticide use by 60%.

HCN production is a known defense mechanism to arthropod pests in many plant species. Its role in cassava is being defined. High cyanogen potential in cassava roots is shown to be detrimental to the development of the burrowing bug, causing considerable mortality.

The integrated control of several diseases including root rot pathogens, cassava bacterial blight, superelongation disease, and the mycoplasm or witches' broom disease have received priority. Root rots constitute a major source of yield loss in cassava, and their incidence is increasing in Latin America. Root rots are caused mainly by species of *Phytophthora, Pythium* and *Fusarium*. Integrated control of these pathogens include planting on ridges, intercropping cassava with corn or sorghum, use of pathogen-free planting material, elimination of affected plant debris after harvesting, and the use of genetic control. The use of biocontrol of root rot diseases using *Trichoderma* as a biofungicide is also very promising. A set of technical recommendations consisting of the use of host plant resistance and several cultural practices has increased yield by as much as 300% in the Pivijay area of Colombia, and as high as 80% in the Varzea region of the Amazon, Brazil.

Several cultural practices have proven to be effective in the control of the cassava bacterial blight disease in tropical environments. Intercropping and crop rotation together with the use of pathogen-free planting material provide the highest reduction in incidence and severity of this disease. The implementation of these integrated control practices in Brazil and Colombia has provided control of this disease as well as in the severity and incidence of the superelongation and the mycoplasm witches' broom diseases. Corrective application of potassium to K-deficient soils has also been found to reduce superelongation disease and increase cassava yields.

The confirmation of the existence of beneficial endophytes or microorganisms able to grow inside cassava tissues without inducing visible necrosis opens the possibility of increasing biomass production by direct application of these endophytes to plantations or by inducing indirect plant protection against detrimental parasites. The treatment of planting material with these beneficial microorganisms, reestablishes yield stability of meristem culture-derived plants and controls root rot diseases.

A CIAT/EMBRAPA four year integrated pest management pilot project, financed by UNDP is in progress in N.E. Brazil. The project focuses on farmer-participatory selection, integration, testing and adaptation of cassava pest and disease management practices at the farm level. This project includes the incorporation of entomology, acarology, pathology, virology, soil conservation and management, and weed control technology components, as well as the use of improved germplasm. This project is also linked to IITA and four west African countries primarily through the introduction into Africa of cassava green mite natural enemies. Cassava green mite predators and mealybug parasites are presently being introduced into Brazil from Colombia, and released in cassava fields.

In the area of crop-soil management, the Program has increased its attention to soil fertility maintenance and erosion control through research in representative ecosystems in both Latin America and Asia. In Colombia, the long-term response of cassava to fertilizer application indicated that reasonable sustainable yields could be obtained on infertile soil with moderate levels of K fertilizer, and to a certain extent P fertilizer. No response to N was observed, provided that soil organic matter was high. In sandy soils with low organic matter, sustainable cassava production requires application of NPK fertilizer.

These results are being corroborated in Asia, where soils are low in organic matter and nutrients. In short-term NPK trials in several Asian countries, cassava has shown a marked response to N application but little response to either K or P. Green manures, particularly of legumes, and application of surface mulch of crop residues, were beneficial in improving soil fertility and hence crop productivity. In addition to these cultural practices, screening cassava germplasm for adaptation to acid and infertile soils (i.e. low in P and K) have revealed the potential for identifying and selecting genotypes with good level of tolerance. These genotypes are incorporated as parental materials in the development of improved germplasm.

Research on soil conservation practices for hillside or upland cassava-based cropping systems has continued both in Colombia and several Asian countries. This work focuses on the identification and evaluation of appropriate technologies which include forage legume cover crops, mulch of weeds and crop residues and live barriers. Results on both continents have shown that soil erosion in cassava-based cropping systems can be greatly minimized by cultivating cassava in contour ridges, with grass barriers, or by using mulch and live ground cover of forage legumes. Agronomic practices that result in rapid canopy closure, such as the use of appropriate genotypes, application of fertilizer in poor soils and closer spacing, also reduce soil loss.

These research efforts on soil conservation are currently continuing in Colombia with the financial support of BMZ, Germany. On-farm evaluation of soil conservation practices are being conducted on three different locations on hilly lands in the Cauca Department in collaboration with farmers' communities, NGO's, national agencies and CIAT's Hillsides Program. In Asia, a five-year soil conservation and management research project in collaboration with several Asian national programs was initiated in 1993 with the financial support of the Sasakawa Foundation of Japan. The project focuses on the development of a farmer participatory methodology for the selection, integration, testing and adaptation of appropriate management practices that have been developed over the past several years.

Future research strategy

Strategic research on pest and disease management will continue to focus on low-input environmentally-sound technologies that will avoid the use of pesticides.

Arthropod pest management will concentrate on the selection of cassava varieties resistant to major pests (mites, whiteflies and lacebugs) and the identification and evaluation of natural enemies of key pests (mites, mealybugs, hornworm and burrowing bugs). Biological control of the cassava green mite in N.E. Brazil and Africa will involve foreign exploration based on analysis of prior geographic surveys. Candidate natural enemies will be evaluated in the laboratory for suitability for foreign establishment. Field experiments will be used to improve methods of establishment and conservation of mite predators. More emphasis will be given to the burrowing bug *Cyrtomenus bergi* and the role of HCN as a defense mechanism in cassava.

Research on the integrated control of cassava bacterial blight and root rots will continue with particular emphasis on determining the feasibility of employing biological control at the field level. The actual role and possible deployment of beneficial endophytes will also be investigated in further depth. Following the characterization of cassava vein mosaic virus and the determination of the epidemiology of this disease, integrated pest management solutions will be developed.

Research in crop-soil management in cassava-based production systems will focus on the seasonally dry and semiarid ecosystems where cassava production is expanding due to continued food shortage in many marginal environments in South America, Africa and Asia. The Program is currently active in seeking additional funds to support these research activities. Work for Latin American hillside ecosystems will continue within the on-going interprogram project.

The two major special projects that are under execution in Brazil (IPM) and Asia (integrated crop-soil management), which both seek to develop farmer participatory methods for designing options and adapting appropriate technological solutions to biotic and abiotic constraints, will both run for the greater part of the next planning period. The information generated and results of these projects will be instrumental in providing feed back which will help determine future research directions. As the Hillsides and Tropical Lowlands Programs reach greater definition with respect to opportunities for integrated crop management in cassava-based systems in their pilot study areas, it is expected that collaboration with these two Programs will increase through the formulation of additional interprogram projects.

(4) Cassava markets

Historical Assessment

Early in the history of CIAT's Cassava Program it was recognized that research on process, product and market development is key to maximising the crop's true potential as a source of additional income for small- to medium-scale farmers. This is especially true in situations where the role of cassava is changing from being a rural staple to a multipurpose carbohydrate source. CIAT has concentrated its research effort on the development of technologies for the small-scale primary processing of cassava into (a) dry chips for the animal feed market, (b) cassava flour for the food industry, (c) cassava starch and (d) the conservation of fresh cassava for human consumption.

At the beginning of the period under review, research on dried cassava for animal feed was phased out. The commercial expansion of dry cassava chip production, introduced by CIAT in collaboration with the Integrated Rural Development Fund on Colombia's Atlantic Coast in the early 80s, had reached a self reliant and autonomous growth phase. The Program has continued to provide technical support to national programs that have research on cassava drying for animal feed, notably Ecuador, Brazil, Paraguay and Bolivia.

In 1992, research on the conservation of fresh cassava was terminated. Pilot scale testing in the city of Barranquilla, Colombia, demonstrated the technical and economic feasibility of the storage technology developed by CIAT and NRI. Problems of urban distribution and farmer organization prevented large scale adoption of the storage technology although market intermediaries have adopted certain aspects of the handling and packaging recommendations. The technology is being used commercially by one cooperative in Colombia, has been successfully pilot-tested in Paraguay and is now under validation in Ghana.

The project to develop high quality flour for human consumption has passed from the pilot phase to semicommercial operation of the processing plant established by

COOPROALGA, a farmers' cooperative on the Atlantic Coast of Colombia. Market studies, including industrial trials of the flour, have demonstrated that cassava flour can find market niches in both food and non-food applications where it has either price or quality advantages over flours and starches from conventional sources (e.g. wheat and maize). The cassava flour processing technology is being employed in Ecuador by the Union of Cassava Farmers in Manabi province and five plants are being installed in different sites in Peru.

A joint research program with CIRAD-SAR, Montpellier, on cassava starch started in 1989 focusing primarily on sour or fermented starch. Evaluation of existing traditional small-scale production units in Colombia identified areas for process improvement to reduce losses and improve product quality. Following on-site evaluation of process improvements, these have been transferred successfully by national institutions to processors in Colombia, Ecuador, Paraguay and Honduras. The "self raising" characteristic of sour starch has been found to be unique in terms of conferring expansion properties to bakery products. This cassava starch characteristic could open up important niche markets in dietary and gluten-free products.

Based on 10 years experience of postharvest research, the Program has defined a four stage methodology for cassava product, process and market development, comprising identification of opportunities, lab and prototype research, pilot scale testing and expansion to commercial scale operation. In collaboration with CIP and IITA, this methodology has been developed in the form of a manual for use by root and tuber postharvest research practitioners. The draft manual was reviewed by national program partners in workshops held in Latin America, Asia and Africa, to incorporate their experiences, and will be published shortly.

The Program initiated plans at the end of the 80s to increase its postharvest activities in S. and S.E. Asia. Given the relatively greater emphasis and investment in the development of postharvest technologies for root and tuber crops in this continent, the focus of CIAT's interventions was to improve the communication among workers in the postharvest area and enhance the transfer of technologies and experiences between countries. Cassava utilization was a principal theme of the 3rd Asian Regional Cassava Research Workshop held in 1990, which was followed in 1991 by a workshop on Product Development for Root and Tuber Crops held in collaboration with CIP. Since then, resource restrictions have limited our activities to evaluating the impact of the development of the cassava flour industry in Indonesia. In 1994, a joint project with CIP has been initiated in N. Vietnam to identify and develop with national institutions opportunities for improved processing of cassava and sweet potato in four distinct regions where these crops are important sources of food and cash income.

A three-year multinstitutional project, financed by the E.U., is now in execution whose objective is to develop new products and markets for cassava in Latin America. CIRAD-SAR is the lead institution. CIAT, NRI, ORSTOM, the University of Valle, Colombia, the State University of Sao Paulo, Brazil, the University of Buenos Aires, Argentina and the National Polytechnic School, Ecuador, are participants. The project has five research areas: raw material/product quality relations, waste treatment, bioconversion of starch and flour, new product development and market studies. CIAT is involved in research on raw material/product quality relations and is the coordinating institution for the market studies.

Future Research Strategy

The Cassava Program's incursion into the area of postharvest processing and marketing at the beginning of the 80s was virtually unique within the CG system at that time. The adoption of a demand led or market driven philosophy to process and product research and the successful hands-on experience obtained through collaborative projects with national institutions in Latin America is now internationally recognized and the approach has been adopted by other research and development institutions involved in rural agroindustrial development, among them CIP and IITA. However, with the exception of conserved fresh cassava for human consumption, the products of primary cassava transformation have a relatively low value especially when sold into existing markets. The long term economic sustainability of small- to medium-scale rural agro-processing will therefore increasingly depend on both product and market diversification. The question therefore arises as to the extent to which CIAT should actively encompass the development of second generation products from cassava.

The strategy that has been adopted and that will be pursued in the next five years will rely on the strengthening of links with food science and technology research institutions in both developed and developing countries that have the infrastructure and human resources to undertake collaborative cassava product development research. The Cassava Program's core competence contribution to these projects will lie in three areas:

(a) the identification, economic evaluation and development with national programs of market opportunities;
(b) research on the relationship between raw material quality characteristics and the physico-chemical and functional properties of cassava products; and
(c) support at the national level to the integration of process and product research with market demand and consumer research.

Plans are already laid to support IITA in the development of a regional postharvest program for East and Southern Africa and it is hoped to build on the experience of the joint project with CIP in Vietnam, extending collaboration to other countries such as the Philippines, Indonesia and India in the future.

In early 1994, representatives of CIAT, IITA, CIP, NRI, ORSTOM and CIRAD-SAR agreed to initiate a dialogue with the objective of achieving a greater degree of communication and complementarity in their respective root and tuber postharvest R and D programs. Bilateral and even trilateral projects among these institutions are already in execution and others are in the pipeline. However, in the past there has been no attempt to identify, as a group, common areas of interest and gaps in our knowledge which could lead to a more coherent and effective deployment of the collective resources of the individual institutions. The first meeting of this group will be held in Salvador, Bahia in November, 1994.

Within CIAT, the Cassava Program's experience in market opportunity identification and assessment of processing options will be an input to a wider cross program proposal involving the Hillsides and Tropical Lowlands Programs. The purpose is to identify in the pilot study areas agroprocessing activities that will create additional income generating activities, thus providing farmers with an incentive to invest in resource conserving technologies.

(5) Institutional development

Historical Assessment

The Cassava Program is part of a global cassava R and D system made up of a wide range of institutions. The effectiveness of our work relies upon the building of strong relations with our partners in the system. This is a two-way process. We need to draw on their knowledge and expertise to help formulate our strategies and, conversely, we have the opportunity to support them in making best use of the products of our research. Traditionally, CIAT has been instrumental in providing information services and training, acting as a convener for professional interchange and a catalyser of collaborative initiatives, and assisting in network formation and operation.

Needs assessment and priority setting has been a major area of concern, both within the Program and among our partners. We were involved in the design and implementation of the first phase of the Collaborative Study of Cassava in Africa (COSCA) and, in Asia, the Vietnamese and Chinese national programs have been supported in the organization and analysis of cassava sector studies. These studies provide information for the formulation of national cassava research plans and feed into a global needs assessment and priority setting exercise that the Cassava Program is undertaking within the framework of the Cassava Biotechnology Network (see below).

The Program has directly participated in the formulation and execution of Integrated Cassava Research and Development Projects (ICRDP) in Manabi, Ecuador, and Ceara, Brazil. Interchange of information and experiences on the ICRDP methodology has been achieved in three regional meetings (1990, 1991, 1992) with participants from seven Latin American countries. The projects have proved to be an important inter-institutional mechanism for achieving closer links between research and development activities, an integration of production, processing and marketing components and a targeting of benefits towards cassava farmers and processors. Adoption and impact studies conducted to analyse both on-farm and region effects of the Colombian ICRDP have shown very favorable rates of return over a 10-year period. Staff reductions in the areas of Agronomy and Utilization have limited the Program's ability to extend the ICRDP methodology more widely.

A major investment was made in setting up a Southern Cone Cassava Development Network involving S. Brazil, N. Argentina and Paraguay. A "training of trainers" project successfully completed the formation of a group of 22 trainers from this network and the production of six learning units on principal cassava production and utilization topics. The elimination of the Latin American agronomy position in 1992 has restricted CIAT's ability to provide support to this initiative and to catalyse similar networks on the Andean and Central American and Caribbean regions.

Networking activities in Asia have been consolidated with the establishment of a regional Advisory Committee made up of cc :try representatives. This consultative and regional planning mechanism was instrumental in securing funding for the integrated crop-soil management project. The 3rd and 4th Regional Network workshops were held in 1990 and 1993. Both reviewed progress in breeding and agronomy with utilization research (1990) and technology transfer (1993) being theme areas that received special attention.

The Cassava Biotechnology Network (CBN) became operative in 1992. CBN seeks to integrate biotechnology into inter-disciplinary research of national programs of cassava growing countries. It supports needs assessment research with the objective of prioritizing biotechnology research towards providing solutions to the principal constraints of small farmers and processors, promotes collaborative research and facilitates exchange of information on biotechnology. CBN has held two scientific meetings, in Cartagena, Colombia (1992) and Bogor, Indonesia (1994). A third is planned for Kampala, Uganda (1996).

The biennial "Cassava Newsletter", published since 1977, keeps cassava workers in touch with each other and informed about a broad range of topics. Since 1991, the newsletter has been produced jointly with IITA. The publication "Abstracts on Cassava" has been discontinued and replaced by a more focused and targeted "Bibliographic Bulletin" that gives priority coverage to gray or non-conventional literature on cassava not widely diffused by commercial data bases.

Centerwide reductions in Institutional Development Support (IDS) since 1992 have led to a significant decline in the number of national program scientists receiving training and a consequent reduction in contact with those that can provide us feedback to orient our work.

Future strategy

The extent to which the Program will be able to maintain or extend the type of activities described in the previous section will depend largely on the success that we together with our partners have in attracting complementary funds for collaborative projects at the regional and global levels. Attention will therefore be given to mobilizing national program support and their demand for the services that CIAT and the Cassava Program can offer so that these activities can be included within both bilateral and multilateral project proposals. Indications are that there will be increasing contact with the private sector, including both small and large processing industries and NGOs who provide technical assistance to the small farm sector.

New initiatives that are at present being discussed include (a) the transfer of the ICRDP methodology to Africa in collaboration with IITA, NRI, CIRAD-SAR and ORSTOM and (b) the formation of a Root and Tuber Crop Network for Central America and the Caribbean in collaboration with CIP, IITA, CATIE and CARDI. CIAT's role as the convening center for ecoregional research in Latin America should greatly facilitate obtaining consensus around national needs in the area of institutional development. In Asia, it is conceivable that, in the medium term, it may be possible to attract resources through a consortium approach similar to the one being developed for rice in Latin America with strong participation of the private sector.

3. CONCLUDING REMARKS

The complexity of the issues that need to be tackled to achieve sustainable agricultural development, especially in the socioeconomically more marginal regions, is substantial. Realizing the true potential of cassava as a vehicle for this development is no less complex. However today, perhaps more than at any time in the past, there is a greater understanding of how this potential can be achieved. CIAT's Cassava Program is confident that it can continue to provide intellectual leadership within a global Cassava R and D system. We know that this leadership role depends on the credibility that we earn through striving for and achieving excellence in our research. Experience has shown us that, in order to meet this goal, we must adhere to two fundamental principles:

(1) Interinstitutional partnerships and links, based on mutual respect and complementarity, are vital for maintaining the relevance of our research.

(2) Interdisciplinarity and an integrated commodity system perspective are critical requirements that ensure a correct prioritization of research issues.

These principles underpin the Program's efforts to fulfil its global responsibilities and to serve the cassava R and D community, especially those who depend on the crop for their livelihood.

EPMR PROGRAM REPORT:

CIAT HILLSIDES PROGRAM

1992 - 1994

20 SEPTEMBER 1994

CIAT HILLSIDE AGROECOSYSTEM PROGRAM

EPMR REPORT: CIAT HILLSIDES PROGRAM 1992-4

EXECUTIVE SUMMARY

A. INTRODUCTION

The Goal of the Hillside Program is "to improve the welfare of the hillside farming community by developing sustainable, commercially viable agricultural production systems." The program's goal addresses the need identified in the CIAT mission to tackle problems of poverty and environmental degradation which go hand-in-hand in the hillsides of Tropical America. The hillside agroecosystem in Latin America is a major contributor to food supply and is the basis of the livelihood of a large population of the rural poor. The total area in hillsides in Tropical America is estimated at 95 million ha of which about 25 million ha are already highly degraded. The CIAT natural resource management definition of the "well-watered" hillsides amounts to 30.25 million hectares. In most of the countries with significant proportion of area in hillsides, the locus of poverty has yet to shift from rural to urban areas. Moreover, World Bank figures for the 1990'ties indicate that rural impoverishment has recently increased in some of these countries.

Causes of degradation in the hillside agroecosystem includes deforestation (24,9 million ha) overgrazing (24.7 million ha) and agricultural activities or domestic use of vegetation (42.6 million ha). Approximately 53 million hectares are estimated as experiencing rapid rates of degradation. The rapid rate of environmental degradation in the hillsides is driven by the unfavorable structure of incentives for hillside farmers to invest in conservation. Income-generating activities that permit capital accumulation and agricultural intensification, and that involve the use of profitable conservation technologies are the key to changing farmers' environmentally destructive management practices. This is the rationale for the program's objectives, which are: 1. To characterize the mechanisms leading to resource degradation and assess technological options. 2. To generate agroecologically and economically viable components, acceptable to farmers, for soil and water conservation and management practices. 3. To strengthen the capacity of national systems to generate and transfer resource-enhancing technology.

History of program development

For 1995, the program's projected core budget is US$1,021,000 for 3.6 senior scientist years, including sociology (program leader), production systems and soils specialist. The senior staff composition has changed from what was originally projected in 1991: from 5.25 SY's and six disciplines to 3.6 SY's and three disciplines on core.

For 1995, complementary funding is projected at US$870,000 (in reality closer to $1 million due to new grants received) and amounts to at least 50% of total budget.

As a result, by 1994, principal staff has doubled from three to six PhD level scientists due to special project funding. In addition to the core funded sociologist (Program Leader); production systems specialist (in Central America); and soils specialist, special project funding was obtained for two additional senior scientist positions (soils specialist; resource economist) in Central America; and a post-doctoral fellow (anthropologist) at CIAT, Palmira. Agreement in principle was reached for one of these positions to be a shared CIAT/CIMMYT soil scientist, posted in Honduras. An Andean hillsides interprogram project was planned with significant additional input by bean, cassava, tropical forages, land use and lowlands' scientists who have activities within this project.

The first official meeting of the Central America Hillside project's (CAHP) steering committee was held in May 1994 with representatives from IARC, regional and national partner institutions. Research priorities were set and a 6 month workplan outlined. Guidelines for cooperation with national and local institutions were agreed upon. The hillside program joined CONDESAN (Consortium for sustainable development of the Andean Ecoregion) and took part in a planning workshop at which a joint bench-march site for CIAT-CIP collaboration was selected, and a special project was developed for submission to donors, for this site in Ecuador.

B. HISTORICAL ASSESSMENT OF MAJOR RESEARCH THEMES

(a) Problem identification and prioritisation

A preliminary analysis by the Land Management Unit identified the following issues in the well watered hillsides: (i) loss of biodiversity in relation to the rapid loss of natural forest cover; dissapearing landraces of traditional crops; loss of wild relatives of useful crop species. (ii) soil erosion, principally loss of topsoil due to water erosion (approx. 25 million ha). (iii) nutrient loss through leaching, identified with monocultives and badly-managed sown pastures, (iv) water quality, associated with high sediment load in feed waters; severe nitrate and organic matter pollution, agrochemical pollution (fungicides, pesticides and fertilizers). In 1993, an ex-ante impact assessment model was developed to aid in prioritising potential lines of research together with the Impact Assessment Unit. Consultations with partner institutions developed priorities for the area-based research.

(b) Strategic research issues

Strategic research issues were analysed and prioritised. Those identified as relevant to the program's capacity are:

- the need to improve methods for extrapolation and targeting of technical soil conservation recommendations for the hillsides
- the development of participatory decision-support systems to assist conflict-resolution and joint action for resource conservation
- generation of "win-win" technologies that serve both production and conservation needs simultaneously
- development and application of participatory research methods to accelerate adoption of conservation practices.

(c) Problem-solving strategy and expected outputs.

To illustrate the programs' approach to problem solving two of the programs four internal subprojects in the Andean project area, are discussed in detail.

C. FUTURE RESEARCH STRATEGY

Within a five year future horizon, the hillside program expects to be able to offer to NARs, NRM agencies and other client institutions in the hillside agroecosystem, a strategy (including a methodological tool kit) which can be used to develop and execute major fundable bilateral projects to improve hillside natural resource management. Future strategy basically involves completion of the hillsides projects initiated in 1993/4, described in the funding request for 1995. New projects to be developed in the period 1994-99 concern biodiversity in-situ conservation in the Tropical American hillsides; together with the CIAT Biotechnology Unit, IPGRI, and potentially CONDESAN/CIP.

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A. INTRODUCTION

A.1. GOAL, OBJECTIVES AND JUSTIFICATION OF THE PROGRAM

The Goal of the Hillside Program is "to improve the welfare of the hillside farming community by developing sustainable, commercially viable agricultural production systems." This goal is derived from CIAT's mission statement (CIAT, 1991) "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." The program's goal addresses the need identified in the mission to tackle problems of poverty and environmental degradation which go hand-in-hand in the hillsides of Tropical America.

The hillside agroecosystem in Latin America is a major contributor to food supply and is the basis of the livelihood of a large population of the rural poor. The total area in hillsides in Tropical America is estimated at 95 million ha of which about 25 million ha are already highly degradated". This agroecosystem supports over 20 million people. Principal countries (shown with percent of area in steep-slope agriculture) include Bolivia, Colombia (40%), Ecuador (65%), Peru (50%), and Venezuela, Costa Rica (70%), El Salvador (75%), Guatemala (75%), Honduras (80%), Nicaragua, Panama (80%), Mexico, Haiti, Jamaica and the Dominican Republic. The CIAT natural resource management definition of the "well-watered" hillsides amounts to 30.25 million hectares.

Other than in Colombia, Venezuela and Peru, the majority of the population of the predominantly hillside countries was rural at the beginning of the 1990'ties. World Bank data show a high proportion of this rural population is today in poverty, ranging from 45% (Colombia) to 80% (Guatemala); and a significant portion is indigent (ie, without means to meet minimal nutritional needs) eg. 23% of rural population is indigent in Colombia; 46% in Peru, 57% in Guatemala (CEPAL, 1990). Female-headed households are a high proportion of the indigent rural population (CEPAL, 1992). Thus, in most of the countries with significant proportion of area in hillsides, the locus of poverty has yet to shift from rural to urban areas. Moreover, World Bank figures for the 1990'ties indicate that rural impoverishment has recently increased in some of these countries.

Causes of degradation in the hillside agroecosystem includes deforestation (24,9 million ha) overgrazing (24.7 million ha) and agricultural activities or domestic use of vegetation (42.6 million ha). Approximately 53 million hectares are estimated as experiencing rapid rates of degradation.

Agriculture in the mid-altitude hillsides is typically based on fallow-rotation systems in which forest or bush fallow is cleared, for cropping with annuals (maize, beans, cassava, upland rice) and perennials, and returned to pasture or bush fallow once yields decline to a level that is non-economic for farmers to continue cultivation. In the more densely populated and drier areas, fallow periods have shortened or fallowing has been virtually replaced by organic or chemical fertilisers. When farmers cannot obtain or afford fertilisers, they work off farm, exacerbating the "feminization" of hillside farming, in which the real farmers are the women managing a subsistence of semi-commercial small farm.

Even in "well-watered" areas, the erratic distribution of rainfall can lead to short but sometimes critical periods of drought stress. Pest disease and weed control are major constraints in annual crops. Degraded fallows, largely synonymous with overgrazed pasture occupy 40-60% of area. Large farms maintain low stocking rates, and sharecrop arable land. This reflects a strategy of investing in land to protect capital. Improved production is frequently not a primary or even important objective of large landowners in the hillsides, who make up about twenty percent of farmers and own 80% of the land. Intensification of production on the small farms is an important part of alleviating the poverty which drives migrants to colonise, deforest and degrade increasingly fragile environments.

Environmental degradation in the hillsides has serious implications not only for the viability of agricultural production in the agroecosystem itself, but for "downstream" lowland agriculture and coastal ecosystems affected by soil erosion and agrochemical pollution in the uplands. Second, the welfare of urban populations which draw their water supplies from water courses originating in the hillsides is also intimately affected by soil erosion, sedimentation of dams, and major land slippage caused by deforestation and cropping without use of soil conservation practices. Third, and potentially the most irreversible damage with major social cost implied by hillside environmental degradation, is the los of biodiversity due to the disappearance of montane forest which between 15% of area (Bolivia) to 57% (Guatemala). The rate of deforestation in the hillsides is higher than in the lowlands, causing a loss of 90 percent of montane forest by 1990. Montane forest has very high biodiversity, possibly higher than lowland forests, especially with respect to herbs and shrubs found between 600-3000m elevation, which are considered important for conserving wild crop genetic resources in-situ. A fourth feature of environmental degradation in the hillsides is the excessive use of agrochemicals characteristic of agricultural intensification, causing soil and groundwater pollution, ecological imbalance in pest and disease complexes, as well as chemically contaminated food.

The rapid rate of environmental degradation in the hillsides is driven by the unfavorable structure of incentives for hillside farmers to invest in conservation. These incentives are shaped by the specific agroecological conditions faced, the technologies available, the prices of inputs used and outputs produced, the opportunities for off-farm employment and migration, as well as cultural and organisational norms of natural resource management. Income-generating activities that permit capital accumulation and agricultural intensification, and that involve the use of profitable conservation technologies are the key to changing farmers' environmentally destructive management practices. This is the rationale for the program's objectives, which are:

1. To characterize the mechanisms leading to resource degradation and assess technological options.

2. To generate agroecologically and economically viable components, acceptable to farmers, for soil and water conservation and management practices.

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

Each objective is discussed in CIAT's Strategic Plan (CIAT, 1991) and Midterm plan 1993-98 (CIAT, 1992).

A.2. HISTORY OF PROGRAM ACTIVITIES (1991-94)

2.1 Program development, funding and staff recruitment.

The genesis of CIAT's hillside program as formulated in the Strategic plan (1991) was threefold: the AEU environmental classification study (Jones et al 1991); and the CIAT internal hillside working group, composed of scientists from the existing CIAT programs, the AEU and the deputy director of Natural Resource Management; and regional partners, primarily in Central America, who former the international hillside consortium (IICA, CATIE, CIMMYT). The working group wrote the goal and objectives for the Strategic Plan (CIAT, 1991). The AEU study which has yet to be ground-truthed and further refined, identified a subsystem of the tropical American hillsides, the seasonally wet hillsides of the northern and Central Andes, Central America and the Caribbean, where similar land use patterns were identified. This subsystem amounting to 30 million of the total 96 million hectares of hillsides in the region was judged by CIAT management to deserve inclusion in the NRM initiative, together with forest margins and savannas, because all have in common, poor acid soils and reliable, well-watered growing seasons (CIAT, 1991: 117) [1]

Subsequently, the 1993-8 medium term plan (CIAT 1992) defined an operational structure for each NRM program. A "vertical" strategy (meaning in depth case-studies conducted by area-based teams) and "horizontal" (meaning comparative research led by the headquarters program) were intended to complement each other, and institutional partners capabilities in the region.

In 1991, CIAT as a member of the International "Hillside Consortium" formed with IICA and CATIE organised an international workshop which brought together public sector and NGOs to discuss sustainable agriculture including problems current in the Central American hillsides. A "focal group" was formed consisting of regional staff of IICA, CATIE, CIMMYT, a Rockefeller postdoctoral fellow assigned to CIAT's AEU, and with sporadic participation by several NGO's and consultants hired by CIAT. The focal group conducted a rapid appraisal to identify sites for "case studies" by area-based teams. A hillside case study site, "La Ceiba", on the Atlantic littoral of Honduras was selected by the focal group in late 1991 for research by the consortium together with the future area-based CIAT team. Subsequently, in Spring 1992, CIAT undertook recruitment of the program leader, appointed in July, 1992.

The goal and objectives in the 1991 strategic plan were formulated in the context of a projected core budget of US$1,284,000 for 1995, with a headquarters team of 5.25 senior staff, including economics, cropping systems, soil organic matter, agroforestry, livestock systems and anthropology specialists. The medium term plan (1992) projected a reduced core budget of us US$930,000 for 1995 with fewer senior scientists positions (all 4 to have been filled in 1992) consisting of soil management, sociology/anthropology, and production systems expertise.

By early 1993, three core-funded senior staff had been recruited; the fourth projected core position was frozen, and remains so today.

1. The seasonally wet or "well-watered" hillsides are characterised by intensive coffee production, cultivation of annuals (cassava, maize and beans are important staples) and cattle-raising. Although the most prevalent form of natural vegetation is forest, about 10% of the forest remains. Perennial cover 30% of area; annual crops 5-20% of land; 20 to 40% of land is under pastures and bush fallow accounts for 10-30% of area. About 10% of the area is flat, 40-50% steep, and 50% rolling.

For 1995, the program's projected core budget is US$1,021,000 for 3.6 senior scientist years, including sociology (program leader), production systems and soils specialists. In summary, the senior staff composition has changed from what was originally projected: from 5.25 SY's and six disciplines to 3.6 SY's and three disciplines on core.

For 1995, complementary funding is projected at US$870,000 (in reality closer to $1 million due to new grants received) and amounts to at least 50% of total budget.

By 1994, principal staff has doubled from three to six PhD level scientists due to special project funding. In addition to the core funded sociologist (Program Leader); production systems specialist (in Central America); and soils specialist, special project funding was obtained for two additional senior scientist positions (soils specialist; resource economist) in Central America; and a post-doctoral fellow (anthropologist) at CIAT, Palmira. Two staff members from the lowland program assigned in November 1993 to work in the hillsides agroecosystem are implementing joint workplans. An Andean hillsides interprogram project was planned with significant additional input by bean, cassava, tropical forages, land use and lowlands' scientists who have activities within this project.

With the approval by Swiss Development Cooperation of US$1,000,000 for the first two year phase of a special project in Honduras and Nicaragua, recruitment was completed for two scientists to be outposted in Honduras, between July-September 1994. Agreement in principle was reached for one of these positions to be a shared CIAT/CIMMYT soil scientist, posted in Honduras.

The first official meeting of the Central America Hillside project's (CAHP) steering committee was held in May 1994 with representatives from IARC, regional and national partner institutions. Research priorities were set and a 6 month workplan outlined. Guidelines for cooperation with national and local institutions were agreed upon.

Partners in the Hillside Consortium also have related projects for the hillsides: which are coordinated through the consultative group of the CAHP. IFPRI (effects of policy on NRM at the farm level); IICA (technology transfer, communications and policy); CIMMYT (Regional Maize Program); CATIE (agroforestry).

The hillside program joined CONDESAN (Consortium for sustainable development of the Andean Ecoregion) and took part in a planning workshop at which a joint bench-march site for CIAT-CIP collaboration was selected, and a special project was developed for submission to donors, for this site in Ecuador.

2.2 Site selection for area-based research.

For strategic research purposes, hillside program scientists consider that capturing variability across a range of conditions in the hillside agroecosystem is more useful than locating one average, representative set of conditions, because of the micro-agroecological diversity typical of the hillsides. Thus, area based studies need to be located in a site or sites which express this range of variability, so that methodology development, comparative analysis of technological options and extrapolation of results can be better tested and targeted for highly variable, site-specific conditions.

In Central America, although the hillsides consortium had selected La Ceiba as the site for area-based research, neither partners (CIMMYT, CATIE, IICA, SRN

(Honduras) nor the prospective donor were in agreement about targeting exclusively the well-watered hillsides or exclusively one site within that subsystem. During the development of the CAPH project in consultation with NARI's, NGOs and partner in August 1992, site selection in Central America evolved to include a range of sites on relation to an important determinant variable for Central America annual precipitation. As a result, La Ceiba was complemented by three additional sites for area based research in Honduras and Nicaragua which cover a wider range of variability within the "well-watered" agroecosystem.

In the Andean Region, the Rio Ovejas watershed in Cauca Department, Colombia was purposely selected. In Rio Ovejas, CIAT programs and partners had upwards of 15 years of commodity program research. The Rio Ovejas watershed covers 100,000 ha and encompasses a diverse range of Andean hillside systems ranging from indigenous slash and burn cultivation to peri-urban, high-input horticulture, and includes CIAT commodities (beans, cassava, forages).

B. HISTORICAL ASSESSMENT OF MAJOR RESEARCH THEMES

B.1 PROBLEM IDENTIFICATION AND PRIORITISATION

Initially three main criteria were considered in problem identification and prioritisation once the well-watered hillside agroecosystem had been selected by CIAT management: CIAT's comparative advantage; the comparative advantages and priorities of institutions in the area-based study sites; and results of the AEU land classification study. In 1993-4, an ex ante impact assessment model was developed to aid in prioritizing potential lines of research.

1.1 CIAT's comparative advantage

In the 1992 medium-term plan, CIAT's comparative advantages were defined as:

- understanding farmer decision-making (methodology development)
- designing multispecies systems together with modelling of biological processes that improve soil fertility in acid soils
- decision support via spatial databases, impact models, expert systems, to strengthen institutional partners.

In the hillsides agroecosystem, numerous institutions are actively engaged in the adaptive testing, validation and transfer of conservation farming techniques. The location-specificity of conservation technology in the hillsides means that IARC research must complement and strengthen this widespread and diverse component technology testing, with relevant "upstream" contributions.

1.2 Results of land classification

The AEU 1991 land classification study had identified the major environmental problems of the well-watered hillsides.

A preliminary analysis identified the following issues:

(i) loss of biodiversity in relation to the rapid loss of natural forest cover; dissapearing landraces of traditional crops; loss of wild relatives of useful crop species.

(ii) soil erosion, principally loss of topsoil due to water erosion (approx. 25 million ha).

(iii) nutrient loss through leaching, identified with monocultures and badly-managed sown pastures,

(iv) water quality, associated with high sediment load in feed waters; severe nitrate and organic matter pollution, agrochemical pollution (fungicides, pesticides and fertilsers).

Assessment of the location and extent of the erosion problem in the hillsides was begun in late 1993 by the Land Management Unit, but at the time of writing, results were not yet available.

1.3 Ex-ante impact assessment

A diagnostic simulation model was developed together with the CIAT impact assessment unit and applied to ex ante assessment of alternative technolgocial interventions. The model considered impacts on soil erosion, nutrient loss, crop productivity and water quality. Biodiversity has still to be included.

1.4 Partners' priorities for area-based research

Consultations with partner institutions developed priorities for the area-based research. In Central America, the 1991 interinstitutional workshop left a standing committee, to continue working on a series of proposals including preparation of an interinstitutional data base and the selection of a watershed as a site for interinstitutonal projects but did not produce a well-defined analysis of partners' priorities for the hillside agroecosystem. Subsequently, the CIAT Central American hillsides project (CAHP) in consultation with Swiss Development Cooperation (SDC) was developed for Honduras and Nicaragua. The CAHP held two expert consultation meetings with individuals considered knowledgeable about the hillsides. The CAHP meetings defined priorities to be used for the planning by the CAHP site-based operating committees, in the development of site-specific workplans in late 1994. In order of priority, these were:

1. Effects of hillside conservation practices and rotational systems of land use on soil degradation and regeneration (via long-term experimentation).
2. Analysis of factors related to successful or unsuccessful adoption of conservation practices.
3. Economic valuation of individual and social costs and benefits of conservation practices for steep-sloped farming.

Low priority was given to research on component technology, on farmers' attitudes or regional analysis of existing land use patterns by the CAHP consultative meeting.

In Colombia, workshops with national, regional and local institutions with active programs in the Rio Ovejas watershed defined a set of objectives for the interinstitutional consortium (CIPASLA) formed to enhance cooperation. The Rio Ovejas planning workshops identified problems and objectives for research in the context of a broader set of development and resource management problems faced by the participant organisations. These include research on:

- alternative production systems, including conservation practices, both indigenous and "exotic",
- strategies to increase the importance of livestock in existing production systems,
- the monetary value of soil conservation and reforestation, and the distribution of benefits among different groups.

B.2. STRATEGIC RESEARCH ISSUES

Strategic research issues were analysed and prioritised by the headquarters scientific staff of the hillside program on the basis of literature reviews, consultation with experts in relevant fields, and the deliberations summarised in section (a) above. Those identified as relevant to the program's capacity are:

- the need to improve methods for extrapolation and targeting of technical soil conservation recommendations for the hillsides,
- the development of participatory decision-support systems to assist conflict-resolution and joint action for resource conservation,
- generation of "win-win" technologies that serve both production and conservation needs simultaneously,
- development and application of participatory research methods to accelerate adoption of conservation practices.

2.1. Extrapolation and improved targeting of results

The payoff to collaborative research with regional scope to improve the capacity of NARS to extrapolate results and to target soil conservation recommendations is expected to be high. The adoption of existing or new technologies in situations where this can be expected to be profitable should be increased by this research; and the instances in which policy inducements are indispensable for adoption should be more readily identifyable.

A major problem is the scarcity of systematic data on the actual extent of soil degradation and its effects on productivity in the hillsides. Important reasons for this deficiency are related to inefficient precision and quantification, together with use of a confusing range of temporal and spatial scales of measurement. Research focussed on improving methodology for characterising the extent and costs of soil degradation, and on systematising the available data requires regional collaboration, due to the diversity of hillside land use classes found in any one country, and because several countries with hillside areas have weak and/or small NARS.

Improving the use of fragile soils on steep slopes in the hillside agroecosystem requires more accurate estimates of effects of soil degradation on potential productivity in order to (a) influence individual producers' discount rates which contribute to low adoption of soil conervation techniques (b) inform planning agencies and policy-makers concerned with land use and the design of policy instruments (especially subsidies) (c) provide a baseline for assessing the potential benefits of new technologies and production systems for improving land use in the hillsides, and (d) determine future research priorities. Furthermore, the extent to which soil quality loss may be limiting the realization of genetic potential in improved varieties, thereby reducing the efficiency of crop improvement research, needs to be assessed in collaborative research with commodity programs.

To improve crop productivity and forage availability, to enhance erosion control and soil physical rooting conditions, and to increase water infiltration, water-holding capacity, and nutrient retention of the soil, the incorporation into hillside production systems of practices for soil conservation and regeneration are being energetically promoted, largely by NGO's with a relatively weak research capability. A widespread process of trial and error is underway. There is a need for well-researched principles to aid the selection of suitable practices and the choice of management required to incorporate them into hillside production systems. Processes determining soil regeneration in acid and moderately-acid tropical hillside soils are poorly understood, and the cause-effect relationships between changes in the properties of these soils and productivity are scarcelyr esearched for the hillsides. There is a lack of satisfactory indicators to measure the tangible benefits of existing or new practices, which hampers their adoption by farmers, and the design of appropriate incentives to promote their use.

The relationship between soil erosion and productivity remains poorly researched and little understood in tropical soils. CIAT has a special project with the University of Hohenheim (funded at over $400,000) conducting research on soil erosion and component soil conservation technologies, principally live barriers and cover crops. This project is presently housed in the Cassava Program, which initiated the project as a crop management research project. The project recently expanded its scope beyond cassava to include other crops.

In view of the substantial resources at CIAT already invested in this research or physical soil erosion, at least in another program; and in the expectation that this project will, if it continues, be relocated, the Hillside Program Andean project area, has prioritized work on soil chemical degradation.

The hillside program's assessment is that a higher payoff can be expected in the long run, to soil physics research, but that results will be relatively slow to achieve, and require methodological innovation, for which the program must depend on collaboration with advanced university soils research departments, now in progress. On the other hand, research on soil chemical degradation is expected to produce results rapidly particularly with respect to the development of sustainability indicators, linked to improving soil quality assessment capabilities in NARS. This is particularly the case for NARS (and NGO's such as Colombia's Coffee Federation) with extensive, historical databases on soil chemical properties which can be analysed collaboratively, and potentially can be linked to GIS analysis to improve regional capability to extrapolate results from testing conservation technologies among similar soil quality (land) classes.

Results of this research will provide needed input to decision support systems.

2.2 Decision-support systems for land use planning and technology design

Natural resource management problems in the hillsides can seldom be resolved by individual farmers; they require collective action. Problem diagnosis with different constituencies leads to conflicting solutions being prioritised, often involving costs to be borne by a different interest group from the beneficiaries. Reaching consensus about the extent and distribution of the costs and benefits of alternative solutions among different constituencies is a central problem for NRM agencies in the region.

Realizing the potential impact of strategic information generated by CIAT on natural resource managemet by local, regional and national institutions depends on the provision of tools in the form of decision-support systems which make this information useful to stakeholders. In Latin America, devolution of responsibility to local and community-based entities means that decision-support systems will become increasingly important "technology" for negotiating alternative land-use scenarios among upstream and downstream stakeholders, characterised by competing and often conflictive interests in the use of the hillsides.

The methodology and computer-based techniques for building interactive decision-support systems for multi-objective, multi-stakeholder land use planning is a fast-moving technological "frontier" (comparable perhaps to biotechnology). It is important for CIAT to develop a core competence in these techniques in order to liase IARC and NARS research effectively with advanced, university-based expertise from the developed countries.

First, in the hillsides adoption of conservation practices has been minimal to date, due to significant discrepancies between the subjective weight given by different interest groups to the benefits of conservative farming, often leading to social conflict. The use of interactive decision-support systems which allow stakeholders to critically review and analyse their opinions and synthesize new positions are likely to be of critical importance to changing perceptions and to implementing change. Methodologies must incorporate stakeholders' values into optional changes, and enable stakeholders to "visualise" and evaluate future scenarios which show the consequences of adoption vs. non-adoption.

Second, in land use systems as highly diverse and intricate as the hillsides, with multiple conflicting interests, setting research priorities and defining data needs is a highly complex task likely to overtax already weak NARS. Guidelines are needed for defining priorities and for screening prototype systems and their components which can be partially obtained interactively with stakeholders but also require empirical measurement to determine the minimum data base required for a decision-support system intended to facilitate planning. Technology design and testing in the absence of modelling tools to assist screening large numbers of permutations for varied environments is likely to be costly, time consuming and thus inefficient.

Finally, building future scenarios (with or without computers) is an important technique for articulating client demand for research input and for obtaining client perspectives on the research output, a principle to which CIAT's natural resource management research is committed in its strategic plan.

2.3 Generation of "win-win" technologies to serve production and conservation needs

Existing research on technology generation for steep-slope agriculture consists mainly of site-specific or single-problem specific experimental work. There is a general deficiency of attempts to derive principles with strategic validity, either at the site level or in a coordinated international/regional efforts. CIAT's hillside program has a role to play in bringing together and systematising existing data from the large number of experiences, past and present, on the performance of given types of technologies in well-characterised micro-environments, to improve generalisation about their effects on conservation and production.

More specifically, research on integrated crop-livestock systems for the hillside agroecosystem has historically been weak in these respects. Research involving the integration of multipurpose trees and shrubs into hillside production systems is almost all concentrated on agroforestry, but not on agro-silvo-pastoral systems.

Long-term strategic research is needed to provide principles for the development of "transition" systems: ie. those which enable farmers to gradually transform their production systems from dependence on monocropped or intercropped short-season annuals, with little or no livestock, which degrade the natural resource base; to systems with a major role for perennials (grasses and legumes as well as trees), which improve soil quality, and nutrient cycling while meeting subsistence and/or commercial production objectives.

An important strategic concept to be explored is the possibility to develop prototype "transition" systems which involve more than one farmer in managing soil, water and vegetation at the "landscape" or multifarm scale. The landscape or multifarm system addresses the issue that appropriate land management in the hillsides will very likely require collective action by numbers of small farm units or plot owners. Similarly, individual owner operators or tenants occupy parts of a landscape that often will include communal property, whether forest, grazing or water resources.

Technology generation for prototype production systems ("transition" systems) requires a sound understanding of the effect market forces are likely to have on the adoption of any given combination of components in these systems, and the opportunities markets can create for "win-win" technologies to succeed.

The literature on erosion control technologies in tropical hillsides is characterized by one dominant theme: disappointing levels of adoption. Given the farmer's circumstances, soil depletion, in many cases is rational from the farmers point of view. As soil degenerates over time yield and income losses build up. At early stages of soil depletion the net returns without soil conservation exceed the net returns with conservation. Over time as soil degenerates further, the gap declines, until eventually, net returns with conservation are higher than those without conservation. Adoption is unlikely to occur until this point, which one study calculates to be at least 40 to 60 years after degeneration begins, depending on the discount rate used. Thus there is a conflict between the farmers economic logic and ecological considerations.

The literature also points out that while farmers consider the monetary benefits of erosion control, such as yield increases, they are unlikely to consider non monetary benefits such as soil resilience, or downstream benefits which accrue to others. Thus the extent to which soil conservation practices are voluntarily adopted by farmers will be suboptimal from society's point of view.

The problems with adoption raised above imply that farmers will have to be offered incentives to induce the timely adoption of soil conservation practices. Incentives have commonly taken the form of subsidies or regulations. The former however is costly, and in many cases induces distortions in other sectors of the economy. The latter is extremely difficult to implement.

"Win-win" technology generation implies a different type of incentive, such as income earning opportunities linked to soil conservation practices. Adoption is expected to occur because of the opportunity to increase income, with soil conservation occuring as a byproduct. This approach derives support from the fact that in the few cases of successful adoption that have occured, soil conservation practices permitted the introduction of high value crops, or supported the introduction of livestock, or generated income by being associated with value-added processes. Linking the market opportunity to conservation practices is however vital, as the literature is replete with cases where the introduction of income generating opportunities without any links to conservation have exacerbated resource degradation.

2.4 Development and application of methods for participatory R&D to accelerate adoption of conservation practices

Hillside agroecosystems are a mosaic of diverse micro-edaphioclimate regimes, user circumstances and cultures. In any one-area the results of technological innovation will be location-specific. An essential task is to develop a replicable approach to innovation, based on strategic understanding of how to intervene in a hillside agroecosystem and how to make transitions to ecologically sound and economically viable alternatives acceptable to users (both on-site and off-site). Determining why some technology options are more acceptable to farmers than others, and the trade-off between production and conservation objectives this involves, requires technology testing which is embedded in community-based participatory R&D.

Such research not only needs to be client-oriented but client-driven in order to ensure its continuous relevance; client-driven implies that users of research need to be involved in decision-making with respect to establishing research priorities, planning and conducting trials, and evaluating results. The methods and institutional arrangements entailed in this approach should be seen as a "social technology" which complements soils and production system research.

Organizing for client-driven community based R&D research can usefully be seen as consisting of three separate tasks:

The first is to identify institutional mechanisms to which all and particularly the poorest segments of a given community have access. Often local institutions tend to maintain and legitimize existing inequalities within a community rather than contribute to their eradication (e.g. Gubbels 1993; Pretty and Chambers 1993). Thus, rather than solely relying on existing local institutions, the challenge is to assist communities in creating new institutional mechanisms to meet new and often conflicting needs *and* to develop ways for these to interface with traditional institutions (Gubbels 1993).

The second task is to identify ways of strengthening community-based diagnostic, analytical and goal formulating capacities. For most farmers, actively identifying needs and formulating demands rather than simply responding to opportunities presented to them by external research or development organizations is something new. Thus, formulating problems in a non-opportunistic manner and perhaps even without having an idea of the contours of what might be a possible solution is a demanding exercise - even for researchers, one might add. It will require substantial support with respect to building capacity for analyzing the present situation and clearly specify goals and objectives to which solutions should respond.

The third task concerns how to organize the interface between farmers and researchers, i.e. finding mechanisms through which communication can take place between researchers and farmers and through which farmers can hold researchers accountable to responding to their needs.

Because hillsides farming is characterized by immense diversity, not only due to agro-ecological factors but also due to socio-economic factors, the task of combining components into what eventually emerges as a multitude of location specific production systems, rests with farmers. Moreover, because recognition of the importance of non-economic objectives in farmer decision-making is in its infancy, understanding such objectives and how to translate these into criteria determining research priorities, necessitates substantial input from farmers.

Secondly, as the research focus moves from agricultural production *per se* towards the much broader issue of natural resource management which has production as an integral part, the target group no longer is limited to the individual farmer but constitute groups of people involved in or affected by certain individual as well as collective management practices. Hence, institutional mechanisms become important for reconciling individual versus collective interests and for directing natural resource management research towards the relevant agents. In this way, "...the need for natural resource management can act a powerful catalyst for communal institutional development" (Murphree 1993:13). Participatory methods for technology assessment, hitherto applied at the individual, field or plot level need to be further tested and adapted to encompass the collective and landscape scales of analysis.

B.3. PROBLEM-SOLVING STRATEGY AND EXPECTED OUTPUTS

The hillside program's approach to problem solving is evolving, but the basic framework as it exists today, involves four interdependent "subprojects". These projects are linked in the following way: (1) research on the effects of soil degradation is primarily diagnostic research to better identify problems and set priorities among them (with respect to biophysical and economic aspects of soil degradation). This diagnostic research is developing indicators and data which are important inputs to a second research project, working with a suite of models being calibrated for tropical conditions, to create decision-support systems. (2) Diagnostic research also "piggy backs" off the research project on design of prototype production systems, which is focussed on technology generation. Technology generation in prototype systems will benefit from the pre-screening of optional components by ex-ante simulation modeling; equally these experiments will provide data to improve the models. (3) Decision-support systems incorporating different types of models, including knowledge-based models drawing on indigenous technical knowledge, will be introduced into participatory organisational models to facilitate conflict resolution and joint action at the community and watershed level. (4) At the same time, community-based participatory R&D methodologies are used to evaluate models, technology components and prototype systems. This ensures that stakeholders in improved natural resource management make an input to the overall research effort.

Ideally all four would be executed together in both Andean and Central American project areas, although the lack of full-time economist and soil organic matter specialist in the headquarters team is a major constraint in the Andean project area.

These four are detailed in the section on "Future Strategy" below. Due to limitations of space, only two are discussed here to illustrate the program's approach to problem solving.

3.1. Ex-ante impact analysis using simulation as a tool for planning community scale land use

The hillsides program aims to strenghten capacity to link different scales of measurement, analysis and organisation (ie watershed-landscape-farm-plot). Land classification studies in combination with ex-ante impact assessment are being used to identify "strategic" watersheds with significant downstream user constituences. The hypothesis is that technology development for "non-strategic" watersheds must focus on achieving on-site benefits, whether to individuals or groups. In "strategic" watersheds, the scope for subsidies or income transfers financed by downstream beneficiaries, may create different opportunities for technical innovation as compared with "non strategic" watersheds.

The application of decision-support systems to screening technology options requires accurate classification and characterization of these different "strategic" vs "non-strategic" environments and the stakeholders in them. Therefore research studies are being carried out to improve soil quality inventory mapping. Indicators of soil quality status are being defined, and studies being conducted to quantify levels of resilience of the soil resource base by measuring potential crop yields and species diversity of soil macrofauna. Other studies are examining "early warning" indicators useful for anticipating soil degradation, specifically soil acidification, and in the near future, ratios of total carbon to macro- and microbiological carbon will be studied. Experiments have been established and sampling of soil macrofauna is well advanced. On the socioeconomic side, a participatory research study has begun to classify different stakeholders and to develop indicators of their well-being. Both soils and socioeconomic studies emphasize methodology development to improve the capacity of NARS, NGO's, and other clients to characterise, classify and extrapolate across different environments and scales of analysis (ie. plot or farm or watershed; individual or household or community).

In situations where multiple stakeholders with multiple objectives are trying to arrive at a consensus, there will generally be agreement on a certain body of information. Information or data that are contentious, but critical, can be identified by the decision makers and provided on demand. This will reduce the propensity for examination of "all" interrelated properties as only those properties deemed necessary by the stakeholders are "examined"

The activity of consensus-building (in addition to research and teaching) can be facilitated and made objective if models with suitable parameters are available to provide criteria for ranking decisions, according to crop production and environmental tradeoffs. Different criteria exist for ranking decisons and the choice will ultimately be determined by the stakeholders.

For strategic purposes, biophysical evaluation criteria we are currently considering relate directly to the critical functions performed by the soil resource and relevant, closely related processes. The criteria are i) current production (income), ii) future production (income), iii) catchment water yield including within catchment use and off-site use, iv) soil acidification, v) soil erosion, vi) watercourse and impoundment sedimentation and chemical contamination, and finally, vii) biodiversity.

A particularly interesting possibility for stakeholders, including policy makers, is the use of validated simulation models in *ex ante* analysis of potentially costly decisions like setting environmental quality standards or assessing tradeoffs for large capital investment projects like irrigation or conservation projects. Sensitivity analyses can identify model parameters which are most responsible for uncertainty in predictions. Those parameters are likely to be candidates for indicators of "system health", and examples of "information" demanded by stakeholders.

In light of recent, fast-moving developments in the field of systems analysis, special purpose models are available for analyzing systems from restricted, highly focused points of view rather than examining "all" interrelated properties. Examples of limited focus models include AEGIS, for studying the spatial distribution of crop productivity as effected by plant environment control and management; TOPOG-IRM, for modeling three dimensional steady state and dynamic simulation of small catchment water yields; and WEPP, a process level landscape erosion model that can simulate the delivery of sediment to watercourses and impoundments.

The data requirements for the different models are overlapping but not identical; outputs are independent but synergistic. The erosion model requires much more sophisticated soil parameters than the production model; the hydrology model has an intermediate demand. On the other hand, the production model has much more sophisticated crop phenology routines and data requirements than either the hydrology model or the erosion model. Another advantage in having available a range of topic specific models is the flexibility in choosing simulation routines to match the availability of data. These models all require calibration and validation for tropical agriculture.

As a first step in developing methods and techniques for conflict resolution and concensus-building, two examples of *ex ante* impact analysis were carried out using simulation as a tool for prioritizing community watershed scale agricultural land use. The first evaluates a proposed small scale irrigation project in the Colombian watershed from the perspective of conflicting uses for the water resource. The second study examines land use changes in a small catchment involving the substitution of forest-pasture-annual crop, and the effect this might have on water yield for the catchment.

The specific objective of the second study was to estimate future trends in water yield due to land use substitutions between a typical short seasoned, shallow rooted, row crop like drybeans (*Phaseolis vulgaris*), a perennial grass pasture, and a typical secondary regrowth forest in a representative micro-catchment in the study area.

A 135 day simulation was carried out using actual climate and soils data from the Rio Ovejas site. Results show that values can be estimated for water yield in a transition from monocrop beans to sown pasture or forest. Results also show an overall reduction in water yield downstream (includes run-off and subsurface flow), at the takeoff point, when reforestation is simulated. This result is contrary to downstream stakeholder beliefs that obligatory reforestation of hillside watersheds will yield more water downstream. This finding illustrates the potential utility of simulation modelling to better inform decision-makers.

Ex-ante analysis like this will be used with area-based hillside consortia in Colombia and Central America to assess the comparative advantages of for example well-managed pasture, or annual crops intercropped with cover-crops, or sown with conservation barriers relative to obligatory reforestation, using data from prototype system trials discussed below.

Participatory research is collecting data on stakeholder-based institutional maps that describe the functioning of formal and informal institutions for natural resource management. This research will help users of decision-support systems to decide with whom, and in what organisational form, to carry out simulation ex-ante.

3.2. Development of prototype multifarm systems for landscape management has reached the stage of establishing field experiments. Closely integrated with this research is economic analysis of market opportunities related to technology design, which has initiated field data collection. Each is described here in turn.

3.2.1. *Experimental research*

A group of collaborating CIAT scientists from several programs developed this hillside project through a "Planning by Objectives" (PPO) process. The problems identified by the PPO for the hillside agroecosystem were:

1. Deterioration of soil quality: soil erosion, fertility decrease, decreased nutrient regeneration (shorter fallows).
2. Unrealized production potential of existing farming systems: lack of complementarity of farm activities, increased pesticide use, poor linkage between farming systems and markets.
3. Poor water management: limited irrigation for small farme ater pollution, limitation of water management due to topography.
4. Low labor productivity.
5. Poor information.
6. Deficient infrastructure.

Based on the above problems and in order to comply with the stated purpose of the project, the expected outputs are:

1. Sustainable agrosilvopastoral systems
2. Stable or improved soil quality
3. Improved water management
4. Improved labor productivity and efficiency

The strategy consists of combining multiple species in systems, covering the range from short cycle shallow rooted monocrops up to deep rooted, perennial to develop more diverse agrosilvopastoral systems. It will include existing systems as well as innovative ones proposed by farmers, national institutions and/or CIAT's scientists.

The site selection for the initial phase will be in the range of 1400 m.a.s.l. to about 1800 m.a.s.l. to ensure adaptation of CIAT's germplasm. The number of farms involved will depend on the availability of land to fit few or several systems. Ideally, at least directly comparable systems will be planted on the same farm with as similar conditions as possible.

In the initial phase, the experiments will be simple and as large as possible including areas for cattle grazing in some instances. They are planned for long term evaluation and in this way (large and simple) they will allow for future additions and modifications as progress is made in the evaluations, and contributions from the collaborators (national institutions, farmers and CIAT scientists) come into the process.

Participatory technology evaluation by farmers, and the establishment of participatory system trials designed by farmers will complement the agronomic research, to provide information on farmers' objectives in system design, and criteria for acceptability.

In the selected farms various alternatives from the following systems will be evaluated:

1. Monocrops: cassava, maize, beans, native pasture (for grazing).
2. Maize + legumes cocktail (green manure or forage) in two contrasting fallows (native grass and older fallow).
3. Maize + two grasses (separate) + legumes cocktail (for grazing) (to compare with 1 above).
4. Cassava + legumes cocktail (green manure or forage) in two contrasting fallows (as in 2 above).
5. Crop rotation: beans, cassava, legumes.
6. Barriers and field(s) perimeter(s) with: grasses, grasses + legumes, and grasses + legumes + trees.
7. Forage species on steep slopes: grasses, grasses + legumes, and grasses + legumes + trees.

These system trials will be established in two or more sites with varying conditions and with three replications in each site in full 1994.

3.2.2. *Economic research*

Economic analysis is testing the basic hypothesis is that technology and institutional linkages are key factors in providing resource poor farmers with market opportunities linked to conservation practices. Some of the options currently being considered by biophysical scientists include perrenial and annual forages, for their potential as feed for dairy cattle,cereals such as millet, to be used as poultry feed for egg production, perrenial barriers such as citronella with potential for industrial use, and vetiver grass with very minimal economic value. The economics research will help biophysical scientists narrow down options for inclusion in prototype systems. At the same time it will provide ideas for new options by identifying new market opportunities, whose erosion control potential will be investigated by biophysical scientists. Their results will in turn feed into the ex ante economic evaluation of potential technologies.

The research comprises the following steps:

a) Identification of market opportunities
b) Evaluation of erosion control potential of identified market opportunities
c) Identification of institutional mechanisms required to support market opportunities with erosion control potential
d) Ex-ante evaluation of adoptability
e) Implementation of institutional mechanisms on a pilot basis
f) Ex-post evaluation
g) Extrapolation to other sites

Given the heterogeneity of hillsides in tropical America, the objective of a study such as this in a particular site is to derive principles about how to proceed with a similar problem in other sites. Criteria will be developed to characterize: a) institutional arrangements. This will be done by characterizing each institution according to the types of transactions costs it reduces, b) soil conservation technologies according to resources required for adoption, and according to effectiveness in controlling erosion, d) farmers' socioeconomic and biophysical environment in terms of transactions costs, resource availability and the extent of soil depletion.

An expert system will then be developed which matches characteristics of the farmers environment to characteristics of technologies and institutions.

The innovativeness of the research lies in the following:

a) The focus of the CG system so far has been on developing biophysical technologies, with socioeconomic constraints taken as given. The objective of this research is to overcome a socioeconomic constraint-lack of market opportunities-by introducing a social technology viz. institutional marketing arrangements.

b) Incentives for adoption of conservation technologies have usually been in the form of subsidies or regulations, the difficulties associated with which are widely known. This study tries to develop a method for voluntarily inducing adoption for income generation reasons, with conservation occuring as a byproduct.

c) The emphasis on transactions costs is in line with new trends in economics research oriented towards relaxing the restrictive assumptions of neoclassical economics (see Pasour, 1993).

d) The use of multiple goal programming to examine tradeoffs between income and resource conservation is rare in tropical agriculture.

C. FUTURE RESEARCH STRATEGY

C.1. GENERAL

Within a five year future horizon, the hillside program expects to be able to offer to NARs, NRM agencies and other client institutions in the hillside agroecosystem, a strategy (including a methodological tool kit) which can be used to develop and execute major fundable bilateral projects to improve hillside natural resource management.

This approach or strategy will consist of
(a) regional land classification using spatial data bases developed with the Land Management Unit and national partners, to identify and select "strategic" or "non-strategic" watersheds for project development.

(b) bioeconomic models for ex ante impact assessment and methods for economic valuation of conservation technologies, to assist NARs and NRM agencies in prioritising interventions to control soil erosion, genetic erosion or agrochemical pollution.

(c) improved methodologies for soil quality assessment, and indicators of sustainability to facilitate extrapolation of results and targeting of existing or new soil conservation practices.

(d) a suite of models calibrated for tropical hillside conditions, which can be linked for use in interactive decision-support systems, tailored to users' requirements.

(e) methodologies, and organisational principles (together with training materials on these) widely disseminated among diverse client groups to catalyse demand for and effective use of decision support and ex ante impact assessment, including all relevant stake holders.

(f) guidelines for combining component technologies (eg. new cassava or low P tolerant bean germplasm, selected for combination with perennial forages, legume cover crops and soil conservation practices) in "transition" production systems.

The role of the hillside program in developing, testing and validating this strategy will be to:

- conduct relevant strategic research to derive generally applicable principles and methods in physical and social sciences.

- construct regional, interinstitutional data bases to ensure agile extrapolation of results among institutional partners working for smaller micro-regions or ecologically analogous "land scapes" in the agroecosystem.

- provide feedback to biodiversity research and germplasm development on in-situ conservation and character selection for the preservation, generation, testing and assessment of genetic resources which serve production and conservation needs; assess new germplasm in prototype "transition" systems and hillside landscapes.

- model the overall strategy in area-based research with partners, and conduct comparative analysis of results from different areas.

C.2 SPECIFIC PROJECTS AND OUTPUTS

Future strategy basically involves completion of the hillsides projects initiated in 1993/4:

2.1. ANDEAN HILLSIDES

Hillsides Project HA01: Effects of Soil Degration and Practices for Soil Conservation and Regeneration on the Potential Productivity of Cultivated Hillsides.

Purpose: To define and quantify the effects of accelerated soil quality degradation and of practices for soil regeneration and conservation on soil properties and their true costs.

Outputs and activities:
- Criteria to stratify and map experimental sites.
- Estimates of loss of yield potential due to irreversable soil quality loss.
- Criteria to evaluate soil improvement practices.
- Prioritized soil properties correlated with soil degradation and regeneration and changes in productivity.
- Acceptability to farmers and management requirements determined.
  Economic value of environmental effects estimated.

Project HA02: **Decision Support Systems for Land Use Planning and Technology Design.**

Purpose: To process information from strategic research in the form of decision-support systems that can be continuously updated to assist consensus-building among stakeholders in the formulation of planf for agricultural land use and protection of ecologically fragile areas.

Outputs:

- A prototype, interactive, computer-based decision-support system for hillsides.
- Methodology for incorporating stakeholders' values into optional changes.
- Guidelines for defining minimum data needs of decision-support systems.
- Priority research issues and areas in the Andean hillsides identified.

Project HA03: **Prototype Systems for Ecologically Sound Intensification of Production in the Hillsides.**

Purpose: To develop agrosilvopastoral systems that improve soil quality, water management, and the efficiency and productivity of labor.

Outputs:

- Sustainable agrosilvopastoral systems.
- Stable or improved soil quality.
- Improved water management in hillsides.
- Improved labor productivity and efficiency.

2.2 CENTRAL AMERICAN HILLSIDES

Project HC01: **Improving Agricultural Sustainability and Livelihoods in the Central American Hillsides.**

Purpose: To help develop more productive and sustainable land use in the hillsides of Central America through research on system components and their interactions, development of policy guidelines, and dissemination of research results.

Outputs and activities:

- Information of sustainable agriculture for the hillsides of Central America.
- Selection of research priorities.
- Selection of representative experimental sites.
- A complete long-term research plan for the project and for specific study areas.
- Implementation of field activites at each selected experimental site.

PARTICIPATORY RESEARCH

Project HP01: **Improving Agricultural Sustainability and Livelihoods in the Tropical American Hillsides.**

Purpose: To implement innovative organizational arrangements for managing prototype systems of sustainable land use, together with pilot incentive schemes designed and implemented with local people.

Outputs:

- Prototype technology assessed for acceptability to farmers.
- Participatory methods adapted for NRM assessment and group application.
- Community-based organizations developed for research and development.
- Trained people.

2.3 NEW PROJECTS

"Dissemination of a model for community-based, participatory, agricultural technology development", a project proposal to the W.K. Kellogg Foundation was recently funded at US$756,000 for three years.

New projects to be developed in the period 1994-199 concern biodiversity in-situ conservation in the Tropical American hillsides; together with the CIAT Biotechnology Unit, IPGRI, and potentially CONDESAN/CIP.

A new area of interprogram project collaboration is being developed with cassava utilisation on product development and processing research to complement the economic research for prototype production systems.

RICE PROGRAM REPORT FOR EPMR

EXECUTIVE SUMMARY

CIAT's Strategic Plan for the 1990's and Beyond directs the Rice Program (RP) to work towards «improving the nutritional and economic well-being of rice growers and low-income consumers in Latin America and the Caribbean (LAC) through sustainable increases in rice production and productivity».The major research achievements during 1989-1994 include:

. 35 varieties of the 70 released in LAC, originated from CIAT generated germplasm.
. The development of a rice variety (Oryzica Sabana 6) adapted to low input poor-highly acid- soils savanna allowed the insertion of rice as component for the sustainable management of the savanna ecosystem in LAC tropics.
. Release of a high-yielding upland rice variety (4-5 tons/ha under best management) for the favorable areas of Brazil.
. A new strategy combining pathotyping and MGR-fingerprinting to study genetic structure of rice blast populations and virulence spectrum is now in place to breed for more durable blast resistance.
. Through the Caribbean Rice Improvement Network (CRIN, 1986-1992), this most difficult sub-region received important benefits in particular. Four varieties were released there, and a new model of training (Cascade Training) contributed to an average yield increase of 46% among technically assisted rice farmers in the Dominican Republic during the period.
. The incorporation of several biotechnological tools to genetically characterize the LAC germplasm for breeding a more durable resistance to blast and to genetically engineer and assist through molecular markers the introgression of new sources of resistance to RHBV.

Benefits of rice research to LAC society have far exceeded their cost. Net present value of these benefits to LAC over the period 1966 to 1990 were estimated at 13.6 billion US dollars. A «social investment» banker investing in CIAT/IRRI rice research for LAC received a return equivalent to an annual interest rate of 69%.

Several major new initiatives are being pursued, such as a proposal to seek financing for reserearch from the beneficiaries themselves (rice producers, consumers and others). Although the RP is an example of a success story, the job is not yet completed. Growing populations and demand continue to devour increases in rice production, and sub-regional shortfalls in production need to be overcome. This has to be done without degrading the environment and the resource base and while increasing economic efficiency.

In terms of its strategy and approach, the RP will concentrate its work on irrigated rice, generating spillover benefits to the rainfed lowland sector; and savanna upland rice, with spillovers to the forest margins and hillsides. The Program's broad objectives are to increase yield and yield stability through genetic diversification, and sustainability through pest and stress resistance breeding and development of components for sustainable cropping systems. We are conscious that LAC's unique socioeconomic, institutional, biotic, and abiotic environments will be key determinants of our approach.

To accomplish the RP objectives, the Program envisages the following approaches: (a) overcoming the *yield plateau* through incorporation of IRRI's new plant type into LAC gene pools using population improvement methodology (a novel approach for rice), (b) broadening the germplasm base for protection from epidemics, backed up by strategic biotechnology initiatives in pest biology and genetics; (c) focusing on rice resistance to abiotic stresses to develop germplasm for *new* cropping systems for the favorable-rainfall savannas, with advanced physiology support in the areas of crop competition, root system characteristics, and adaptation to acid, aluminum-saturated, low-P soils; (d) conducting strategic pest biology ecology research to better assess regional constraints and identify appropriate IPM/ICM solutions to them; and (e) enhance institution-building and information and technology exchange with NARDs via networking, training, and other means.

During the last five years, as a result of budget cuts and reorganizations in CIAT, the program reduced the scope of its activity from a multidisciplinary commodity program to a germplasm-development entity. Core senior staff positions in the Program declined from 7 to 3.7. These factors of course have affected the volume and delivery of important outputs. Cuts in special project funding exacerbated the trend: INGER and CRIN networks lost their funding during the period.

I. INTRODUCTION AND BACKGROUND

Within the CGIAR, CIAT has regional responsibility for rice in Latin America and the Caribbian (LAC). While IRRI retains global responsibility, CIAT's Rice Program (RP) tackles strategic research in cases where a comparative advantage is apparent through a regional approach (eg., LAC-specific pests, adaptation to cropping systems unique to LAC such as the mechanized savanna upland rice, etc.) Close collaboration is maintained with IRRI, WARDA and CIRAD so that global strategic advances are delivered as soon as possible in forms tailored to the needs of LAC.

The goal of CIAT's RP, as stated in the Strategic Plan, is to improve the nutritional and economic well-being of low-income consumers and producers in LAC through sustainable increases in rice production.

CIAT's RP originated in the 1950s as a collaborative effort between the Colombian Ministry of Agriculture and the Rockefeller Foundation to solve severe outbreaks of the Rice Hoja Blanca Virus (RHBV). This evolved into a comprehensive breeding program within ICA, with Rockefeller personnel incorporated into CIAT's RP in 1967. The objective was to bring the Green Revolution in rice to LAC by developing high-yielding varieties (HYV) and production technologies for irrigated environments.

During its first two decades (1970's-80's), CIAT's RP concentrated on the following areas: (1) developing improved germplasm for irrigated and rainfed lowland, and for favored upland agro-ecosystems; (2) developing improved production technology components; and (3) specialized in-service training.

In the late 1960s, the first HYV (IR8) came to LAC. In the 1970s, new irrigated varieties with more acceptable grain quality and tolerance to diseases and insect pests (eg., the CICA group) allowed irrigated yields to double, from about 2 to 4 tons/ha. By 1992, mean regional irrigated yields were 4.6 t/ha. Between 1966 and 1991, with the release of the new HYV, production of paddy rice in LAC overall went from 9.9 million to

18.4 million tons. This is an annual growth rate of 2.8%, distributed between 1.7% for yield growth and 1.1% for annual area expansion. CIAT played a key role in this LAC *green revolution.*

In 1982, CIAT added a station in eastern Colombia, at Santa Rosa near Villavicencio to better address blast disease and adaptation to acid soil savannas. In 1984, agronomy and socieconomics capabilities were added to the RP. Because of extensive pesticide use, scientists skilled in IPM/ICM added these subjects to the agenda in 1985. By 1989, the number of core senior staff in the RP reached its maximum --seven. Additionally, two external scientists (one from CIRAD-CA and one from JIRCA's Japan) were seconded to the Program by their institutions. The CIRAD addition provided the capability to institute a novel breeding approach to broaden genetic diversity, namely population improvement mathods such as recurrent selection, which are normally available only to breeders of cross-pollinated crops. The JIRCAS support provided a new capablility in plant physiology. Thus, by the end of the 1980's the RP had attained sufficient critical mass to be able to address rice improvement from a wholistic, commodity approach.

However, the core complement soon began to fall, down to 3.7 at present. The creation of new agro-ecosystems Programs in 1991-2, along with the simultaneous and unexpected decline in CIAT's budget meant that cuts had to be made in commodity Programs. The result was that the commodity-oriented approach of the RP had to be narrowed to a germplasm-only focus. This was supported in the case of savanna upland rice, by by agronomy and systems research in the savannas Program. However, similar support was not available for irrigated lowland rice.

In the early 1990's, the RP began close collaboration with CIAT's BRU and VRU to assess the potential usefulness of biotechnology, mainly anther culture, molecular markers, and DNA fingerprinting, to characterize pathogen diversity, to identify, tag and transfer genes conferring resistance/tolerance to intractable problems of regional importance, and to help broaden the genetic base. Research on genetic transformation was added in 1993. These have been done in close collaboration with advanced institutions such as Florida, Cornell and Purdue Universities and Dupont Co. The Rockefeller Foundation has provided important financial support for this work.

II. COLLABORATION WITH MAJOR GLOBAL RICE INSTITUTIONS

The RP visualizes its role as a relatively small but effective regional actor in a global array of international institutions that focus on strategic rice research. The RP takes an opportunistic posture, capturing the benefits of new advantages generated anywhere, and delivering them to LAC as soon as possible. Likewise, we provide the benefits of our work freely and openty to others. Examples of these interactions are presented below:

- IRRI. There are frequent ongoing interactions and visits. In November 1992 the whole CIAT rice team visited IRRI to discuss a common research agenda. Activities in breeding, plant physiology, pathology, entomology, modelling, socioeconomics, and biotechnology were analyzed and complementary research activities were agreed upon. Intensive germplasm exchange and methodology sharing followed.

- WARDA. Team members from WARDA and CIAT met at CIAT in August 1991 to familiarize themselves with each other's research programs and explored areas of collaboration in blast, germplasm exchange, root physiology and anther culture.

- Tripartite IRRI-CIAT-WARDA: WThe three institutions agreed to meet annually to ensure close coordination/collaboration. The 1994 meeting will take place in early October.

- CIRAD. As described earlier, there a CIRAD senior scientist is stationed at CIAT, collaborating in the areas of population improvement and breeding in both, upland and irrigated rice. Germplasm exchange has demonstrably benefitted both institutions. There is important joint work on the blast fungus underway. A CIRAD physiologist will be visiting CIAT in October to explore collaboration.

- JIRCAS. As mentioned before, a JIRCAS physiologist has been posted to CIAT since 1991, He is helping us gain a basic understanding of the mechanisms of rice adaptation to nutrient stresses in acid upland soils, and develop screening methods.

- Global upland rice breeding workshop series: CIAT, IRRI, WARDA, CIRAD, NARS: Given the shorter history of upland rice improvement and more diverse environments involved, a special emphasis to increase information flow and collaboration on this agro-ecosystem was agreed upon by these institutions in 1993. The furst of a planned biennial workshop series was hosted by CIRAD, in Montpellier in September, 1993. Important areas of collaboration were agreed upon, priorities discussed and information exchanged. A JIRCAS breeder may join the next workshop.

- In rice biotechnology, key contacts have been the Universities of Purdue and Cornell, and Dupont Company. When mature, innovative methodologies are incorporated into ongoing breeding work. Such technologies include anther culture, DNA and MGR-fingerprinting and RFLP gene mapping.

- Participation in Scientific Networks. The RP participates in the RF Biotechnology Network, and the USA's Rice Technical Working Group. Through such networks contact is maintained with key scientists working in strategic areas such as biotechnology, breeding, plant physiology, weed science, pathology and socioeconomics.

III. CONSTRAINTS TO THE RICE PROGRAM's MISSION ACCOMPLISHMENT

In the 1992 Inter-Center Review of Rice the panel referring to CIAT stated «With respect to Latin America and the Caribbean, the Panel notes that there is perhaps a case to be made for reducing the level of core support marginally. However the matter is not a clear cut; in fact, some of the indicators used in the analyses suggest that additional funding could be justified». The panel also mentioned that the Program has been very efficient.

However, at present, the budget constraints compromise the RP capacity to accomplish its regional mandate as it has done in the past. Since 1989, CIAT's RP has drastically reduced its scientific mass (from 7 senior staff positions to 3.7) substantially affecting research activities to germplasm enhancement, testing and distribution. The areas of the program Leadership, Entomology, Socioeconomic, and Irrigated Breeding are the most affected. The phasing out CRIN and reduction of INGER's activities, is reduced the Program credibility and the strong and effective linkage with NARDs in the region. The assembly of a regional consortium to fund essential irrigated rice activities is being attempted. The weakening of the Program's research capacity is jeopardizing CIAT's commitment to rice in LAC.

IV. MAJOR RICE RESEARCH CONSTRAINTS IN LAC

Several biotic and abiotic constraints affect rice production in LAC. A rough estimate of the value of production lost due to major diseases, weeds, soils, climatic factors, and physiological constraints that could be addressed through research amounts to about US$880 million per year. Pests such as blast, leaf scald, grain discoloration, RHVB, spittle bug, leaf cutter ants, and weeds account for about 80% of production losses in both irrigated and upland rice environments. To deal with these constraints and sustain yields, farmers apply increasingly large amounts of toxic agrochemicals.

High aluminum saturation, iron toxicity/deficiency, drought stress, and low temperatures during the growing season are the most important regional abiotic constraints to stable yields of rice. In some cases, those constraints affect grain quality.

LAC rice production problems differ in many respects from those observed in Southeast Asia, South Asia, and West Africa. RHBV and its vector *Tagosodes orizicolus* are present only in LAC. Similarly, yellow mottle virus found in Africa is not found in LAC. Some pests like blast are common to LAC, Africa, and Asia, but virulence diversity and frequencies are different. Direct seeding has always been a prevalent feature of rice in LAC, which together with often poor water control has resulted in serious weed problems that have lead to the widespread use and abuse of herbicides in the region.

V. REGIONAL PARTNERS

CIAT collaborates actively and closely with national rice research and development institutions, aiming to strengthen them and increase their effectiveness in creating new varieties and related technology. While they are considered a strong group relative to national research teams on other CIAT crops, their depedence on CIAT in the germplasm area does not appear to be waning. The percentage of varieties released directly from CIAT germplasm has increased steadily since 1967, to a current level of 65% (last two years' average).

Four major national rice research models are found in LAC: (1) as a research department within the Ministry of Agriculture (Belize, Costa Rica, Honduras, and Paraguay); (2) through national and/or state agricultural research institutes or centers (Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, El Salvador, Guatemala, Guyana, Mexico, Nicaragua, Panama, Peru, Uruguay, and Venezuela); (3) attached to a government-sponsored rice development project (Haiti, Jamaica, and Suriname); or (4) the existence of a decentralized rice research institute (Cuba and the Dominican Republic). Many of these public-sector institutions are facing declining budgets, and are engaged in major re-organizations at present, often aiming to increase private-sector participation and attain semi-autonomy (partial independence from govenment control).

Rice research is also carried out by farmers' organizations, private companies, universities, and regional institutions. Farmers' organizations are important in Colombia and Venezuela, and to a lesser degree in Argentina, Nicaragua, Peru, Ecuador, and Uruguay. In Colombia, joint research efforts by FEDEARROZ, ICA, and CIAT have been highly successful research consortium. Private-sector activity appears to be increasing with the trend towards reduced governmental control of agriculture across LAC.

Regional associations helping to coordinate and stimulate rice research in the region include the PROCISUR network, which coordinates research among Southern Cone countries (Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay), and the Central American Rice Research Network, which links Central American rice researchers. CIAT coordinates the INGER-LAC germplasm network, and formerly the CRIN network (both seeking renewed funding).

A survey conducted by the RP in 1987-1988 indicated that almost 300 scientists, 35% of whom had at least an M.S. degree, were working on rice. Fifty percent of the researchers had more than 7 years of experience. Overall, 63% of the scientists' time went into research-related activities focusing on agronomy and breeding. The data suggested that a critical mass of scientists exists within many research organizations, but there is scant representation of some disciplines. In countries like Brazil and Cuba, and to some degree Colombia and Mexico, full interdisciplinary teams exist.

The field of expertise most frequently found within rice programs throughout the region is breeding. A study conducted by CIAT on the status of rice improvement in the region indicated that all rice programs have a germplasm evaluation system using either introduced or locally generated materials. A total of 14 programs representing 7 different countries and nearly 95% of the rice-growing area have active rice breeding programs.

While most NARDs have a good picture of the biophysical constraints limiting rice production in their regions, they do not have the means to characterize their breeding materials for reactions to all priority constraints that can be addressed through varietal tolerance or resistance. There is also little effort in crop management. Most NARD's agronomic research fails to effectively address the problem of weeds, which is the most serious biotic limitation to rice yields throughout the region. In socioeconomics, there is insufficient capacity in constraint analysis, prioritization, and thorough technology evaluation. Furthermore, as for most commodities, there is a weak linkage between technology generation and transfer.

VI. REGIONAL NETWORKS COORDINATED BY CIAT

A very important achievement of the RP over the last five years was the strengthening of regional cooperative networks of rice improvement scientists which, *if sustained*, will help the region itself gain the capability to effectively address its most pressing problems related to rice improvement. However, they are now in crisis for lack of funding.

Since 1976, CIAT has coordinated, in collaboration with IRRI, the regional branch of the global germplasm exchange and testing network called INGER (International Network for Genetic Evaluation of Rice), funded by UNDP until 1991, and jointly by CIAT/IRRI since then (funds will no longer be available after 1994). This network provides a mechanism for national breeders to easily access the elite breeding materials of almost any other breeder in the world. CIAT/IRRI enhance this process for LAC by pre-selecting materials best adapted to this region, and by convening workshops to enhance skills in genotype selection for local needs.

The Caribbean is the most difficult area for achieving progress in LAC, due to its poverty and fragmentation. Yet it is the most needy, having the lowest rates of rice self-sufficiency and lowest per-capita incomes. The Caribbean Rice Improvement Network, CRIN was created in 1986 through funding provided by CIDA (Canada), focusing on this sub-region. It was coordinated by CIAT, and executed collaboratively among CEDIA (Dominican Republic's National Program), CIAT, and IRRI. It depended on INGER for germplasm inputs, and was additionally involved in adaptive research on smallscale mechanization IPM and ICM. Cuba, Suriname, the DR and Guyana used CRIN germplasm parents for their own breeding. The promotion and adaptation of small machinery for rice farmers and IPM were relevant points on CRIN's agenda. With the support of CIAT's staff numerous IPM training and collaborative research activities were conducted. Highlights of this endeavor were the Caribbean IPM Network, and The Round Table on Rice Plant Protection held in Cuba. CRIN edited de newsletter «Arroz en el Caribe» with two issues a year , and published six Memoirs on the scientific events it had sponsored.

VII. IMPACT

Germplasm released, and production increases

The LAC Green Revolution has been an outstanding breakthrough by any measure. The key factor triggering these increased yields and production has been the IR-8 plant type developed at IRRI and adapted to LAC conditions by CIAT, in close collaboration with NARDs. Modern semidwarf varieties grown primarily in the lowland (water-saturated, anaerobic soil) systems, combined with appropriate management practices caused a 44% regional average yield increase for the irrigated sector, from 3.2 to 4.6 t/ha, since 1967. The increase in production efficiency also stimulated expansion of the irrigated rice area by 57%. Regional rice production increased from 9.9 to 18.4 million tons from 1966 to 1990, Despite the prevailing impression, the Green Revolution is not yet over; varietal releases based on the same plant type are still moving into areas late to adopt modern technology.

CIAT-derived germplasm, itself building on an IRRI base (fundamentally, the IR-8 plant type) dominates the irrigated sector of LAC. Since 1967, 89 out of the total of 239 rice varieties released in the region, or 37%, originated from CIAT. (40% originated from countries themselves, 15% from IRRI and 8% from other NARS). The percentage of CIAT-gernerated germplasm achieving varietal release has increased steadily over the period, from 9% during 1967-71 to 50% over the last five years. During the last two years, the rate reached 65%. This trend would seem to indicate that NARS are not achieving the strength needed to supplant CIAT's role in the generation of advanced germplasm; in fact, the opposite seems to be the case.

Approximately 30% of LAC's rice is produced in the uplands but this agro-ecosystem was largely bypassed by the Green Revolution. Improved tall varieties giving only modest yield increases still predominate in the mechanized portion of the upland ecosystem. Subsistence upland producers continue to grow low-yielding traditional varieties. Average farm yields are about 1.2 t/ha, although new varieties recently developed by Brazil's national program (CNPAF) apear to be edging this upwards to the 1.5 ton level. New high yielding lines generated at CIAT are being released in Brazil (Progresso, 1994) and Colombia (Oryzica Sabana 6, 1991) and seem likely to stmulate a quantum jump, moving average yields up by 100%, (to the 2.5 ton level) over the next decade.

Regional networks coordinated by CIAT increased interactions with NARS, accelerating the rate and volume of varietal releases. Germplasm distributed through INGER-LAC, from 1976 to 1993, accounted for 38% of all varietal releases in LAC. Four varieties were released through CRIN efforts (in the Dominican Republic, Belize, Jamaica and Guyana). The institution and human-resource strengthening effects of these networks are not as easily quantified as varietal releases, but is nonetheless a necessary and critical element to sustainable agricultural development. CRIN developed an intense training agenda, and such these efforts resulted in an average yield increase of 46% among participating farmers in the DR.

Economic benefits

Among consumers, the benefits of research have been most important to the poor. Case studies at several locations in LAC indicate that per-capita consumption of rice is fairly similar across income levels. As income level declines, consumers tend to eat almost as much rice as wealthier people, but they reduce their purchases of more expensive foodstuffs such as beef, and milk. Furthermore, while rice is the largest single source of calories to the diet in LAC, the decline in purchases of more expensive foodstuffs as income declines also leaves rice as the major source of protein to the diet. For the poorest 20% of the LAC population, rice supplies more protein than beans, beef and milk combine. It is not commonly realized that rice plays such a critical role in protein supply to the poor.

The cost of rice to consumers dropped by over 40% from 1967 to present. While global production trends largely control rice prices, the gains in efficiency in LAC allowed it to retain its share of the production sector, providing food security to the region. The net present value of the benefits of research delivered to LAC society over the period were estimated at 13.6 billion US$, and the internal rate of return (IRR) on the research investment was estimated as 69%. On an annualized flow basis, CIAT's RP was estimated to have generated benefits worth about 60 times more than its cost, for each year since 1967. This rate of benefits delivery far outstrips any other observed at CIAT over the past quarter century.

The benefits of research go mainly to consumers (67%). athough producers also gained substantially (33%), particularly on a per-capita basis (since producers represent less than 0.5% if all LAC consumers). This benefits distribution is probably quite healthy; it provides an incentive for producers to continually invest in more efficient technologies and thus create societal benefits, most of which are subsequently transferred to consumers. The fall in rice prices, along with other factors such as urbanization and preference for rice as a food, have in turn stimulated rice consumption; per capita consumption rose from 26 kg milled rice in 1967 to 37 kg in 1990 in LAC.

During 1989-1994, rice growers in Colombia, Ecuador, and Venezuela have substantially reduced on average the unnecessary use of pesticides, particularly those of insecticides and fungicides. The data from Colombia shows that farmers reduced about 55% of total volume applied and one-third of number of spraying over this period. The number of farmers not applying those pesticides has risen to 42%. A similar trend is documented for Venezuela and Ecuador. This pesticide reduction has translated into higher profit margins, and less significant health and environmental risks. While falling prices for rice were a major incentive for farmers to reduce input usage, CIAT's efforts in IPM helped NARS assist farmers in the process of reducing input usage most effectively.

VIII. CHALLENGES AHEAD: ISSUES AND STRATEGY

The region's current population is 448 million, which is expected to increase at a rate of 1.6% per annum. Rice production in LAC has expanded to more than 18 million tons in 1990, but demand is expected to increase in the future at an annual rate of 2.3%, reaching about 24 million tons in 2000. Thus, important deficits could occur by the year 2000, unless past rates of yield gains can be sustained and even increased above those of the last two decades. Given this situation, it is logical to think that regional needs and expectations have to be closely examined from a regional, rather than global, perspective.

CIAT's new mandate calls for a strategic shift from a commodity-oriented agenda to an ecosystem-oriented one. Building on criteria of efficiency and equity, the lowland ecosystems (including both irrigated and rainfed lowland) represent an opportunity not only for a higher yield plane but also, even more importantly, to meet regional rice demands of poor population groups (eg. urban consumers). The additional focus on upland rice in savannas will allow the Program to address equity concerns of present and future generations by contributing a key technology (rice germplasm) to the rational sustainable utilization of this ecosystem to satisfy food needs, helping release pressure on fragile forest margins. Building on these aspects, CIAT considers its strategic role in rice research to be based both on irrigated rice (efficiency, equity, and sustainability) and savanna upland rice (growth, sustainable use of resource base, protecting of forest).

Rice is a crop where pesticides use is very high with respect to other crops in LAC, resulting in high production costs and damages to the environment. Incorporation of resistance to pests and the development of more weed competition rice cultivars are strategies to reduce pesticide use in rice. Further progress will come from assisting NARDs to develop and fund effective IPM research and implementation programs. CIAT's scientific input will be in increasing the knowledge in pest biology and ecology. Such knowledge would be incorporated into innovative information-management techniques such as expert systems to deliver complex information packages in a user-friendly form. Work in other areas, such as biological control is also contemplated, particularly in conjunction with the Disease and Pest Management SRG.

CIAT's RP agenda, as presented in the following sections, attempts to reflect complementarities in research with sister IARCs, NARD, and NGOs based on current comparative advantages and research opportunities for the system worldwide. Given the nature of irrigated rice in LAC, the agenda balances the research portfolio between strategic and applied research areas as outlined from here on, following a cluster of activities recommended by the TAC. Also, one research activity attempts to cope with more than one challenge. We see three major challenges for the 1990's: 1) lowland rice improvement; 2) upland rice improvement; 3) integration with three CIAT's agroecosystem programs, and 4) reduce losses to rice pests.

IX. CIAT'S RICE RESEARCH PRIORITIES

CIAT's comparative advantage lies in addressing those constraints and opportunities which are distinctive to LAC. Rice hoja blanca virus (RHBV), for example, and its insect vector *Tagosodes orizicolus* are present only in LAC. Some pests like blast are common to LAC, Africa, and Asia, but virulence,diversity and frequencies are different. Direct seeding of irrigated rice has always been a more important practice than transplanting in LAC, in contrast to Asia and Africa. Higher labor costs and lesser land development than in Asia, however present a generally less-developed standard of water control in LAC, which exacerbates weed and disease problems, and in turn stimulates higher rates of agrochemical usage, with the associated environmental consequences. The mechanized acid-soil savanna culture of upland rice is unique to LAC, requiring plant types different from those needed elsewhere. Hight-performance, input-responsive upland plant types with commercially-acceptable grain quality must be combined with rustic characteristics such as tolerance of extremely infertile savanna soils.

A rough estimate of the value of production lost due to major diseases, weeds, soils, climatic factors, and physiological constraints that could be ameliorated through research amounts to about US$880 million per year (about 20% of the total regional crop's farm-gate value). Among the abiotic stresses, major diseases include blast, sheath blight, RHBV, leaf scald and grain discoloration. Insect problems include whitebacked planthopper, rice leaf miner, stem borers, spittle bug, and leaf cutter ants. Weeds, often ignored as pests from the germplasm improvement point of view, nevertheless account for about 80% of all production losses to biotic factors in both irrigated and upland rice environments. To control all these pests, farmers apply large amounts of costly and hazardous agrochemicals.

Abiotic stresses are also a priority for research, particularly for the acid-soil uplands, which are characterized by high aluminum saturation, low water holding capacity (drought stress) low cation content, and silicon deficiency. For irrigated rice, low temperatures are a major destabilizing factor in the temperate parts of LAC.

Today, the Work Plan of the RP includes seven projects, focused on key priorities, grouped into three Project Areas: *Lowland Rice Improvement* (projects: Improved Lowland Gene Pools, and Information and Technology Sharing), *Upland Rice Improvement* (Improved Upland Gene Pools), and *Reducing Losses to Rice Pests* (Durable Blast Resistance, Rice Traits to Enhance Weed Control, Diversified Tagosodes/RHVB Resistance, and Integrated Pest and Crop Management).

1) Lowland Rice Improvement

Rice breeding for the region's irrigated rice depends on a genetic core of 12 landraces that although they do not represent a narrow base seem to have reached a plateau in terms of yield potential. Numerous studies analyzing genetic advances in yield potential of irrigated rice indicated that after initial improvements obtained by introducing a set of plant traits necessary for local adaptation, yield potential per se reached a plateau. Most efforts have been directed at assuring that the potential expresses itself in the field rather than raising it. This approach has resulted in significant yield improvements on farms. But recent evidence indicates that the best farmers, mostly have almost managed to realize the genetic yield potential at the farm level, generating renewed interest in new genetic materials with higher yield potential.

Greater yield stability and potential gives this sector an important comparative advantage over upland rice in fulfilling regional increases in production. Most countries in the region need to continue to maintain high rates of self-sufficiency in rice as a primary food security goal.

The ideal scenario would be to provide rice at lower and stable real prices to consumers while still increasing income to producers. Although this could be done through price subsidies and trade barriers, these may have high social costs. A more rational policy would be to increase productivity through investments in research to raise potential yields per hectare at even higher rates than before, and to develop new IPM/ICM technologies that reduce current high unit production costs in the more stable and productive environments. Such technologies would directly impact on the new goals of the CGIAR -reduced pesticide inputs protect the environment, and increases sustainability, while lower food costs for rice preferentially benefit the poor (the main rice consumers), thus improving equity.

1.1) Improved lowland rice gene pools

The Green Revolution was not a single event; although the major milestone was the achievement of semidwarf stature and high harvest index obtained at IRRI in the early 60's, subsequence breeding efforts done by CIAT's RP steadily improved this prototype, particularly for earlier maturity, improved grain type, and better pest resistance while maintaining the yield potential. Pests rapidly evolve to overcome resistances, and breeders have to constantly bring in new resistance sources just to maintain the same level of varietal performance as before. We call this «maintenance breeding».

Until 1989 the main objective of the breeding program was to develop high-yielding lines with good grain quality, and resistance to rice blast, RHBV and the planthopper *Tagosodes oryzicolus*. Several strategies were adopted as explained in the 1986-1989 RP Report. Since 1990 the objectives have been: (1) Shifting the basic orientation of the breeding program from development of lines that can be used directly as varieties by national programs, to generation of parents with outstanding traits that can be used as donors in crosses; (2) Broadening the available genetic variability by continuing the incorporation of cultivars from Africa, Asia, and Europe; crossing breeding materials from different groups, exploiting wild species, and using population improvement methods (recurrent selection), and by using genetic transformation to introgress genes into germplasm adapted to LAC; (3) Stabilizing yields and reducing production costs by developing lines with higher and more stable resistance to major diseases and insects, particularly: blast (*P. grisea*), RHBV, *Tagosodes oryzicolus*, leaf scald, grain discoloration, lodging resistance and good grain quality; and (4) Use of anther culture as a breeding tool to help broaden the genetic base by facilitating interspecific crossing and gene recombination and DNA fingerprinting to characterize genetic diversity in LAC.

Future research strategy will concentrate on the incorporation of number of new traits that are being generated in other Projects, as well as globally, which promise to continue the remarkable record of past impact. Those important new traits, however are usually in genetic backgrounds that are not well-enough adapted to LAC direct seeding conditions. A visit will be paid to IRRI next October to select breeding lines from the IRRI-new plant type project and special attention will be given to the evaluation and incorporation of this into our LAC-adapted gene pool in collaboration with IRRI and CIAT's plant physiologist and breeders. This Project will combine the total set of traits into backgrounds adapted to the LAC lowlands. Other traits to be added over the next five years include greater yield potential, traits to enhance weed control, more durable resistance to blast, diversified resistance to *Tagosodes* and RHVB, better grain quality in sub-tropical zone, and possibly novel sheath blight resistance.

Breeding activities for irrigated and favored upland rice for tropical conditions are carried out in close collaboration with ICA/CORPOICA and FEDEARROZ in Colombia, and with ICTA's rice program in Guatemala. Three breeding sites are used in Colombia and two in Guatemala for the tropical areas. On the other hand, excellent and continued collaboration with the rice programs of INIA-Chile, IRGA-Brazil, INIA-Uruguay, and INTA-Argentina allow us to generate breeding material for the sub-tropical irrigated conditions.

Germplasm generated is made available to national programs in three ways: 1) INGER nurseries; 2) breeder's workshops; and 3) selection by breeders from national programs visiting Santa Rosa. Germplasm distributed through these channels resulted in the commercial release of 35 improved lines in LAC, including Oryzica Llanos 5, the only variety out of CIAT-germplasm to remain resistant to rice blast after five years of commercial production.

During the last five years emphasis has been placed on grain quality, one of the most important breeding objectives. The RP devoted resources to understand the genetic control of factors affecting the expression and heritability of white center and gelatinization temperature in some breeding populations. Results indicate that there is no maternal effect on the expression of white center and gelatinization temperature but rather different degrees of dominance. Quality laboratory was phased out during 1993. Therefore, activities related to grain quality parameters will not be addressed.

The Board, in 1993, recommended to phase out core support for this important component of the RP, and suggested that CIAT contact the private rice sector in the region to get them involved in funding irrigated rice breeding activities. A project was written targeting to form a consortium to deal with the priorities set by them, but if the idea does not come through the region will loose the most important germplasm sources for varietal release they have.

1.1.a) Lowland rice gene pools for recurrent selection

A recurrent selection program to increase the yield potential of lowland rice was initiated in 1993; several gene pools developed by CIRAD-CA and EMBRAPA/CNPAF were evaluated at CIAT-Palmira. Observations were made on plant and grain type, yield potential, and earliness; single plant selections were made in each population for the next cycle of recombination. Besides, diverse parental sources for high yield are being identified and will be incorporated in each population. Further more, a CIAT irrigated breeding line carrying sterility gene obtained through mutation from TOX 1011-4-1 was crossed to 14 diverse parental sources to develop another base population.

1.1.b) Anther culture and training for National Programs

This section, as well as the next one, cut across ecosystems, nevertheless, to follow CIAT's project organization they are mentioned within low land rice improvement. Effort has been placed at CIAT, since 1985, to incorporate anther culture as a tool for breeding. At present, doubled haploidies (DH) are used by the Rice Breeding section to accelerate the production of fixed lines; to ease the broadening of genetic diversity; and to facilitate the tagging of genes by RFLP and PCR mapping. Currently, we are evaluating the possible use of DH in the selection for stable resistance to blast through recurrent selection.

A research project, partially supported by the Rockefeller Foundation, was initiated in 1990 to elucidate the factors affecting the androgenetic response of highly recalcitrant true-indica (adapted to tropical irrigated environments) and upland (tolerant to acid soils) genotypes.

The methodology developed at CIAT increased the AC response 16 fold for indicas (from 0.06 to 0.98 green plants/anther) and 10 fold for uplands (from 0.46 to 4.77 green plants/anther). A cost/benefit analysis was made by the RP to compare breeding without and with anther culture. The analysis indicates that the implementation of this AC method could be used for varietal development, reducing the costs up to 26% respect to the Pedigree Method and giving an annual return of 7-12%. This analysis could serve as a framework for the adoption of anther culture by NARDs' breeding programs.

Collaboration with other breeding programs had also been an important task. In the period from 1989-1994, DH lines were produced for IRRI, and the National Programs of Brazil, Chile, Mexico and Perú. Scientists from Argentina, Brazil, Colombia, Panamá, Perú and Venezuela were trained in our laboratory during this period. In 1992, CIAT assisted WARDA in the setting up of an AC facility adequate to process large volumes of material at a reasonable cost. This assistance included the training of a WARDA scientist at CIAT.

With the support of the Rockefeller Foundation, CIAT organized a two-year technology transfer program on anther culture for the rice breeding programs of Latin America. The main objectives of this technology transfer program include: to transfer the anther culture methodology developed at CIAT for integration of doubled haploidies into rice breeding programs. In 1994, the First Latin American Course-Workshop on Rice Breeding with Anther Culture was held at CIAT. Twenty participants from 10 institutions of 8 countries were brought together as teams of two per institution, one tissue culture specialist and one rice breeder. The Second Workshop will be held in 1995 at Argentina and Brazil.

1.2) Information and technology sharing

INGER-LAC has the responsibility to promote multidirectional germplasm and breeding methodology exchange among the Latin American countries, Asia, and the international research centers. In the last five years the major issues for the network have been: to stimulate a more intense germplasm flow from NARDs with strong breeding program; to improve the composition of the nurseries distribute to better suite the needs of each NARD; to characterize the germplasm for distribution; information exchange; and to get financial support for the continuity of the INGER's activities.

Between 1989 and 1993, through the network 35 varieties were release in 15 countries, based on CIAT germplasm. The nursery design evolved from fixed sets of lines to a more interactive set. The NARDs are requesting that future exchanges also have to contemplate segregating materials and improved populations.

Information exchange is done through reports, conferences, and workshops. From 1989 to 1992 the nursery report was published every semester. After that, due to scarcity in resources, it has been published yearly. Two major conferences were organized by INGER (Mexico, 1991, and Brazil, 1994). In this period the conference changed to include not only breeding activities but also agronomy and socioeconomic. In Mexico, for the first time the conference had to look for funds to organize the event; together with the National Program in the country 30% of the costs were covered. In Brazil the situation was similar and more than 50% of the funds were raised. Future events have to be organized based primarily on external funds.

Workshops centered on breeding have been carried on in Guatemala (1989), Dominican republic (1989), Colombia (1990), Mexico (1991), and Venezuela (1992). For the last two events main resources were pulled out from the region. These events evolved from selection of fixed lines to management of segregating populations, evaluation of breeding methodologies, and understanding of the genetic variability available in the region. Similar to the conferences, the workshops have to be looked as self-financed activities for the future or at least to have a minimum cost for the network.

INGER-LAC put together a data base on germplasm information. It contains a list of all crosses made by the NARDs, IRRI, WARDA, CIRAD-CA, and IITA, lines exchanged through INGER nurseries, and IRRI's germplasm bank. To exploit these data a computer program was developed to provide information on the genetic base of each material. It also has data on the majority of the rice scientists in the region.

A project was prepared by CIAT and passed to IRRI to look for financial support to INGER-LAC for the next five years, as part of the global network activities, however up to now the project was not submitted to a donor. If this financial support does no come through this major activity of the RP will phase out and the region will loose its most important source of germplasm and information exchange.

2) Upland Rice Improvement

The tropical uplands of LAC constitute an abundant under-utilized resource base and major source of land for expansion of the region's agricultural frontier for present and future generations. The 300 million hectares of acid-soils savannas of LAC have been used almost exclusively for cattle raisen, an activity done with very low input.

Worldwide, the greatest concentrations of uplands are in Brazil and Africa. Brazil has a strong national rice research program (EMBRAPA/CNPAF) for uplands. While Brazil is trying to increase national upland rice production as a whole, CIAT's strategy is to develop rice germplasm as an ecosystem management component. In Africa, WARDA has the mandate for rice research in this ecosystem. For unfavored areas, IRRI gives higher priority to rainfed lowlands and deepwater and tidal wetland ecosystems than to upland areas. This opens a window of opportunity for CIAT to complement its research work on this ecosystem with IRRI and WARDA. But CIAT's RP is by itself short-handed in terms of a critical mass of scientists compared with EMBRAPA/CNPAF and IAC in Brazil.

In Brazil, based on political decision to exploit the region, creation of strong and well focussed research organizations, and availability of amendments (mainly lime), cropping systems were developed. But, in other countries like Colombia, Venezuela, Bolivia, and Guyana, where the ecosystem represents a significant amount of unexploited area, very limited results were generated, consequently farmers do not have alternatives to make more productive and sustainable this area.

This section of the RP has been the one with the most opportunities for cross-program and SRGs interaction. Since the release of the first set of improved lines the RP has been working closely with the Savanna and Tropical Pasture Program, and lately with the Tropical Lowland and Tropical Forage Programs, and the SRGs, in the development of sustainable production systems for the acid-soils savannas. This trend will continue, now focussing on the understand of the physiological aspects of rice-pastures competition and determining the genetic control of the traits involved on them.

2.1) Improved upland rice gene pools

Breeding for upland rice in LAC is concentrated in Brazil, Colombia, and Mexico, and each program deals with a different set of constraints. Brazil's programs are those of EMBRAPA/CNPAF and IAC. The genetic base of the more traditional Brazilian upland cultivars is made up of 6 Brazilian landraces. The more modern cultivars have African and Asian germplasm, basically seeking blast resistance. Although the genetic base of upland rice in Brazil seems to be expanding, yield potential has only increased an average of 17.3%, suggesting that there is much room for yield improvement. Also, by concentrating on the most-unfavorable environments, most resulting cultivars are not highly responsive to the new improved cropping systems now arising in Brazil's more favorable (higher rainfall) upland rice-growing areas, thus limiting yields there.

The Mexican upland rice improvement group is exploiting an Asian upland indica genetic base, in an attempt to identify drought tolerance and blast resistance. In Brazil and Mexico, cultivar improvement efforts for rainfed environments concentrate on most-unfavorable conditions.

CIAT began breeding upland rice in 1984, targeting the development of improved lines that would allow the creation of sustainable and low input cropping systems for the high rainfall acid-soils savannas, emphasizing tolerance to soil acidity, resistance to pests (blast, *Tagosodes*, and RHBV), grain quality, and earliness.

In 1989, the first set of improved lines generated by CIAT was evaluated in large scale trials, on farmers field, in the Colombian Llanos. Preliminary results showed that the yield potential of the best lines (around 3.5 t/ha) were between 13 to 42% superior than the check and had tolerance to soil acidity (aluminum saturation above 85%), resistance to major pests, and superior grain quality.

The project stopped concentrating efforts in running multilocational and large size yield trials and went back to breeding activities, from 1991 onwards line development assumed the most important role again. In 1991, Oryzica Sabana 6 was joint released by ICA, FEDEARROZ, and CIAT for the Colombian Llanos, to promote the adoption of improved pasture through rice-pastures association.

Germplasm exchange with Brazil has been going on since the beginning of the breeding work, as result of it a CIAT's line was released named «Progresso», in 1994, by EMBRAPA/CNPAF, together with the state institution of Mato Grosso. The advantages claimed for the variety were the high yielding potential (4 to 5.0 t/ha) and the excellent grain quality (similar to the irrigated rice planted in the South), traits not found in the Brazilian commercial upland varieties.

The use of broad genetic base has allowed wide germplasm adaptation with the release of Oryzica Turipana 7, in 1992, for the small farmers of North Coast of Colombia; the line yielded 1 t/ha more than the local checks. Sacia 1, released in Bolivia in 1993, has a similar story.

Germplasm and information exchange has been a key component for intercenter collaboration. CIAT, IRRI, WARDA, and CIRAD-CA intensified contacts after the International Upland Rice Breeders Workshop, held in Montpellier, in 1993. Every year advanced lines, parental materials, and segregating populations are exchanged among the centers. We also have joint multilocational trials in each center to understand grain quality aspects and genotype by environment interactions.

2.1.a) Upland rice gene pools for recurrent selection

NARDs see CIAT in a stronger position to deal with more medium to long term alternatives for understanding the mechanisms of tolerance and resistance of biotic and abiotic stress under acid soil conditions while they devote most of their resources to applied research. Therefore, to achieve more complementarity to NARDs work, CIAT decided to lessen the effort in line development and to emphasize population improvement by creating gene pools for specific traits using recurrent selection. NARDs in the region would be able to use the improved gene pools as sources of improved lines.

Late 1992 CIAT brought from Brazil and French Guyana upland rice populations developed by EMBRAPA/CNPAF and CIRAD-CA (former IRAT). After two years of evaluation and selection progress was made for blast resistance and earliness. They were also used as source of male-sterility for the introduction of new lines and construction of a new population.

2.1.b) Physiological mechanisms for acid-soil tolerance and suitability in cropping systems

Since the major screening for rice-pastures association and edaphic adaptation in the breeding work was conducted through the on-site screening, the basic genetics and physiological knowledge has been unknown for many years. To give useful information to breeders the follwoing studies are emphasized: (1) evaluating the soil acidity (low pH, high Al saturation) and nutrient constraints (low P and Ca in acid soils), and; (2) evaluating rice germplasm for adaptation to such environments; (3) studying of the mechanisms involved in such adaptation, so that appropriate germplasm screening techniques can be developed; (4) defining plant-type implications for adaptation to these ecosystems, including requirements for intercropping, such as rice-pasture associations; and (5) collaborating on research with CIRAD-CA, EMBRAPA/CNPAF, and ICA will be explored and expanded accordingly.

Preliminary results of rice adaptation to low fertility on acid soils imply: a) restricted increase of the root/shoot ratio with respect to that under high fertility conditions, b) having thin roots, so that root length density is adequate for soil exploration and nutrient extraction, root mass and length per se without indication of root thickness may not be good enough indicators of adaptability to low-fertility acid soils; c) having high nutrient use efficiency; and d) root distribution analysis over time indicate that Al toxicity may not be the major constraint for rice growth in such soils.

Other results suggest that even for the varieties susceptible to acid-soils, the major growth limiting factors on savanna soils are the deficiencies of Ca and Mg, and not the Al toxicity.

Inheritance studies on acid soil tolerance revealed that tolerance is dominant, showed intermediate to high broad sense heritability, is controlled by a few genes, and can be easily improved through simple breeding methods. Similar studies are being conducted for phosphorus and potassium.

In savanna soils (oxisols and ultisols), the supplying capacity of phosphorus is very limited. As a part of the inter-program project 'Phosphorus Acquisition and Recycling in Low P-Supplying Tropical Soils', the plant traits and mechanisms related to the efficient P acquisition and utilization will be identified for upland rice. The development of

P-efficient rice genotypes and the cropping system with these will be pursued as a parallel effort with other crops. The study of the physiological mechanisms for efficient P acquisition is being conducted in collaboration with IRRI and National Institute of Agro-Environmental Researchers, Japan.

Recent joint work, stimulated by the RP with the Savannas Program, has identified silicon deficiency as a major, previously unrecognized nutritional constraint for upland rice on LAC's 2.5 million hectares of acid savanna soils. This deficiency reduces yields by 50% and greatly increases susceptibility to the major diseases of this agro-ecosystem, neck blast and grain discoloration. Studies to find genetic and crop management solutions are being initiated.

Modeling work based on the physiological makeup of CIAT's germplasm will be used to explore plant-type needs for adaptation to specific niches in the region (GxE interaction), study sensitivity to ecosystem constraints of physiological parameters affecting yield potential, and help focus on research objectives for plant-type and root work. This activity should also give national programs access to this kind of work, and generate a broad data base for further validation and enhancement of the models. CIAT's RP has established close collaboration with IRRI in this endeavor.

3) Reducing Losses to Rice Pests

Several weed, fungus, virus and insect pests continue to reduce LAC rice production, equivalent to a farm-gate loss of US$ 704 million annually, or 18% of the crop. Additionally, farmers continue to over-use pesticides, seeds and fertilizers to minimize the risk of epidemics. Those inputs account for 42% of total production cost (an estimated US$870 million per year).

3.1) Durable blast resistance

Rice blast disease, caused by the fungus *Pyricularia grisea* continues to be the most devastating disease of rice worlwide in both irrigated and upland production systems. Cultivar resistance has been the preferred means of controlling the disease, thus developing durably resistant lines is a high priority for the CIAT rice program. However, resistance breaksdown due to the present of many pathogenic races of the fungus inducing farmers to rely on environmentally damaging and costly fungicides for disease control. Production of new sources of resistance inflates the cost of rice breeding programs worldwide.

Research for blast control at CIAT prior to 1990 included the use of resistant cultivars and adequate crop management, while in the last five years it has been concentrated on the development of rice cultivars with durable resistance. The CIAT rice program bred in 1989 Oryzica Llanos 5 suitable for both irrigated and favored upland conditions in a «hot spot» environment for blast, where populations of the pathogen remain high throughout the season and pathogenic diversity is high. This culivar has been grown commercially in Colombia for more than six years without breakdown, and reported as resistant in several hot spots in Asia by IRRI. Resistance remains stable because several resistance sources were combined in this line and selected through a long and complex breeding scheme.

Characterizing variability in virulence frequencies of the blast pathogen, a highly necessary step for developing durable blast resistance, has been conducted in the last seven years. Combination of virulence factors in several cases were found to be associated with poor fitness or with deletereous effects for the pathogen and this phenomenom is of great value for the development of durable blast resistance.

3.1.a) Application of biotechnology to characterize the blast pathogen and resistance

A critical evaluation of pathogenic diversity to explain the durability of the resistance in Oryzica Llanos 5 has been carried out in Colombia combining both virulence studies and molecular tools such as DNA-fingerprinting. Studies on genetic structure and virulence diversity of the fungus done in collaboration with Purdue Univesity and the BRU using DNA-fingerprinting indicated that the absence or low frequency of combinations of virulence genes is due to the genetic diversity among the pathogen population where certain virulence/avirulence genes are specific to each genetic lineage suggesting that this phenomenon is certainly of great value for the development of durable blast resistance. These results are allowing CIAT to use a precise strategy to develop disease resistance since combinations of resistance genes can now be directed toward resistance to the combination of virulence genes which are absent or in very low frequency in the pathogen population.

Resistant cultivars with unknown resistance genes to one or several genetic lineages of the pathogen have been identified. Using RFLPs and RAPDs markers we have tagged specific genes and gene combinations that provide resistance against part or an entire MGR lineage rather than just against individual races. Disecction of the resistance genes present in the variety Oryzica Llanos 5 is being conducted in close collaboration with IRRI.

The new strategy combining pathotyping and MGR-fingerprinting provides a way to define the genetic organization and distribution of rice blast pathogen diversity and to incorporate appropriate resistance genes. Future breeding strategies in the region for the development of blast resistance will have to be based on the characterization and understanding of the genetic diversity and variability of the blast pathogen together with the use molecular marker assistance for the identification of relevant resistance genes. This strategy developed at CIAT to attack a formerly intractable problem is serving as a model used by other rice research programs at IRRI and several NARDS in Asia. We at CIAT are developing a project to characterize the genetic structure and virulence diversity of blast populations in Latin America. Training of NARDS scientists on these techniques are being conducted at CIAT. An expert meeting was held at CIAT in 1993 to coordinate blast research between CIAT-IRRI-PURDUE with the participation of Cornell University and the Dupont company.

3.2) Rice traits to enhance weed control

Since 1992, when we moved into a physiology position, activities became more strategic and germplasm oriented. Weed activities evolved into a project seeking to incorporate competitive ability into rice germplasm, which at the same time identified rice characteristics for better intercropping with pastures.

While tillage and herbicides will continue to play a major role in the future, there is clearly a need for complementary approaches to weed control which are cost-effective and environmentally-friendly, reducing hazards associated with herbicide use. A research program has been started on traits to enhance weed control in rice. One goal is to develop more competitive rice cultivars by identifying traits for competitiveness within adequate and highly productive rice plant types. Initial studies on early competition, including detailed growth analysis, indicated that competition effects can be measurable relatively early after emergence. Plant biomass, interception of light penetration and leaf area were the best indicators of rice competitiveness, plant height and tillering were of lesser relevance. Contrasting differences among rice cultivars were found in root distribution patterns under competition. More competitive plants had denser root systems throughout the profile and reduced weed root growth.

Two more aspects are considered to enhance rice competitiveness against weeds: allelopathic rice germplasm and genotypes for water seeding. Under tropical conditions rice seedling establishment under water is poor due to the low oxygen content of the flooding water, thus fields must be drained for seeding. However, a flooding film of water also impedes the germination of most weeds. Provided with germplasm tolerant to anaerobic conditions, farmers with leveled fields and uniform water level, could sow rice directly through the flood water without having to drain the field. Weeds would thus not be able to emerge and compete with the crop. Eventually, aquatic weeds that can establish under flood could be controlled using rice allelopathy, since such germplasm is active against some relevant water-loving weeds, such as *Heteranthera spp.* and *Cyperus iria.* Together with enhanced crop competitiveness, this last alternatives offer a formidable «package» for drastically reducing herbicide use in rice.

3.2.a) Integrating rice improvement within agropastoral systems

This is a project designed within the philosophy of enhancing rice competitiveness with weeds. It was initiated in 1994 with the financial support of the British ODA. The factors involved in interference of rice cultivars with pasture grass species are being studied collaboratively with EMBRAPA/CNPAF, Brazil. This will identify traits and rapid screening methods to select for reduced yield losses from pasture competition in agropastoral systems. Existing models will be applied to develop a mechanistic understanding. Crosses will be made to see how traits perform across a range of genetic backgrounds. The effects of competition will be studied by Brazilian scientists. Exchange visits and workshops will help develop skills and disseminate findings.

Preliminary information showed that significant competitiveness could be found in cultivars of excellent plant type and yield potential, and that useful variability for competitiveness exists: yield reductions by pasture competition ranged from 11% to 70% with respect to a weed-free check. However, the growth of the pasture was inhibited by the shading of rice canopies. Shading by the most competitive variety was four times higher than that of the least competitive variety. Root parameters (root length density and dry weight) measured in monoculture did not correlate well with rice yield losses by pasture competition. However, deep-rooted plants appeared to be more competitive, whereas plants with heavy biomass investment in shallow rooting tended to compete less favorably with the pasture.

3.3) Diversified *Tagosodes*/Hoja Blanca Resistance

Rice hoja blanca virus (RHBV) causes severe recurrent epidemics in the Andean, Central American, and Caribbean countries of tropical LA. The planthopper insect *Tagosodes oryzicolus* is a serious pest of rice that causes direct damage and is the vector of RHBV. The uncertainly of epidemics induces farmers to spray insecticides as many as 5-6 times to control this planthopper vector of RHBV as «insurance».

Sources of resistance to the planthopper and RHBV have been genetically analyzed and the mechanism of resistance have been partially studied. Some sources seem to have at least two genes for resistance. The identification and characterization of these different sources of resistance to RHBV and *Tagosodes* are forming the basis for gene pools that can be used in rice breeding programs. Progress has been made on the molecular characterization of RHBV and this has led to the current project to genetically engineer rice plants to be resistant to RHBV. A rice transformation system has been successfully developed at CIAT and transgenic plants have been produced. These transgenic plants are being analyzed to determine if they are resistant to RHBV.

Funding for rearing and maintaining the colonies of Tagosodes both for screening for resistance to the planthopper and to RHBV is tenuous. If funding is cut, the ability to screen germplasm for resistance will be severely limited.

The absence of an entomologist since 1992 in the RP has significantly affected the output in this project area. Now the positions has been reduced to part time position and possibly will only be filled as part time of a post doctoral position. This change has led to instability in the entomology section and most of the IPM related activities have been terminated. These include control measures for *Tagosodes*. If the irrigated rice breeding position is eliminated this will even further reduce the expected outputs of this project area.

Detailed studies on the genetics and mechanisms of resistance to the planthopper are being done in order to develop suitable strategies to most effectively utilize these genetic traits. Improved rapid screening techniques and methods to determine if the gene are being pyramided need to be developed. This activity is expected to take 3-4 years and result in well characterized gene pools that are easy to incorporate in rice breeding programs.

Over ten different rice lines have been identified as resistant to RHBV. A resistance gene was identified by a molecular marker and additional markers would be useful in developing strategies to pyramid RHBV resistant genes. This activity is expected to result in well characterized gene pools that are easy to incorporate in rice breeding programs.

3.3.a) Genetic transformation of rice with viral genes for novel resistance against RHBV

The molecular characterization of RHBV has led to the design of novel virus-resistant strategies to genetically engineer commercially-grown rice cultivar, these were funded by the Rockefeller Foundation starting in 1990 and 1993, respectively. Control of RHBV by plant transformation is being attempted at CIAT by following two different strategies: the coat protein-mediated cross protection and antisense RNA strategies. This work is being conducted in collaboration with the RP and the BRU. The project duration is 2-3 years.

The expected outcome are desirable rice cultivars that are resistant to both the insect vector and RHBV.

3.4) Integrated pest and crop management

In this project the most important activity is the development of functions relating levels of weed infestation, with the corresponding crop yield loss in order to have a quantitative basis for estimating economic thresholds of weed infestation. The aim is two fold: a) to have an objective basis for deciding about the need for weed control, and b) to have a tool allowing the selection of diverse (not just chemical) weed control alternatives. The expected output is a reduction in herbicide use and its substitution for a more diversified and environmentally friendly approach. Adequate predictions were obtained if weed populations were quantified by parameters closely related to the competition process. These yield loss relationships were used to establish economic thresholds for weed infestations. With results from the Cauca Valley it was concluded that with the use of thresholds up to 30% of herbicide inputs could be reduced. Using this approach prototype expert systems package was built with the collaboration of the Economy section of the RP.

For red rice, competition experiments generated a data matrix where rice yield losses were a function of the density of red rice and the duration of the competition period. A response surface yield loss function was obtained that allowed to predict losses from diverse red rice infestation and weeding scenarios and thus select economic management alternatives. To reduce herbicide use, preventive measures-particularly the production of red rice-free seed and other strategies to avoid reinfestation, including aggressive legislation are of paramount importance.

3.4.a) Workshop on rice IPM in LAC

This activity is funded by FAO and will congregate, at CIAT, scientists from: Cuba, Brazil, Venezuela, Colombia, the Dominican Republic, and Ecuador to discuss a multidisciplinary, holistic IPM implementation project. Such project will be submitted for external funding.

Other activities contemplated imply that ICM and IPM concern judicious application of technologies already available, tailored to local needs. CIAT as an international institution has a comparative advantage in a) convening discussion and drawing attention to the potential of these approaches, b) matching donors with opportunities in specific localities, c) developing information tools such as expert systems models, d) facilitating transfer of technologies, and e) developing strategic research needs such as methodology development, basic pest biology, ecology and epidemiology.

X. NEW PROJECT INITIATIVES

. Jointly with EMBRAPA/CNPAF a project targeting to identify major traits and screening techniques to select for reduced yield losses from pastures competition in agropastoral systems was proposed and accepted by the British ODA in 1994, preliminary data on this project was reported elsewhere in this document.

. CIAT's Board recommended, in 1993, that the irrigated rice breeding activities carried by the RP was passed to the region. A project proposal to finance this initiative was prepared together with the private sector with the objective to continue some of the activities considered of high priority for them.

. INGER-LAC up to 1993 has been part of a global activity coordinated by IRRI, to implement that, there was a senior staff posted at CIAT. The project will expired at the end of 1994 and a proposal seeking external funds was prepared targeting the next five years. The proposal is expect to be on donor' hands in the near future.

. CRIN operated in the region until 1992. The external evaluation made on the project showed that it presented one of the highest rate of return in the area. Using this as support a new project was proposed along the same lines -germplasm improvement and exchange- and submitted to donors in 1991. The process is still under consideration.

. CIAT developed expertise in applied biotechnology to help breeding rice and beans. A proposal was prepared by CIAT and Cornell University aiming to establish a world wide network to explore map-based introduction of genes for yield and quality improvement in these two crops. The project includes NARDs in Latin America and Asia, Cornell University, IRRI and CIAT.

. A regional initiative for integrated pest management in Latin America is a central part of CIAT's new vision in resource management research and one of its main contributions to sustainable agriculture. Working through cross-program scientific resource groups, we will assess the needs in major agroecologies and design projects for implementating IPM in rice. Pilot projects already underway will serve as models for such projects.

. Following CIAT findings with respect to blast lineages a project proposal has been prepared to finance the research at National Programs level to characterize the blast pathogen populations in the region for developing durable blast resistance. The collaborating institutions include the Purdue University and NARDs in Latin America.

XI. CLOSING REMARKS

The population of the world is growing by nearly 100 million people every year. Much of this increase will occur in Asia where it will be difficult to add new areas of arable land into cropping systems. LAC has a relatively modest population compared to the arable land available. The current population in LAC is 448 million and it is increasing at a rate of 1.6% per annum. Rice production in LAC was 18 million tons in 1990 and the projections is that the demand will grow to 24 million tons in 2000. Thus, rice production must increase 25% in ten years or LAC will become a net rice importer. If rice production can be significantly increased especially in the upland sector, the LAC could be in a position to be a major rice exporter. The irrigated sub-tropical areas could produce the types of rice that are in high demand in Asia. With cooperation between CIAT, NARs, NGOs and private industry, the rice sector in LAC can dramatically increase rice production and add to world food security.

The RP has a unique feature as a commodity program at CIAT. It not only has the challenge of producing abundant and cheap food to match the requirements of an ever increasing population in Latin America, but it also has to link with the Center's ecoregional effort. To comply with the first challenge, **irrigated rice** research to increase the yield plateau and ensure stable yields, as well as international germplasm testing and distribution, must be continued in spite of the current budget loss. For this a major task is underway to attract funds from the region, primarily through the creation of a Consortium involving NARDs and private sector. The development of a common research agenda and integration of interested parties is a big task ahead. Prospects are good, but the recent loss of the leader position further weakens the program and its credibility, thus compromising the success of this objective.

The RP will continue, and further expand its participation in CIAT's **ecoregional mechanism**. Our upland activities are developing germplasm for cropping systems for rainfall-favored upland ecosystems on acid soils. An interdisciplinary approach and across program interactions have been implemented and are key for success.

Rice production costs are high and the RP should develop ICM/IPM components to lower these. Efforts will continue in the incorporation of resistances to biotic stresses and the development of weed-competitive cultivars to reduce pesticide use, as well as in the development of more nutrient use efficient lines to reduce fertilizer use. The program has now structured its activities in a project fashion. Such projects represent our future thrusts and initiatives for external funding. Although the RP is an example of a success story, however the job is not yet completed. Growing populations and demand continue to devour increases in rice production, and sub-regional shortfalls in production need to be overcome. This has to be done in a sustainable way without degrading the environment and the resource base; yield gains should be maintained at a stable and declining real price, that is, at a low cost to producers, consumers, and the economy as a whole. These are some of the challenges we face in the 1990's.

TROPICAL FORAGES PROGRAM
Report for the EPMR review, October 1994

Executive Summary

There have been some major breakthroughs in research in the last five years which have set a firm foundation for transfer of new technology to NARS. It has also been a turbulent five years with major changes in the goals and direction of CIAT, reduced capacity in the Center (including tropical forage research), changes in priorities of the donors and structure of the CGIAR system, but with new capabilities in technology for research into genetic diversity and genetic manipulation and for communication. The Tropical Forages Program (TFP) is well placed to continue strategic research in areas where it has a comparative advantage.

The major breakthroughs in the period 1989-94 have been:

(i) The identification of a tropical forage legume which offers a similar potential as white clover does for temperate areas. *Arachis pintoi* has proved to be productive and persistent and can be used equally well as the basis for sustainable grass-legume pasture systems or as for a cover crop in tree plantations, reducing:- soil erosion, the requirement for nitrogen and herbicides, and labor for weed control.

(ii) Legumes are now being accepted by farmers in different ecoregions and farming systems. These include the use of *Arachis* for dairying and tree crops in Central America and *Stylosanthes* for beef production in the forest margins of Peru and for cover crop and feed meal production in south China.

(iii) A plant improvement team has manipulated apomixis in *Brachiaria* to introduce spittlebug resistance and in the process mapped the apomixis gene. This was achieved by close collaboration between geneticists, entomologists and biotechnologists within CIAT and NARS researchers in Brazil.

(iv) Advances in the knowledge of mechanisms of host-plant resistance, plant adaptation to acid soils, and antiquality factors affecting feed quality, together with new biotechnology capabilities will allow more rapid genetic manipulation of traits.

(v) Forage germplasm identified by CIAT for acid infertile soils is now being evaluated and used not only in Latin America but in Southeast Asia, China and West Africa. This comparative advantage has evolved from the decision in 1971 to select forages for harsh conditions with respect to soil fertility and pest and disease virulence. It places CIAT in a strong position from which to participate in the new Systemwide Livestock Research Program of the CGIAR.

There is need for recognition of the structural and organizational changes that have taken place during 1989-94. In 1991, the then Tropical Pastures Program had a mandate for research in areas of Forage Diversity, Forage Improvement, Forage Utilization, Pasture Management, Livestock Production Systems and Technology Transfer with a staff of 17 Senior Scientists and 4 postdoctorate fellows. To-day the Tropical Forages Program has a mandate in three areas: Forage Diversity, Forage Improvement

and Forage Adaptation and Utilization with a staff of 9 Senior Scientists, 4 of whom are new appointees. Thus there has been a period of adjustment to the new mandate, and orientation for new appointees. In addition, considerable time and energy has been expended in accommodating the Program to a situation of reduced expenditure per senior scientist and formation of a Project system. The TFP has emerged with high morale and a new sense of mission. Considerable tribute must go to the local staff whose dedication enabled us to maintain the momentum of research.

We are aware that our interaction with NARS partners in Latin America has been at a reduced level during this period of transition; which same period has also been a transition for them as governments have moved to reduce expenditure. We have a strategy in place to renew the previous strong linkage, one which will involve them as partners in both strategic research and technology transfer. Improved communication using new electronic technology will facilitate close interaction.

In brief, our future strategy is to concentrate research in areas in which CIAT has a comparative advantage. This will be reviewed from time to time with NARS and other IARC's. Presently, these are considered to be in genetic resources, forage improvement and research on processes and mechanisms that will facilitate evaluation and selection. Research in these areas is supported by specialists in forage germplasm, genetics, animal nutrition, agronomy, plant nutrition, entomology, pathology, virology and biotechnology. Resources will also be used to ensure there is continuing contact and exchange with farmers and NARS in the development of new technology.

The following summary report is presented in the format of the new project system for the areas: Forage Diversity, Forage Improvement and Forage Adaptation and Utilization. Additional comments have been made on our interaction with other Programs and the Scientific Resource Groups and how we see our role in the new global livestock initiative.

Introduction

Program Goal. The goal of the Tropical Forages Program (TFP) is to develop forage components for farming systems on acid infertile soils of the humid and sub-humid tropics which will contribute to increased and more efficient meat and milk production, soil improvement and erosion control. The Program seeks to achieve this goal through research in three areas: forage diversity, forage improvement, and forage adaptation and utilization. This research is integrated where feasible with that of other Programs within CIAT, national research organizations in developing and developed countries, and other IARC's.

The TFP recognizes the role of forages in the development of sustainable agricultural systems as well as for livestock feed. Forage species can improve soil fertility, physical structure, and biological activity, protect soil against erosion, reduce the need for herbicide use in weed control and, as has been documented recently, sequester large amounts of carbon at depth, thus contributing to minimizing the greenhouse effect of increasing atmospheric CO_2.

Changes in Program structure and activities since 1989. The situation in the last five years has been quite dynamic due to changes in available resources within the

CGIAR and the need to switch some resources from research on mandate commodities to research on natural resource management. In addition there have been conceptual changes within both national and international organizations. The most important have been the demand to develop stronger accountability, leading to formalization of the project system, the realization that integration and multi-disciplinary approaches make most effective use of resources, and the demonstration that technology needs to be developed with participation of the end users.

Through this period of change we have endeavored to maintain our comparative advantage in strategic research. The impacts we are seeing now are the results of research initiated five years ago, while what we are doing now will have its major impact in the next five years. We have maintained the momentum of research while assimilating a revised mandate and organization, and developing new approaches to our interaction with the NARS.

A large structural change occurred in 1989 when the previous Tropical Pastures Program (TPP) was modified to become a germplasm development program in August 1992. The old TPP had also been involved in research on pasture management and utilization and natural resource management in the areas of production systems and nutrient cycling. Some TPP scientists were transferred to the Savannas Program (now Lowlands Program). Close interaction with these scientists has been maintained. As the new CIAT Programs evolved it became apparent that the TFP needed to maintain some research on forage utilization and management. This has been accommodated within the Project on development of forage components.

There has been an organizational change from Sections to one of Projects. The Sections functioned around a Senior Scientist in a particular discipline, while Projects are organized around a theme with multi-disciplinary inputs. The TPP had previously initiated such changes through multi-disciplinary research e.g. in the nutrient cycling project based at Carimagua, and hence the transition has been reasonably smooth.

There have been 15 releases of new cultivars by NARS of promising accessions identified by CIAT since 1989. By 1989, forage evaluation activities had evolved from the savannas of Colombia, begun in 1970, to the humid forest area of Pucallpa in Peru in 1985 (transferred to Caquetá, Colombia in 1991), and Central America in 1987. Evaluation directed towards multiple use of forages in the hillsides was commenced in Cauca, Colombia, in 1993. Activity in evaluation has also extended from herbaceous legumes to shrub legumes because of the need for MPTS with forage value that are adapted to very acid soils.

The global mandate for acid tolerant germplasm has been executed more vigorously. In West Africa, grass, legume, and multi-purpose tree and shrub (MPTS) germplasm was evaluated over 15 sites in cooperation with IEMVT and ILCA. A position was established in Southeast Asia in 1992 with a scientist based at IRRI.

Activities have become more focused to achieving a given outcome within a given time frame, given reduced resources and the introduction of the project system. More resources are presently deployed towards improvement in the grass genus *Brachiaria*, and legume genera *Arachis*, *Stylosanthes* and *Centrosema* than in other genera. Further, there is a change towards more strategic research in areas where CIAT has a comparative advantage. This includes research on host-plant resistance mechanisms for insects and diseases, use of molecular markers for increasing the knowledge of genetic diversity, adaptation of plants to acid infertile soils, and the nature of tannins.

Major client and regional interaction. Our major clients are the farmers for whom we are developing forage components, the NARS in tropical America, Southeast Asia and West Africa through whom technology is developed and transferred, and donors. We have regional interactions with PROCITROPICOS, CATIE and other IARC's.

Funding constraints mean more attention has been given recently to the priorities of donors. RIEPT networking and training has continued to be strong in Central America but has decreased in South America due to limitations of funding and organizational changes within the NARS. More interaction is taking place with NGO's, farmer cooperatives and the seed industry rather than only through government officers. Direct interaction with farmers is increasing in development of forage components. This has led to exploration of new ways to maintain active collaboration with our partners.

The impending formation of ILRI with a global mandate for livestock research has the implication that our activities related to livestock production, while still independent, will be coordinated more closely with those of ILRI and other IARC's through the Systemwide Livestock Research Program.

Program Areas and Projects

The TPP was reviewed in 1991 (CIAT, 1991b; CIAT, 1992b), then changes were initiated with the formation of the TFP in August 1992. These changes are recorded in more detail in the Strategic Plan (CIAT, 1991a), the Medium Term Plan (CIAT, 1992a) and the revised Action Plan of June 1994 (CIAT, 1994). The Biennial Report of TFP (CIAT, 1993) and the Proceedings of the Arachis Workshop (Kerridge and Hardy, 1994) provide more detailed information of activities of the TFP.

The activities of the Program now fall within three areas: Forage Diversity, Forage Improvement and Forage Adaptation and Utilization. The following presentation has been assembled around these areas as they form the structure for our current research.

Program Area - Forage Diversity

Exploiting the genetic diversity among and within wild species continues to be the basis for tropical forage improvement. CIAT has focused on identifying forage germplasm adapted to very acid infertile soils and the high disease and pest environments of the humid and subhumid tropics.

The large ex-situ collection of legumes and grasses which has been assembled and to a large extent evaluated in the field, provides underlying strength to the TFP. From this collection, key genera have been identified and a portfolio of forage germplasm options established for the savannas (Llanos and Cerrados), humid and subhumid tropics of tropical America (CIAT, 1992b; CIAT, 1993).

There are now two formal Projects within this area - Genetic Resources of Tropical Forages and Forage Ecotypes with Known Environmental Adaptation. The first includes acquisition by TFP staff, the conservation activities of the Genetic Resources Unit (GRU), and the maintenance of the rhizobia and mycorrhizae collections. The second involves the identification of forage germplasm for different environments, its increase for more widespread evaluation and the development of an integrated database of plant characteristics and land use information.

Project - Genetic Resources of Tropical Forages

Purpose: To acquire, characterize, conserve, document, and distribute forage germplasm, rhizobia and mycorrhizae for evaluation for environmental adaptation on acid infertile soils of the humid and subhumid tropics.

The GRU was developed for the efficient conservation of the genetic resources of beans, cassava, and tropical forages of collections which had been assembled for commodity improvement. The activities of the forage unit within the GRU are integrated with other activities of the TFP through this Project which receives resources from the Program and the GRU.

The period since 1989 has been one of consolidation and improved organization of the collection. This was facilitated firstly by the work of a post-doctoral fellow and then by the appointment of a curator. There are now 21000 accessions of 150 genera and 700 species in the collection. Acquisition has become more focused either to meet deficiencies in the collection for particular environments or farming systems or to enlarge the genetic base of species which have been shown to have potential for forage or soil improvement. There is considerable interaction with other organizations holding forage genetic resources.

Notable **achievements** have been:

Acquisition

- A large increase in accessions of *Arachis pintoi* and *Cratylia argentea* from Brazil and *Desmodium* spp. and *Pueraria phaseoloides* from Vietnam by collection.
- An increase in *Paspalum* spp., *Panicum maximum*, and *Sesbania* spp. and other MPTS by exchange.

Conservation and distribution

- Acceptable phytosanitary procedures have been established.
- An active program of seed increase for renewal and long-term storage is in place together with a plan for full duplication in alternative storage sites.
- Distribution of approximately 3000 samples annually.

Characterization and identification

- Morphological and biochemical characterization of *Arachis*, *Brachiaria*, and *Stylosanthes* to assess genetic diversity.
- Re-organization of a reference herbarium.
- Taxonomic studies on *Brachiaria* and *Galactia* by visiting scientists.

Documentation

- The genetic resource data base has been established on ORACLE.
- An inventory of species held in the GRU has been published.
- Catalogues of the collection from Colombia, Central America & Mexico, Southeast Asia and Venezuela and a world catalogue for *Centrosema* have been published.

<u>Rhizobia and mycorrhizae</u>

- Addition to and maintenance of the collections and continued supply of cultures for research and for distribution with seed samples.
- Publication of a catalogue of rhizobia strains for tropical legumes.

Collaboration: NARS and other IARC's have collaborated closely in the acquisition and exchange of germplasm. These include CENARGEN, ILCA, ICRISAT,CSIRO and CATIE. Within CIAT there is also interaction with the VRU and the BRU.

The major **impacts** in this project area have resulted from the re-organization of the tropical forages germplasm collection, the new database which allows integrated management of the collection and unit and the large increase in acquisition of *Arachis pintoi*. CIAT is recognized as a safe repository for rhizobia by other organizations.

The major **constraints** are the shortage of resources to hasten the multiplication, duplication and safe storage of the collection, the need for a conditioned area for temporary storage of seed awaiting processing and the inability to commence research in in-vitro conservation of non-seeding species, e.g. *Arachis glabrata*, seed physiology with respect to long term storage and field rhizobia studies. It is essential that there is continued support for the rhizobia and mycorrhizae units.

There has been **reduced activity** in acquisition of new species through a change in strategy to become more selective in terms of acquisition. The main **component** added has been a higher level of organization and management of the collection as a major genetic resource. This has been accompanied by the increased use of biochemical characterization to identify the extent of genetic diversity.

Future strategy. The first priority has to be given to maintenance and security of the collection and efficient data management to assist in distribution. Secondly, we wish to more closely integrate this forage collection with those of other organizations. Steps have been taken to achieve this through an international forage genetic resources network involving NARS and IARC's under the Systemwide Livestock Research Group. Thirdly, there will be an increased focus on research. This will include studies of genetic diversity using biochemical and molecular markers on both the ex-situ collection and in-situ diversity to develop appropriate strategies for germplasm conservation , reproductive biology, seed quality and storage, and in-vitro culture of non-seeding species. A program will be implemented to produce seeds free of viruses.

Project - Forage Ecotypes with Known Environmental Adaptation

<u>Purpose</u>: To identify forage ecotypes adapted to climate and soil and resistant to pests and diseases for the humid and subhumid tropics, with persistence, high quality feed value and the potential for soil improvement.

New forage germplasm can be effectively deployed only if there is some knowledge about tolerance to diseases and pests in specific climatic and edaphic environments. These plant adaptation characteristics and the GRU passport and characterization data then need to be linked with GIS land use data bases to facilitate deployment of the germplasm. CIAT has its own primary evaluation sites in major ecosystems but can also utilize data from NARS through the RIEPT data base.

Evaluation of most of the CIAT germplasm in the harsh acid soil, and disease and pest prone environment of the Colombian Llanos at Carimagua has resulted in selection of germplasm with a very wide range of adaptation. Such germplasm has performed well in less harsh environments. However, relying solely on Carimagua as a primary evaluation site can mean that some useful germplasm has been excluded. Further, there is a need for special purpose germplasm for particular situations e.g. fodder shrubs, legume mulches, soil covers, and erosion barriers. The current and planned activities reflect the changes that have been made recently to meet these needs.

The main activity in the last five years was a continuation of evaluation of collections in the major ecosystems. Evaluation activities have been reported in the RIEPT workshops for the humid tropics (Keller-Grein, 1990) and the savannas (Pizarro, 1992). The current and planned evaluations are to complete evaluation of material of key species that have not been grown out, evaluation for specific needs e.g. for increased soil fertility conditions of intensive crop-pasture systems, and multilocational evaluation of species with high potential e.g *Arachis pintoi* to assess genotype x environment interaction. Primary evaluation sites now include Carimagua (Llanos), Caquetá (humid tropics) and Cauca (hillsides) in Colombia, Planaltina (Cerrados) in Brazil, San Isidro (humid tropics) and Atenas (subhumid) in Costa Rica and Cavinti (humid tropics) in the Philippines.

Notable **achievements** have been:

Forages for the lowland humid tropics

- Major evaluations completed of the genera *Calopogonium, Desmodium, Pueraria, Brachiaria, Panicum* and *Paspalum* at sites in Brazil, Colombia, Costa Rica and Peru.
- RIEPT workshops held in Peru (humid tropics) and Brazil (savannas).

Multipurpose trees and shrubs

- In the humid tropics, *Codariocalyx gyroides* was very productive under poorly drained conditions and *Desmodium velutinum* in better drained conditions.
- In acid soil hillsides, *Cratylia argentea* and *Flemingia macrophylla* were outstanding.
- In the more fertile subhumid site at Atenas, one accession of *Leucaena leucocephala*, CIAT 17263, gave very high wet and dry season yields.
  Forages for hillsides
- The University of Hohenheim-GTZ team working with the Cassava Program has identified legumes and grasses for use as soil covers and erosion barriers in cassava-based systems.

Southeast Asia

- New introductions of specific accessions of *Stylosanthes guianensis, Arachis pintoi, Centrosema pubescens, Desmodium ovalifolium, Andropogon gayanus, Brachiaria brizantha* and *Panicum maximum* were outstanding (for details see p.2-13, CIAT, 1993).

West Africa

- a multi-site evaluation over 9 countries and 13 sites identified a suite of potential new forage germplasm for these countries.

Forage value

- the importance of concurrent evaluation of digestibility with agronomic evaluation was demonstrated, in particular, for the shrub legumes and in the assessment of the *Brachiaria* collection.

Movement of germplasm for different ecoregions to NARS

- 230 sets of germplasm were distributed to 55 countries outside Colombia in the last 5 years.
- Revised lists of germplasm with high potential have been produced and distributed to NARS.

Collaboration: Interaction with NARS through various networks: RIEPT (tropical America), SEAFRAD (Southeast Asia) and RABAOC/AFRNET (Africa). Within CIAT, there is collaboration with the Lowlands, Hillsides and Cassava Programs in the selection of new germplasm and with the GIS and BRU units.

The major **impact** in evaluation has been in identification of new productive accessions in the key genera, *Arachis*, *Calopogonium*, *Leucaena*, *Panicum* and *Paspalum*. These accessions are now being evaluated as components for production systems. Potentially useful MPTS species for tropical ecosystems have been identified as *Cratylia argentea*, *Codariocalyx gyroides* and *Desmodium velutinum*.

The major **constraint** in this project is to maintain effective linkages with NARS as their organization and personnel change and to do this with a reduced number of outreach agronomists who developed and maintained close contact in the past. The capacity to produce large quantities of seed of potentially useful accessions for bulk distribution to NARS has been lost. NARS now only receive 'gram' lots of seed for evaluation and initial increase. We have lost capacity of statistical and modelling expertise in GIS database development.

New components initiated since 1989 have been the multi-site evaluation in West Africa, the agronomy position in Southeast Asia and new evaluation activities in South America directed to short-term pastures for crop-livestock systems and multipurpose forages for smallholders in the hillsides.

Future strategy. Further evaluation for environmental adaptation will be linked more closely with evaluation for performance as a component of production systems involving farmer participation, particularly for smallholder farming systems. Linkages with NARS will be developed on the basis of mutual collaboration. CIAT will act as a resource for forage germplasm, specialist assistance and training. NARS will be asked to nominate national scientists to actively interact with CIAT as partners in evaluation of germplasm.

Program Area - Forage Improvement

The search for useful tropical forage species from thousands of accessions of wild plants has narrowed the number of useful genera to 16-20 with approximately double that number of species. This is still far greater than the number of genera and species used widely in temperate pastures. But we observe that fewer than half that number (of tropical species) are used widely in different parts of the world. Deficiencies emerge as a species becomes commercial and further research is required to overcome these deficiencies. Priorities need to be set as to where the greatest impact can be made with available resources.

The decision was made to restrict intensive research to the genera *Brachiaria*, *Arachis* and *Stylosanthes* with limited input into *Centrosema*. *Brachiaria* is the most widely sown tropical grass genus. Research is justified on legumes because of their high feed value and nitrogen fixation. While *Stylosanthes* is the most widely sown of the tropical genera, *Arachis* appears to have similar potential. *Centrosema* has always been regarded highly as a genus but has limitations of seed production and susceptibility to foliar blight. Priorities were also set by taking into account the activities of other research groups.

We use forage improvement in the broad sense of enhancing productivity and the range of adaptation by exploiting a wider genetic base and the development of management techniques to enhance utilization. Genetic recombination will be used where desirable attributes are not found in a single natural accession, where objectives are well defined and the required attributes are strongly heritable.

Project - Genetic Enhancement of *Brachiaria*

Purpose: To improve the utility and productivity of *Brachiaria* forage grasses through the utilization of natural genetic resources complemented by genetic manipulation.

Brachiaria species originating from Africa have been planted over 50 million ha in tropical America, the majority to *B. decumbens* in which productivity is severely limited by spittlebug attack. Considerable variation exists between and within species in resistance to spittlebug and leaf cutter ants, in edaphic adaptation and in forage quality. Genetic manipulation depends on the availability of sexual accessions which are compatible with the potentially useful accessions which are mainly apomictic.

During 1989-94 the evaluation of the major portion of the collection made in east Africa in 1984-85 was completed and a major breeding program has been initiated to combine spittlebug resistance, while retaining other desirable attributes of edaphic adaptation, other pest and disease resistance and high feed value, in an apomictic cultivar.

Notable **achievements** have been:

Characterization

- Collection characterized by morphological traits, isoenzymes and reproductive mode.

Evaluation

- Superior accessions have been identified within *B. decumbens* (higher feed value and productivity), *B. brizantha* (higher feed value, productivity and improved adaptation to infertile soils) and *B. humidicola* (higher crude protein).

Genetic recombination

- Hybrid recombinants with resistance to spittlebug have been produced.

Apomixis

- The apomixis gene in *Brachiaria* has been mapped to 10 map units.
  Tissue culture
- Successful regeneration from callus tissue was achieved with five *Brachiaria* spp.

Spittlebug resistance

- A greenhouse screening technique which is reliable, but of limited capacity, was developed to assess damage by larvae and adults of spittlebug.
- Sources of antibiotic resistance to spittlebug were identified.

Leaf cutter ant resistance

- Demonstrated that resistance is associated with inhibition of the fungus, on which the ants depend for food and for which they collect leaf material.
- A laboratory bio-assay based on fungal growth on aqueous leaf extracts was developed.

Foliar blight resistance

- Reliable inoculation and screening procedures for field and glasshouse were developed and sources with high levels of resistance identified.

Edaphic adaptation

- Determined that adaptation to acid infertile soils is not associated with Al toxicity.

Collaboration: There is active collaboration with CNPGC/EMBRAPA in genetic studies while discussions are being held with CORPOICA for evaluation of new lines. Within CIAT, there is active collaboration with the BRU and VRU.

The major **impact** in this project has been through the ability to manipulate apomixis, which has been further advanced by the mapping of the apomixis gene. This opens the possibility for cloning the gene and transfer to other crops. The research into the nature of leafcutter ant resistance allowed the development of a rapid screening technique.

The major **constraint** in the program to introduce spittlebug resistance is a reliable field screening technique for assessing resistance on large segregating populations. Entomological research has been curtailed temporarily by the transfer of the scientist involved in this research. Research into seed dormancy is limited by resources.

New activities introduced into the project have been mapping the apomixis gene, the regeneration of plants from callus tissue and studies on the mechanism of edaphic adaptation.
A workshop will be held in October 1994 to assess present knowledge and set priorities for future research and collaboration.

Future strategy. The program of recombination and selection for spittlebug resistance will be completed. The success of this activity will open the possibility for further improvement through increasing feed quality, enhanced edaphic adaptation including possibly associated nitrogen fixation, incorporation of foliar blight resistance and reduced seed dormancy. A program will be initiated to fine map the apomixis gene in conjunction with the BRU.

Project - Improved forage *Arachis genepools*

Purpose: To broaden the range of adaptation of forage *Arachis* species by increasing the available genetic base, to improve agronomic utility and to facilitate *in situ* conservation through population biology studies.

A. pintoi is the first legume to give high productivity and long-term persistence when grown in association with aggressive tropical grasses in the humid tropics. The same applies for *A. glabrata* in subhumid areas. Further, *A. pintoi* has great potential as a green cover in tree and horticultural crops and *A. glabrata* as a hay crop. More diverse germplasm could extend the range of adaptation. Little is known of the potential for disease and pest outbreaks when a uniform cultivar is grown extensively.

A workshop held in May 1993 summarized the extent of knowledge of the genus and suggested priorities for further research (Kerridge and Hardy, 1994). These priorities can be separated into (i) acquisition of a wider range of germplasm and (ii) promotion of the presently released cultivars to create demand and provide feed back on limitations. Characteristics that will be looked for in new accessions are greater tolerance to drought and low temperature, more rapid establishment, and contribution to soil improvement. Improved management techniques are needed for seed production in some situations. There has been limited research on seed quality and storage. The workshop also highlighted the success other countries have had with species other than *A. pintoi*.

Notable **achievements** in this project have been:

Acquisition

- More than 100 accessions of *A.pintoi* and *A. repens* are available, 65 in the CIAT GRU.

Evaluation

- Trials in Central America, Brazil and Southeast Asia have identified accessions superior to the one now released officially in 5 countries; in Brazil, an accession adapted to the long dry season conditions of the Cerrados.

Establishment

- Some genetic variation has been demonstrated in the rapidity of establishment.
- There is response to fertilizer placement adjacent to the seed at establishment.
- Heavy grazing favors rapid establishment

Seed quality

- Seed quality will deteriorate with storage at ambient temperature in humid conditions

Collaboration: CIAT and ICRISAT are collaborating with CENARGEN in the acquisition, conservation, distribution and evaluation of wild *Arachis* germplasm.

The main **impact** that is emerging is the wide range of genetic variation that is available.

The main **constraints** are the limited resources being applied to research into establishment and seed quality. There is also an opportunity and need to relate the genetic diversity that is being acquired with that in the natural populations with a view to *in situ* conservation of this resource. The more intensive acquisition and evaluation, and studies on genetic diversity have all been **initiated** in the last five years.

Future strategy. In addition to the extensive evaluation of *A. pintoi*, multilocational evaluation of a wider range of *Arachis* species is planned. CIAT will be a partner in a collaborative project with CENARGEN and ICRISAT on the 'Preservation of wild *Arachis* species' with CIAT taking the lead in studies on the population biology of natural populations. Activities will be closely coordinated with the evaluation of *Arachis* in production systems.

Project - Stylosanthes cultivars with anthracnose resistance and persistence

Purpose: To develop genepools of *Stylosanthes guianensis* and *S. capitata* with durable resistance to anthracnose and high persistence under grazing.

The potential for *Stylosanthes* was first demonstrated in Australia where *S. humilis* became naturalized over vast areas until it succumbed to anthracnose. Since then 1 million ha of more resistant *S. scabra* and *S. hamata* have been sown. Similar expectations were held for South America where *Stylosanthes* species occur naturally in all ecosystems but susceptibility to anthracnose has limited commercial exploitation. Nevertheless, *S. capitata* cv. Capica continues to show promise in the Llanos and *S. guianensis* cv. Pucallpa in Peru while EMBRAPA has released *S. guianensis* cv Mineirao for use in the Cerrados in Brazil. The cultivar Pucallpa has had outstanding success in South China.

Nonetheless each of these cultivars is known to be susceptible to anthracnose in specific environments. With this knowledge and the evidence that susceptibility may develop with time in the same environment due to evolution of new strains of the pathogen, *Colletotrichum gloeosporioides*, there is a need to maintain ongoing research to ensure that durable resistance is developed and maintained. This is more realizable now that molecular techniques are available for quantifying genetic diversity of the pathogen and marking resistant genes.

Early work on pathology concentrated on the diagnosis and documentation of the disease. More recent studies are evolving to development of effective inoculation techniques for studies on host-plant resistance, epidemiological studies of the disease and new strategies such as gene cloning and transfer as an alternative to genetic recombination and selection.

Another apparent limitation with the current cultivars of *Stylosanthes* is low seed production, particularly under grazing and low seedling vigor. Thus while the cultivars might be adequate for short term pastures in crop-livestock systems they will not regenerate in perennial pastures.

The current situation in this project is that

(i) lines of *S. guianensis* selected for anthracnose resistance and higher seed yield during the last five years are currently being evaluated in small plot trials and under grazing.

(ii) studies have been initiated to determine the genetic diversity of the pathogen in four diverse locations and to investigate new strategies for achieving durable resistance and

(iii) studies of factors other than disease that may affect persistence have been initiated.

Notable **achievements** have been:

Evaluation and characterization
- The outstanding potential of *S. guianensis* CIAT 184, now grown widely in Peru and China as a feed and green cover, has been confirmed in trials in Southeast Asia.
- Biochemical characterization of the *S. capitata* and *S. guianensis* collections have shown wide genetic diversity.

New anthracnose resistant gene pools
- Anthracnose resistance has been maintained at Carimagua over several years.
- The new hybrid lines have been shown to have high feed value.

Studies on pathogenic diversity of anthracnose
- Inbred lines of *S. guianensis* have been assembled as differential hosts.
- An inoculation procedure was developed for evaluation of host-plant resistance.

Utilization of natural bacterial resistance
- Bacterial isolates of potential bio-control agents have been identified
- A gene with antibiotic properties was cloned from *Erwinia* sp.

Collaboration: The studies on pathogenetic diversity are being conducted jointly with CPAC and CNPGC/EMBRAPA and CSIRO.

Stylosanthes guianensis cv Pucallpa (CIAT 184) is having a major **impact** in farms in the Pucallpa region of Peru. In Southern China, where it is grown primarily as a cover crop and for production of feed meal, the area sown now exceeds 100,000 ha.

Future strategy. Emphasis will be given to a better understanding of pathogen genetic diversity to provide guidelines for future research on recombination and selection to develop durable disease resistance. Concurrently research will be conducted on achieving disease resistance with cloned microbe genes. Plant competition studies will be conducted to determine whether low seed yield and seedling vigor in grass associations limit persistence and if sufficient variation exists to increase seed yield and seedling vigor.

Project - *Centrosema* genepools with resistance to foliar blight

Project: To develop *C. brasilianum* lines with resistance to foliar blight while maintaining high seed yield and other desirable agronomic characteristics

Centrosema contains several species with demonstrated high feed value and an ability to grow in association with tropical grasses and which can also be used as cover crops. For pastures, use is limited by growing points that are readily removed by grazing animals and low seed set with consequent poor regeneration, except for *C. brasilianum* which

has the limitation of high susceptibility to foliar blight.
The genus *Centrosema* was thoroughly reviewed at a workshop held at CIAT in 1987. Further work has been limited to publication of the proceedings and their translation into Spanish, a multilocational trial of *C. pubescens* and sowing a wide range of accessions of *C. brasilianum* to observe the effects of natural selection.

In 1993, it was decided that the most profitable lines for future research would be to investigate increasing natural seed production or to combine foliar blight resistance in *C. brasilianum*. There appeared to be a good possibility to do this using known resistance in *C. tetragonolobum* which is cross-compatible with *C. brasilianum*.

Notable **achievements** have been:

Evaluation

- Publication of the *Centrosema* workshop proceedings.
- Completion of a multi-locational trial of *C. pubescens* at 18 sites.
- Promising *C. macrocarpum* and *C. schiedeanum* accessions identified for the hillsides.

Identification of sources of resistance

- A reliable inoculation method for evaluation of foliar blight resistance.

Production systems

- In Peru, local researchers have shown *C. acutifolium* to be a excellent cover legume for tree crops in the humid tropics because of rapid establishment and ability to resist weed invasion.

The major **impact** has been the demonstration of a reliable inoculation method for the pathogen, *Rhizoctonia*, which is the cause of foliar blight. Lack of a suitable method has limited selection for foliar blight in forages and other crops.

As mentioned above the major thrust of earlier years in acquisition and evaluation was terminated because further advances depended on genetic recombination and selection for which resources were limited. The recent advances in selection techniques will allow further research to proceed as more resources become available.

Future strategy: Firstly, we will investigate the progress that can be made in combining foliar blight into *C. brasilianum*. Secondly, the possibility for increasing seed production in other species such as *C. acutifolium*, *C. macrocarpum* and *C. pubescens* will be investigated.

Program Area - Forages adaptation and utilization (Forages for Acid Soils)

Projects in the areas of Forage Diversity and Forage Improvement will provide species and ecotypes with potential for use in production systems. But in many cases these need to be further evaluated as components of farming systems with farmers participating in the adoption of them and assessing their utility. Problems that arise in their adoption such as persistence, acceptability by animals and nutrient management need to be investigated. This information can then be used in the evaluation of new accessions and breeding lines.

In some cases new technology and new species will require promotion. In particular, this applies to the adoption of legume technology which is new to the majority of farmers in tropical America. But promotion will have negative effects if the technology does not hold up under farm conditions. These activities require effective interaction and communication between various groups. The TFP is a relatively small group and will not be effective in developing and delivering new technology without close collaboration with others. This is the rationale for networking and communication activities.

Project - Forage ecotypes with high feed quality

Purpose: To assess the quality and feed value of forage genetic resources for infertile acid soils in the humid and subhumid tropics.

We advocate that forages should have an acceptable feed value whether their primary purpose is for feeding or for some other use such as soil improvement. A demonstrated high feed value will assist in the adoption of legumes and grasses for fallow improvement and erosion control. The introduction of legumes, which we know will lead to more sustainable forage systems, will be facilitated if it can be demonstrated that they increase animal productivity. For example, some of our recent studies have shown that whereas introduction of legumes in a pasture gives a considerable increase in milk production using cattle with at least 50 percent of *Bos taurus* genes, this is not the case for local cattle with only *Bos indicus* genes.

The search for shrub legumes for acid soils has demonstrated the limitations of many adapted legumes due to antiquality factors, in particular tannins. An understanding of the role that tannins play in reducing digestibility but at the same protecting protein in the rumen will facilitate the development of screening procedures. Further, we know that tannins are often produced in relation to various stresses but little is known about the interaction of plant growth and tannin production due to environmental variation.

Both quality and antiquality factors in forage are strongly influenced by soil fertility and climate as well as plant genetics. It would be useful to know to what extent feed quality can be assessed by plant nutritional attributes and influenced by nutrient management.

Notable **achievements** have been:

Development of a screening procedure for tannins

- Improved understanding of how tannin structure affects their biological activity.

Forage ecotypes with improved quality

- New *Stylosanthes guianensis* lines in association with *B. dictyoneura* increase milk production in Friesan-cross cows from 5 to 8 liters per day.
- Identification of *Cratylia argentea* as a suitable fodder for sheep and dairy cattle.
- Identification of the shrub *Desmodium velutinum* as a high quality fodder.

Collaboration: New *Panicum maximum* and *Stylosanthes guianensis* lines are being assessed under grazing in collaboration with CORPOICA. The work on tannins is being carried out with advanced research laboratories in New Zealand (Massey Univ.) and England (NRI). There is planned collaboration with the Lowlands Program on the effects of tannins on litter decomposition.

The major **impact** in this project has been the progress made in defining the effect of tannins on intake and nitrogen utilization by ruminants. This research on the nature of antiquality factors in legumes is a **new component**.

Future strategy: In the research on antiquality factors, emphasis will be given to better defining the contribution of tannins and other phenolic compounds on depression of cell wall digestibility and to the formulation of legume mixtures to dilute tannins and increase rumen ammonia and nitrogen flow to the small intestine. The possibility of reducing tannins by blockage of the pathway for synthesis of tannin is being explored with CSIRO. The effect of environmental factors on the quality of *D. ovalifolium* will be investigated.

Project - Adaptive attributes of forages to acid soils

Purpose: To identify attributes that confer tolerance to infertile soils and contribute to efficient acquisition and utilization of nutrients.

Improved knowledge of such attributes will lead to development of more effective screening procedures in plant selection. Further, there is a need to identify plants that acquire and utilize nutrients efficiently and at the same time maintain an adequate level of mineral nutrients for animals. Improved knowledge on nutrient acquisition and utilization and intra-specific variation will assist in devising management strategies to overcome production constraints such as legume persistence and degradation. These adaptive attributes are associated with root development and function and influenced by plant exudates and microbial activity in the rhizosphere. Forages are among the most efficient plants at nutrient acquisition and knowledge of the processes involved will have a spin-off effect for other crops.

Notable **achievements** in this area have been:

Adaptive attributes of grasses and legumes

- It was shown that grasses and legumes adapt to low fertility acid soils by increasing the amount of dry matter partitioned to roots at the expense of shoot growth.
- The decrease in shoot growth is mainly due to a reduction in leaf expansion, the rate of net photosynthesis per unit leaf area being maintained.

Acquisition and utilization of nutrients

- Differences were shown between grasses and legumes in the efficiency of acquisition and utilization of nitrogen, phosphorus and calcium.
- It was shown that *Arachis pintoi* acquires more phosphorus than associated grasses, which could be a factor in its ability to persist in association with them.

Collaboration: The studies on nutrient acquisition are being conducted jointly with the University of Hohenheim, Germany. There is close collaboration with scientists in the

Beans and Rice Programs and the BRU on nutrient acquisition.
The major **impact** has been the progress made in identifying the root and shoot attributes of grasses and legumes that contribute to greater acquisition and efficient utilization of nutrients from low fertility soils.

Future strategy: Emphasis will be given to identifying ecotypic variation within species in the ability to acquire and utilize nutrients efficiently. These differences will be explored in relation to meeting the mineral nutrient requirement of ruminants.

Project - Forage components of known performance in production systems

Purpose: To develop and evaluate the productivity and environmental and socioeconomic impact of forage components for different production systems.

New forage germplasm does not become useful as such until it is developed as a component in a production system. The feed value of component associations needs to be assessed through some measure of animal production if they include new species. Likewise, the contribution of forages for sustainability needs to be evaluated by soil measurement and crop husbandry. Knowledge of the basis for success of grass-legume associations is a necessary precursor for selection procedures. Seed production technology and forage delivery systems must be developed to increase adoption of new forage species and cultivars. While many of these activities can and indeed are being undertaken by other Programs in CIAT and NARS, the TFP needs to maintain expertise and activity in these areas in order to initiate and foster such collaboration.

Notable **achievements** have been:

Stable grass-legume associations

- Early indications of good persistence by *Arachis pintoi* based pastures have been verified, and new information obtained on productivity.
- *Arachis pintoi-Brachiaria humidicola* and *B. dictyoneura* associations in the Llanos have remained productive for the full length of experimentation (5-6 years) and consistently produced liveweight gains of 160-200 kg/head and 450-600 kg/ha.
- An *A. pintoi-B. brizantha* association in the humid tropics of Costa Rica has produced an average liveweight gain of 960 kg/ha compared to 560 kg/ha from a pure *B. brizantha* pasture.
- An *A. pintoi-Cynodon nlemfuensis* pasture at Turrialba produced 10.8 liter/day of milk compared with 9.5 liter/day from a *C. nlemfuensis* pasture fertilized with 100 kg/ha N.
- The proportion of *Arachis* increases with heavy grazing suggesting that elaborate management practices are not required to maintain legume balance.
- It has been shown in the humid tropics of Peru, Ecuador and Colombia that *Desmodium ovalifolium* forms stable associations with grasses but evidence from Costa Rica indicates it is not as productive for dairy cattle as *A. pintoi*-based pastures.

Contribution of legume-based pastures to soil improvement

- It has been shown that there is an increase in available soil nitrogen, an accumulation of Ca and K in the surface soil layer, increased biological activity and increased sequestration of carbon compared to native pasture and crops.

Grass-legume associations for crop-livestock systems

- The legumes, *Stylosanthes capitata cv* Capica, *Centrosema acutifolium* cv Vichada and *Desmodium ovalifolium* CIAT 350, selected for long term pasture associations, have also proved to be suitable for under sowing with rice in pasture regeneration.

Forages for soil cover, green manure and erosion control

- *A. pintoi* has proved to be very suitable as a cover crop for plantations of oil palm, coffee, citrus and banana in humid regions.
- In coffee areas in Colombia it reduces the need for weed control after the first year and reduces the nitrogen fertilizer input by 50 percent.
- *Stylosanthes guianensis* CIAT 184 has proved to be well adapted to smallholder farming situations in Southeast Asia and in China.
- *Centrosema acutifolium*, also selected as a pasture legume, has been chosen over *A.pintoi*, *S. guianensis* and *D. ovalifolium* as a cover crop for palm plantations in Peru.

Seed supply systems

- Successful seed systems were developed for smallholder farmers in Bolivia and Peru.
- Rotating funds set up to initiate these schemes have now become self-sustaining.

Forages for smallholders in Southeast Asia

- within 3 years of commencement of operation in the region, farmers are now using germplasm selected by CIAT on their farms.

Collaboration: Most of the activities in this project involve collaboration with others including other CIAT Programs, NARS and farmers.

A major **impact** has been made in the development of stable and productive grass-legume pastures and the use of forage legumes for covers, in particular, using *A. pintoi*, *S. guianensis*, *S. capitata* and *C. acutifolium*. This would not have occurred without the concurrent development of seed systems for these species. The value of improved grass-legume pastures for soil improvement has been well documented.

The **components** of the previous TPP on pasture management and production systems are not being continued in the TFP. However, emphasis is still placed on evaluation of new forages to the stage of demonstrated acceptability by farmers. **New components** on the use of forages for fallow improvement soil covers and green manures, and shrub legumes for hillsides are being developed.

The major **constraint** is the lack of resources to implement research on pasture ecology and plant competition, and on seed biology and seed systems of potential cultivars.

Future strategy: Firstly, we will continue to develop linkages that will assist in financing and implementing the development of forage components for production systems in the savannas, forest margins and hillsides. Secondly, we will strive to ensure that new forage components are evaluated with other components in these farming systems with farmer participation in the research and development process.

Project - Institutional support and skill acquisition for delivery of forage systems

<u>**Purpose**</u>: To facilitate interaction with national organizations, develop effective channels for disseminating information and provide non-degree training.

The main means of achieving interaction with NARS has been through networks. In the RIEPT network in Latin America the NARS collaborators evaluated the germplasm using their own resources following the procedure suggested by the TPP and often after having received relevant training at CIAT. The network was largely CIAT-driven with input by the NARS through an advisory committee. Special project funding provided funds for coordination activities, training, conferences and 'seed' money to facilitate on-farm evaluation and development of seed systems. The network provided new technology to NARS and feedback and recognition to CIAT. It was most appreciated by countries with minimal resources but regarded as slightly paternalistic by those who were more self sufficient.

The activities of the RIEPT resulted in the rapid evaluation and adoption of new forage germplasm as evidenced by the number of cultivar releases in the 1980's. e.g. for *Andropogon gayanus*. There were large regional meetings which allowed ready exchange of information and experience. With the cessation of funding in 1992 there has been reduced visual activity of the network such as travel and meetings. However, the RIEPT has still continued to function through supply of germplasm and feedback of information for data analysis. Some 50 sets of germplasm have been supplied for regional trials since 1992.

To facilitate easier interaction, the RIEPT was nominally split into 4 units, MCAC (Mexico, Central America and the Caribbean), Llanos, Cerrados and the Humid Forest. Only the former has continued to function actively because there is an outposted agronomist who can respond to changes in the organization in the countries in the region and because these smaller countries are dependent on some form of support. At the time of the last RIEPT meeting in November 1992, there was a call for a change in the operation of the RIEPT, in particular, in the evaluation methodology.

Personnel and organizational changes have been so great in most countries in the last two years that there is little hope of revitalizing the network in the same format that it operated previously. Also it may not be desirable because the instability has resulted in NGO's taking the initiative for forage development in several countries. It has been suggested by CIAT that a new network should be built on the basis of representation of national networks. This practice is being followed in MCAC. Another suggestion is to attach the network to professional associations such as ALPA (Latin America) and PCCMCA (MCAC) which have regular meetings. PROCITROPICOS could serve as a network for the savannas. 'Pasturas Tropicales' could become a wider RIEPT medium for research articles and notes.

The activities suggested for the continuing operation of networks (CIAT, 1994) reflect the present reality. The other reality is that straight out funding for livestock related activities has become unfashionable. New networking will only be financed on the basis of forages contributing to sustainable agricultural systems.

Notable **achievements** have been:

RIEPT network

- A conference on research in the humid tropics was held in Peru in 1990.
- A conference on research in the Llanos and Cerrados was held in Brazil in 1992.
- A workshop on seed technology was held in Colombia in 1992.
- 190 individuals from 22 countries have been trained since 1989.

MCAC network

- Workshops were held on seed production in Costa Rica and Honduras.
- A workshop was held on-farm evaluation and project design in Panama in 1993.
- Regular newsletter production and distribution commenced in 1993.

Networks in South America

- Newsletter production and distribution commenced in 1993.

Network in Southeast Asia (in collaboration with CSIRO)

- A consultation meeting was held in the Philippines in 1989.
- Two regional meetings have been held since research activities began in 1992.
- 17 persons have received short-term training in forage evaluation & seed production.

Publications

- The TFP has continued to support the publication of Pasturas Tropicales which remains the only journal devoted to forage research that accepts articles in Spanish and Portuguese.

There have been major **impacts** in tropical America in the release of new cultivars, the review and publication of research activities in the humid forest and savanna regions and through the training workshops in seed production and on-farm evaluation. The **impacts** in Southeast Asia have been through the release to NARS of germplasm adapted to infertile soils and a recognition CIAT's strength in tropical forage research.

The major **constraint** is the availability of personnel to facilitate the formation and interaction of national networks which will form the basis for a revitalized RIEPT. The main **component** terminated has been the external funding for RIEPT. A **new component** established is the network activity in Southeast Asia.

Future strategy: The future strategy in networking will be to facilitate the formation of effective national networking. CIAT will continue to provide the forage genetic resources, the capability for training, a communication medium and leadership for facilitating the international networks built on a foundation of national collaboration.

Other issues

Interprogram activities.

There is close interaction with the Lowlands and Hillsides Programs and the BRU, GRU, VRU and GIS units in achieving the research objectives of the TFP and those other Programs. This has been mentioned in the above presentation of Project Activities. Such collaboration can be readily accommodated within the existing activities of the Projects. Another form of collaborative research is that involved in mapping the apomixis gene in *Brachiaria*. A successful outcome will have some direct benefits to the *Brachiaria* Project but far greater benefits for Center-wide crop improvement projects.

There is also opportunity for the Scientific Research Groups to initiate research across Programs, using the resources of scientists within these Programs, for activities that do not fit neatly into the present Project Objectives. An example would be research into the use of micro-organisms for bio-control. This might be initiated within the TFP because of the expertise available in the Program for such work but would involve and have benefits for several commodities.

Interaction with IARC's

IRRI. Currently, the TFP has a staff person located at IRRI, Philippines, who collaborates in the IRRI Upland Rice Systems Program in addition to SEAFRAD network activities.

ILRI. The TFP has had continuing input into the development of the strategic plan for ILRI. The strength of research on tropical forages in CIAT has been recognized but it is felt there is still a need for greater recognition within the Strategic Plan for ILRI of the research in the Lowlands and Hillsides Programs at CIAT on production systems and natural resource management and a higher resource allocation made for the area of feed resources research in Latin America. CIAT will maintain an independent Tropical Forages Program responsible to the CIAT board but with ILRI acting as a convener for (i) greater integration of forage research activities and (ii) allocation of resources for System-wide research through an Inter-Center Livestock Program Group. We have maintained that the Tropical Forages Program at CIAT should remain intact because:

(i) It is a strong multi-disciplinary forage genetic resources, improvement and utilization program that is well integrated with the other Programs and Units at CIAT. Research is supported by specialists in plant geography and biology, genetics, animal nutrition, forage agronomy, plant nutrition, pathology, entomology, virology and biotechnology.

(ii) It addresses the main limitation to livestock production on infertile soils in Latin America and other regions , namely, the lack of high quality feed.

(iii) Current strategy is an equal focus on the identification of forage materials for both natural resource management and livestock feed.

(iv) It has had a high success rate in terms of new cultivar release (8 grasses and 12 legumes released in 15 countries, including Asia) and in developing new forage components that have been adopted in animal (legume -grass pastures), crop-livestock (rice-pasture) and tree crop (covers and green manures) production systems.

(v) A global mandate for forage and pasture genetic resources is recognized by CGIAR (CGIAR, 1994. Challenging Hunger. The role of the CGIAR. CGIAR Secretariat)

Currently, discussions are focused on the operation of the proposed Systemwide Livestock Research Program which will be convened and co-ordinated by ILRI. CIAT has submitted several proposals to the interim committee, suggesting CIAT participation in ecoregional activities in Southeast Asia and West Africa, ILRI involvement in CIAT's ecoregional program in Latin America, a Center-wide seed systems initiative and a Forage Genetic Resources Network. CIAT will be represented on the Livestock Program Group which will convene and co-ordinate Systemwide Livestock Initiatives.

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TROPICAL LOWLANDS PROGRAM

EXECUTIVE SUMMARY

The Tropical Lowlands Program was inaugurated in late 1993 by merging the existing Savannas and Forest Margins Programs of CIAT's Division of Natural Resource Management. The overall goal of the new Program is to develop and adapt technologies for sustainable production systems for the acid-soil savannas and forest margins of tropical America while reducing the pressure for environmental degradation by maintaining or enhancing the quality of the natural resource base.

The strategies to achieve these goals revolve around three inter-related research areas:

- analysis of trends in land use patterns, leading to agro-ecological characterization of the savannas and forest margins,
- analysis within current patterns of land use to determine the production, resource conservation (degradation or enhancement) and socio-economic circumstances; these analyses are cross-sectional since some of the trends that occur over time are also simulated in space, and
- development of prototypes of sustainable agro-pastoral and agro-silvo-pastoral systems, based on an understanding of the bio-physical and socio-economic processes that affect resource management.

The areas chosen for specific research projects were selected after a thorough process beginning with the classification of the entire Latin American and Caribbean region and characterization of the farming systems in representative regions in close consultation with NARS and other national bodies concerned with land-use issues. Currently the Program is focusing its research activities in the Meta region of the Colombian llanos, the Uberlandia region of the Brazilian Cerrados and the Acre/Rondonia region of the Brazilian forest margins.

The Program has established two long-term experiments in the savannas of both Colombia and Brazil to investigate sustainable crop rotations and ley-farming systems. These efforts are complemented with on-farm trials on prototype systems or components of systems. In the forest margins the Program participates in the global project on alternatives to slash and burn agriculture (ASB) and supervises activities of this project in Latin America.

As part of the activities required to achieve sustainable agricultural development in the savannas and forest margins of tropical America, the Program has been active in developing collaboration with numerous national, regional and international research and development institutions that have similar interests. Two senior scientists, one soil scientist from the International Fertilizer Development Centre (IFDC) and an ecologist from the French Centre de Cooperation Internationale en Recherche Agronomique pour le Dévelopment (CIRAD), have been seconded to the program and other international links have been formed via the MAS (management of acid soils) consortium. The Program has also been interacting in the development of joint projects with NARS from Bolivia, Brazil, Colombia and Venezuela, IICA and PROCITROPICOS and is developing a network of reseachers in agro-pastoral systems.

In relation to CGIAR system-wide initiatives, in addition to participating in the ASB project, the Program's activities form a substantial part of the document submitted to TAC on the role of CIAT as the eco-regional convening centre for Latin America and the Caribbean. On the basis of the Program's strength in soil-plant studies, CIAT has been proposed to act as the convening centre for a CGIAR system-wide effort on soil, water and nutrient management.

At its inception in 1992, the Savanna Program consisted of four senior scientists and two post-doctoral fellows. In September, 1994, the Tropical Lowlands Program has nine senior scientists and three post-doctoral fellows. Over this period the group has published some 70 articles in refereed journals and books (52%) and conference proceedings.

INTRODUCTION

The goal of the Tropical Lowlands Program is to develop and adapt technologies for sustainable production systems for the acid-soil savannas and forest margins of tropical America, while maintaining or enhancing the quality of the natural resource base and so reducing environmental degradation.

Historical background

In August, 1992, CIAT created the Savannas Program incorporating activities from other CIAT Programs. In 1989, the Rice and the Tropical Pastures Programs together with the Colombian Agricultural Research Institute, ICA (now CFORPOICA), and the Colombian rice grower's association, FEDEARROZ, began a substantial research project in the Colombian Llanos to integrate experimental lines of upland rice and existing commercial cultivars of pasture grasses and legumes. The Savannas Program developed this rice-pasture project as a major activity to address the issue of sustainable agro-pastoral systems for the neo-tropical savannas. In December, 1993, it was merged with the Forest Margin Program to form the Tropical Lowlands Program. The goal of the new Program was to develop sustainable and productive agricultural systems for the acid-soil savannas and to reduce the pressure on tropical forests by developing ecologically and economically sou: i production systems for already deforested land of the forest margins.

Agro-ecosystem Program Strategy

The initial strategies for all CIAT's agro-ecosystems was to integrate options of land use and farming systems that help relieve market and social pressures on the most fragile environments. The programs had four general objectives:

- Characterization of the dynamics of land use and farming systems and their influence on the use of resources.
- Improve the production systems while at the same time preserving the natural resource base through strategic research.
- Further development and testing of prototype technologies.
- Enhancement of national research systems through training and research partnerships

Savanna Strategy

In 1991, CIAT created a Savannas Working Group, which, jointly with EMBRAPA's Center for Agricultural Research in the Cerrados (CPAC), characterized the Cerrados of

Brazil, which constitute 80% of the neo-tropical savannas. The study was based on existing secondary information, including data on farming systems, land use, and censuses. In 1991 and 1992, we initiated feasibility studies of the rice-pastures system using Delphi surveys and rapid rural appraisals in both the Cerrados and the Llanos. These are part of a continuing effort to evaluate the feasibility of the technological options generated by on-going research.

At the same time, CIAT contracted a Brazilian NGO, the Instituto Sociedade, População e Natureza, to conduct a socio-economic study of the Brazilian forest margins and savannas. All these activities, supplemented by analyses made by CIAT's economists, were key components that allowed the Savanna Working Group to formulate the Program's research strategies and to select the study areas where its activities are and will be concentrated.

Forest Margin Strategy
Implementation of the Forest Margin Program was delayed as a result of staff recruiting problems. Currently one senior staff is outposted to the Acre/ Rondonia region of Brazil where he forms part of the global slash and burn project overseen by the International Centre for Research on Agro-forestry (ICRAF). The objective of this project is to develop alternative sustainable agriculture for slash and burn farmers, while recuperating existing degraded land and thereby relieving pressure for further deforestation.
The main strategies are:

- Characterization and diagnosis of the target ecosystem, of the various resource users and of the policy environments in each area,
- Investigation of potentials to recuperate degraded pastures and hence reduce the pressure for further deforestation, via selected forage germplasm, appropriate management and multiple purpose trees,
- Testing of improved annual crop germplasm of rice, beans, maize and cassava and investigation of potentials to improve management and use of existing forests. The approaches include analysis of land use patterns over time and space, policies and on-farm decision making to understand causal factors of deforestation, bio-physical research to identify and evaluate alternatives to slash and burn, research on social and economic potentials for adoption of such alternatives and collaboration with partners on the application of farmer-participatory research methods to ensure technology adaptation and adoption.

CIAT is active in all project avtivities. Site characterization is being done by EMBRAPA, CIAT, IFPRI and ICRAF at Theobroma in Rondonia and Pedro Peixoto in Acre. An interview questionnaire was recently developed, tested, modified and administered at both sites. The outposted CIAT agronomist is evaluating germplasm of annual food crops and forages tolerant to acid-soils with EMBRAPA. ICRAF and CIAT are evaluating potential agroforestry-based permanent cropping systems and improved fallows.

Implementation of the Tropical Lowlands Program Strategies
The Savannas Program's strategies to achieve its goals were set out in April, 1993, in a document entitled "Making Resource Management Plans Operational: The CIAT Savanna Program". Presented in some detail, these remain relevant to the new Program, although they will remain dynamic and will evolve as the understanding of the savanna and forest margin eco-systems increases. At present the strategies revolve around three inter-related research areas:

- analysis of trends in land-use patterns, leading to agro-ecological characterization of the savannas and forest margins;
- analysis within current patterns of land use to determine the production, resource conservation (degradation or enhancement) and socio-economic circumstances; these analyses are cross-sectional since some of the trends that occur over time are also simulated in space;
- development of prototypes of sustainable agro-pastoral and agro-silvo-pastoral systems, based on an understanding of the bio-physical and socio-economic processes that affect resource management.

These research areas are essentially similar for both the savannas and forest margins. However progress in the forest margins lags behind that of the savannas for the reasons mentioned above.

Major clients and regional impacts
Over 70% of the population in Latin America is urban and poverty is higher in the cities than in the rural sector. The Program's research in savannas will result in increased production of staple urban foods such as maize, rice, beef and milk at reduced costs. The program's clients are savanna farmers and settled migrants in the forest margins. Socio-economic studies will be aimed at policy makers for these agro-ecosystems.

The development and adoption of improved technologies will not only increase food production from the savanna areas and offer viable alternatives to farmers in the forest margins but should also alleviate the threat of further environmental degradation including deforestation.

HISTORICAL ASSESSMENT OF RESEARCH ACTIVITIES

The activities of the program are presented under four major research themes:
- Ecosystem and agroecosystem characterization and dynamics,
- Farming system characterization and participatory research,
- Strategic agricultural production system research, and
- Institutional relations and collaborative research projects.

Ecosystem and agroecosystem characterization and dynamics (Projects TC03, TL03, TA51)

CIAT took a geographic information system (GIS) approach to identify problems and opportunities in natural resource management in the early 1990's. In stage 1, all of Latin America and the Caribbean were mapped in broad environmental classes then in stage 2 a short list of classes was chosen followed by the systematic description of actual land use (Stage 3) and finally clustering of areas with similar environments and land use patterns and their problems that were relevant to CIAT's current and future research (Stage 4). These analyses resulted in the selection of the hillsides, savannas and forest margin areas as targets for CIAT's Natural Resource Management Division. Further details of these events will be published in the report of the Land Use Program (LUP) hereunder.

Savannas
CIAT's LUP led a study of the agro-ecological characterization of the Cerrados of Brazil and part of the Llanos of Colombia. In the Cerrados, the studies were based on

secondary information, which was introduced into a GIS database and was completed by the LUP in July 1992. In a follow-up workshop with various EMBRAPA Centers in September, 1992, priorities were assigned to 12 candidate areas based on their representativeness, intensity of land use, perceived demand for technology and relative strength of local institutions. Four of those areas (Uberlândia, in Minas Gerais state; Rio Verde, in Goiás; Campo Grande, in Mato Grosso do Sul, and Rondonópolis, in Mato Grosso) were given high priority.

The Savannas Program, in collaboration with Brazilian scientists, undertook the responsibility of performing rapid rural appraisals (RRA). The aim was to verify the findings of the initial characterization, to determine with more precision the characteristics of the main farming systems and to identify problems and opportunities in the area of resource management. The RRA's were complemented with additional secondary information and were subsequently analysed by the RRA team. The process concluded in late 1993 with the selection of Uberlandia as the main area of interest for the program. This area has three of the 18 land classes identified for the Cerrados within a 60 km radius. Currently, research priorities for joint projects are being implemented and developed with EMBRAPA and the University of Uberlandia.

A similar initiative was undertaken in 1993 for a sample of the Llanos of Colombia, in the area of influence of Puerto López. Here traditional cattle ranching is in a dynamic process of change to mechanized agriculture under the influence of economic factors ant the rice-pastures technology. As in Brazil, the use, analysis and interpretation of secondary information is led by the LUP, in cooperation with the Colombian National Geographic Institue (IGAC). The next step is the incorporation of additional data based on socio-economic, farming systems and soils surveys, which have been collected over time by the previous Tropical Pastures Program and more recently by the Rice and the Savannas Programs. Preliminary contacts were established with several Venezuelan institutions interested in a similar study for the Llanos of that country.

Forest margins
The LUP conducted a large-scale characterization of the Brazilian Amazon in 1992. The study was part of CIAT's efforts to define the environmental classes in tropical America and included factors such as length of growing season, temperature, rainfall, soil acidity and additionally selected social variables, accessibility and legally protected areas. The analysis defined forest margins as "those areas that are tropical, lowland, seasonally wet with acid soils where the land use is some combination of slash and burn agriculture with extensive cattle grazing".

Farming systems characterization, dynamics and participatory research

(Projects TC01, TC03, TL01, TL03, TA01,TA51)

Savannas
Existing farming and ranching systems in the savannas offer many opportunities to assess the implications of alternative, and highly contrasting management practices on the evolution of natural resources and on agricultural productivity. We hypothesize that some of the temporal trends in the condition of these resources is replicated over space, such that cross-sectional studies could, within the limits imposed by varying policy scenarios, provide estimates of temporal trends.

Cross-sectional studies have been started at a modest scale in the Colombian Llanos and Uberlândia, one of the high priority areas of the Cerrados. More comprehensive studies will require additional resources.

The rapid rural appraisals in the Cerrados led to the identification of a small number of farms in the Uberlândia area with sharply contrasting management, particularly in the use of inputs. There are also large differences in agricultural productivity, soil quality and economic performance, amongst others. One of these farms, on very fragile, sandy soils, has records of inputs and outputs going back 10 years. During this time the farm was transformed from a traditional, extensive cattle ranch to a management-intensive agro-pastoral system with regular, planned rotation of crops with pastures.

Preliminary analyses shows that soybean yields increased when planted after pastures and that the older the pasture, the higher the yield. Moreover, about half the farm is now sown to crops each year, but, because pastures planted after 3-4 years of crops are more productive, it now carries more cattle than the whole farm did before. Soil parameters are being monitored in fixed sites. The data show that the size of the soil aggregates declines under crops, but that the soil physical properties and organic matter content recover during the pasture phase of the rotation.

Brazilian researchers estimate that about half of the 78 million ha of sown pastures on the Cerrados suffer some degree of degradation. We hypothesize that this large area of degraded pasture, almost invariably all without a legume, provides a unique opportunity to introduce crops and renovate the pastures at the same time. The areas where these pastures are found are already heavily exploited, so that increasing pasture productivity will help prevent exploitation of the remaining areas of native vegetation.

Several exploratory and participatory trials have been established in Uberlândia on farms with contrasting soils and systems with differing fertilizer inputs. Results so far indicate that the vigorous regrowth of pasture grasses in a low input system severely reduced rice yields. But legumes, particularly *Stylosanthes guianensis* cv. Mineirao, established well in all soils. In contrast, in the high input system both corn yields (7 t/ha) and grass establishment were excellent, but here the legumes suffered badly from competition. These results have important implications in terms of compatibility of crop and pasture germplasm, which are being taken up with colleagues in the germplasm programs.

A similar strategy is being followed in the Colombian Llanos, where we are undertaking monitoring and on-farm participatory research activities on a smaller scale, again in contrasting farming systems. These studies are also supported by socio-economic characterization based on regular surveys and monitoring of whole farm inputs and outputs.

In contrast to the Cerrados, pastures in the Colombian Llanos at present are more important than crops, particularly in those areas where soil and topographic constraints limit their potential for cropping. We are therefore concentrating in the Llanos on the potential contribution of forages to increase farm productivity and to prevent degradation. On seven contrasting farms and ranches that vary widely in resource endowment and management intensity, we are monitoring material input/output ratios. We have also selected fields in contrasting systems of land use, and are monitoring soil chemical, physical and biological parameters, biomass productivity and, where applicable, animal productivity.

Native pastures cover about 90% of the llanos of Colombia, 78 % of the llanos of Venezuela and 50-60 % of the Cerrados of Brazil. It is implicit that as land use in the savannas intensifies, the native savanna will come under increasing pressure. We are therefore complementing the studies based on introduced crops and forage species on the Colombian Llanos with studies of the dynamics of native vegetation in response to system intensification. These studies are conducted at several complementary scales of aggregation, in both flat and undulating lands.

An inventory and classification of the vegetation using satellite images of differing spectral frequencies has been undertaken in collaboration with IGAC, Bogotá, and the Ecole Nationale Agronomique of Paris-Grignon. The classifications are verified (ground truth) in field studies at Carimagua, and the extent to which trends in plant dynamics and soil cover can be detected by satellite images is being assessed.

In a census of native vegetation, conducted in collaboration with the National University of Colombia, Palmira, 150 species (108 genera of 45 families) were identified. These were classified into the main.vegetation groups in the well-drained, flat savannas using statistical clustering techniques, and were related to physiographic features of the land. Two keys were prepared for the identification of the main savanna grasses, one based on vegetative characters and another on floral characters.

If native pastures are mismanaged by overgrazing or injudicious burning, their species composition changes and they are said to degrade. To understand how degradation as a process is related to trends in population dynamics, a long-term experiment on time and frequency of burning and grazing intensity on native savanna is being carried out at Carimagua. The timing of burning exerts a powerful influence on the productivity and the dynamics of botanical composition of the pastures. Dutch students are assisting with preliminary studies of the vegetation in the undulating Serranía savannas to relate the species composition to management practices and soil type. This work, together with studies in designed experiments, have shown that there are important botanical compositional and production differences in the native savanna related to natural soil fertility in the flat lands and to the topography in the undulating Serranía lands.

A student from the University of Paris conducted a preliminary survey of soil macro-fauna under native pastures compared with gallery forest, improved pasture and several crops. Compared with the gallery forest, the savanna had lower diversity and numbers of macro-fauna. An old *Brachiaria decumbens*/Kudzu pasture maintained the diversity and dramatically increased the populations of earthworms. In contrast, crops of rice, and especially cassava, almost eliminated macro-fauna.

Forest margins

The sites selected in the settlement migration areas of the forest margins of Brazil are Pedro Peixoto, Acre, and Theobroma, Rondonia. They are being characterized as part of the alternatives to slash and burn project (ASB). Soils are mainly acid infertile oxisols with some ultisols and are generally shallow. Farm size is 40-200 ha with little or no mechanization or use of chemical fertilizers and lime. The region has a 3 month dry season and about 2000mm annual rainfall. Cultural practices are limited mainly to hand weeding.

Settlers come from either the north of Brazil and have little experience of agriculture, or from the south and are better educated and have more experience. Most have moved at least once since they arrived in the region. Farmers organizations exist but are poorly supported. In the Rio Branco-Acre area, basic food crops such as rice, beans, maize and cassava are grown mainly for family consumption using genotypes passed from neighbor to neighbor. Constraints to production include lack of resistance to diseases, low soil fertility and soil compaction.

In Pedro Peixoto there are more cattle and some surplus milk is produced. Pastures tend to be overgrazed resulting in compaction, soil erosion and weed infestation. Technology is urgently needed to recuperate these pastures; but technologies such as the "Sistema Barreirão" are not feasible due to lack of capital, machinery and inputs. Some agro-forestry exists in home gardens using fruit trees such as mango, banana, jackfruit, pineapple and oranges. Extractive activity in the forest, including timber and rubber, is declining as an economic enterprise.

The land use pattern in Pedro Peixoto is complex and includes clearing of primary forest followed by 1-3 years of annual crops, cassava and then fallow for several years or conversion to pasture. Some annual cropping is followed by conversion into perennial plantations of rubber, coffee, cocoa. The challenge is to develop alternative sustainable production systems.

Livestock and deforestation
Cattle ranching is one of the major contributors to deforestation in Amazonia, where overgrazing is more attractive than maintaining the productivity of land already under pasture. An objective is to analyze the role of livestock in the process of deforestation, and define the niches and potential contribution of livestock in humid forest margins. A solution is to develop new technologies including new species and intensified pasture management to increase pasture persistence. A socio-economic analysis, based on a conceptual framework of the causal interlinkages at contrasting levels of aggregation, will be used to characterize land management and pasture technologies needed to reduce deforestation and to identify the policy changes required. This work involves collaborators in EMBRAPA, IICA and the Global Slash and Burn Project. Rockefeller Foundation has been asked to provide a Post Doctoral Fellow.

Strategic agricultural production system research
(Projects TC01, TC02, TC51, TL01, TL02,TA01, TA51)

The savannas of South America are considered by many to be the last agricultural frontier. The ecosystem has been used traditionally for extensive grazing on native grassland species where the only form of management was fire. This type of agriculture has gradually given way to increasingly more intensive systems during the past thirty years especially in the Brazilian Cerrados where native grasses were first replaced with improved exotic grasses and then by crops, usually grown in monocultures with high inputs and the use of heavy machinery. This transition is now beginning to take place on the Colombian Llanos.

The Brazilian experience has shown that monocropping with high inputs cannot be sustained due to the deterioration of soil physical properties with consequent increases in erosion, weeds and pests. Alternative systems that lessen or reverse the deleterious effects of monocultures are required to make the productive potential of the savannas truly sustainable. Among these alternatives are the agro-pastoral systems developed at CIAT and EMBRAPA during the last five years. In these systems, pastures are established in association with rice or maize, the produce of which helps to defray the cost of inputs necessary to realize the full potential of improved forage germplasm. Grain legumes, green manures and inter-crops are other possible components, which could increase the stability of systems involving annual crops.

To determine the impact of these alternative systems on the long-term use of the soil resource, the Tropical Lowlands Program has established long-term experiments on the Colombian Llanos and the Brazilian Cerrados to quantify the soil and soil/plant processes associated with changes in primary biomass productivity in typical systems. It was recognized in establishing these experiments that the deleterious (or beneficial) effects of various agricultural practices are often subtle and only manifest themselves over long periods of time. This undertaking therefore requires a commitment of resources, both material and human, which are often only available at the level of an international agriculture research center.

"Culti-Core": A long-term experiment to investigate sustainable crop rotation and ley farming systems for the Llanos

The "Culti-Core" experiment was established at the CORPOICA/CIAT Research Station at Carimagua on the Colombian Llanos in 1993 to study the bio-physical and agronomic processes contributing to sustainability, or lack of it, in a spectrum of alternative production systems based on component tolerance to soil acidity. The experiment includes "fertilizer lime" systems (lime applied at low rates solely as a source of calcium and magnesium) based on Al-tolerant, upland rice grown in continuous monoculture or in rotations with green manures, cowpeas or adapted mixed pastures, and "remedial lime" systems (lime applied to reduce levels of soluble Al in soil) based on maize in continuous monoculture or in rotations with green manures, soybeans or less-adapted but better quality mixed pastures. All systems are managed to optimize production and minimize soil degradation by conserving crop residues, maintaining soil fertility, controlling weeds and other pests. The plots are large enough to be grazed in the case of pastures, and to permit the use of conventional machinery, which could influence soil physical and biological properties.

"Culti-Core" is a multi-disciplinary project involving several institutions whose expertise complements the germplasm, crop physiology, nutrition, root dynamics and systems expertise in provided by CIAT. A major factor in the initial success of the project has been the active participation of CORPOICA, which, in addition to sharing responsibility for infrastructural and logistical support with CIAT, has assumed responsibility for crop agronomy, management and the monitoring of soil physical properties. Furthermore, acid-soil tolerant soybean germplasm developed by CORPOICA is being used in the remedial lime systems in rotation with the acid-soil tolerant maize of CIMMYT. Issues of crop nutrient requirements, soil fertility, nutrient cycling and management are being addressed by IFDC. Additional support from IFDC will be provided in the use and adaptation of existing crop simulation models developed under the IBSNAT umbrella. The CIRAD ecologist is monitoring the weed dynamics, and soil biologists from the Universidad de Complutense (Spain) and ORSTOM (France), through a graduate student project, are monitoring soil macrofaunal dynamics as influenced by systems and soil management.

Understanding the many processes that contribute to and interact with each other in determining the stability of any particular system will enable more confident extrapolation of results to other agroecosytems. Consequently, the dynamics of soil chemical, physical and biological processes are being studied in the Culti-core experiment as well as several related satellite experiments designed to provide more detailed insight. These data will allow the Program to adapt, develop and validate integrated computer models that simulate the effects of system components and management on system sustainability. A modelling approach is considered by the group to be the principal vehicle for extrapolation with which it should be possible to simulate and test the long-term effects of different system configurations and management practices in a wider range of environments without the necessity for costly repetition of similar experiments.

"CPAC" Experiment: Integrated annual crop-pasture systems and the efficient use of natural resources and inputs

This long-term experiment on crop-pastures was established in 1990 with the collaboration of EMBRAPA-CPAC (see the Tropical Forages Program Report 1987-1991, Vol 2, pp. 15-16).

Crop performance

After three consecutive cropping seasons, results are showing that soil fertility management, rather than land preparation, is the major factor influencing crop performance. Corn grain yields and above ground biomass produced this year were significatively higher in the corrective fertilizer treatment. Furthermore, enhanced crop growth diminished weed competition, which probably affected corn yields and growth observed in the maintenance fertilizer strategy (low fertility treatment). Weeds like *Pennisetum pedicellatum* and *Acantospermum austrule*, commonly found in annual cropping systems, were the dominant species in this treatment.

The effect of land preparation on soil physical properties and root growth was assessed by opening several root profiles in the corn, pasture and native cerrado treatments. Penetrometer readings and soil bulk density measurements were made at several depths in each profile. Mechanical resistance increased with depth in both land preparation treatments (disking and plowing) in the corn plots. However, it was lower in the 0-25 soil layer of the flexible preparation method (plowing), due to the deeper soil preparation. There were more roots in the 7.5-25 cm soil depth in the maintenance fertilization treatment, and in response to fertilizer in the corrective fertilizer treatment in both methods of land preparation. These results suggest that soil fertility constraints in the sub-soil, relieved by application of gypsum, influence root development of crops rather than soil physical limitations .

Pasture and animal productivity

The superior animal performance of the grass-legume association, observed during the first year of grazing, continued during the second year. This was due to the significant contribution of *Stylosanthes mineirao* to the total available forage biomass and to the nitrogen supply to the grass via litter decomposition. This was reflected in increased N concentration in tissue of *Andropogon gayanus* in the grass-legume pasture compared to the grass-only pasture (1.59 ± 0.2 vs 1.13 ± 0.01). Maintenance fertilizer and increasing grazing intensities had greater effects on botanical composition of the pastures but had lesser effects on animal gains.

After the last dry season there has been a drastic reduction of legume content in the pasture. A preliminary evaluation showed a 50% mortality of the plants in the high grazing intensity (10% higher than that recorded in the low grazing intensity treatment). Affected plants showed evidences of mechanical damage cause by animal trampling.

Mechanical resistance under pastures was higher in the top soil of the pasture systems compared to the cropping systems and the native cerrado. However, absolute values are still not limiting root growth according to previous work conducted at CPAC. There were more *A. gayanus* roots in the 0-65 cm layer than in either the Cerrados and the continuous cropping systems.

Mycorrhizal activity.

Native populations of VAM fungi of the genera *Gigaspora, Scutellospora, Acaulospora* and *Glomus*, is low (12 spores/50 g) in the native Cerrado. After two years, the pasture and cropping management systems have increased mycorrhizal population and activity. During pasture establishment in the first year spore numbers in the 0-20 cm soil depth of the pastures increased 25-fold compared to the cerrado, although it declined in the second year. Root colonization followed similar trends. Cropping with soybeans increased populations three-fold during the first year and increased to reach similar levels as the improved pastures in the second year. The differences are probably associated with differences in root morphology and dynamics of mycorrhizal dependency.

Off-site environmental and social impact of intensification in the savannas

Intensification in the savanna while making a major contribution to agricultural production, has resulted in negative off-site effects, such as destruction of gallery forests, siltation and pollution of rivers, large reductions in rural populations and loss of genetic diversity. External benefits are the ability of improved pastures to act as a carbon sink (see page 19), and that the savanna could divert pressure from primary forests.

The problem is to devise policy, institutional or technological mechanisms that induce farmers to adopt practices that reduce negative external effects, while minimizing the impact on efficiency and growth. Farmers are unlikely to support research on externalities, since the benefits accrue off-farm. There is thus a clear need for public sector research to provide these analyses for policy makers in the region. The focus will be on market-based solutions that minimize the need for external enforcement, emphasis on the link between technology and externalities, and the provision of tools to policy makers for managing externalities.

Nutrient use efficiency, requirements and cycling in component crops

Lime-potassium-magnesium balance.

Complementing the Culti-core systems trial on the Llanos are a number of satellite experiments designed to assess more accurately the nutrient requirements of component crops, and to estimate nutrient losses and use efficiency under alternative management strategies. The Oxisols and Ultisols of the savannas are not conducive to the efficient use of nutrient inputs. Their low ability to retain nutrient cations (Ca, Mg and K) together with high acidity and soluble aluminum implies that fertilizer applications need to be carefully balanced to avoid nutrient deficiencies, inefficient use of inputs and losses through leaching. Experiments are therefore being conducted to determine the optimal balance of lime, Mg and K for the component crops, to study the dynamics of applied cations and soil acidity, and the interaction of amendments on nutrient fluxes, fate and residual value. These experiments will continue for at least four years to provide both basic data with respect to nutrient requirements in the Culti-core component crops, but also to quantify residual effects and nutrient losses.

Phosphorus residual value.

Savanna soils also possess mineralogical properties that cause high P-fixation capacity.

However, fixed P is often available, if more slowly, and may have substantial residual value. Furthermore, systems that direct P inputs into pools that are protected from fixation would help improve use efficiency of P fertilizer. But development of such systems requires knowledge of the processes that affect both the residual value of previous P fertilizer applications and its rate of movement between P pools in the soil. Experiments have been established on the Llanos,

- to determine the optimal levels of soluble phosphate fertilizer for the component Culti-core crops,
- to characterize the fate of P applications (uptake by crop, removal in products, immobilization in organic matter, reversion to less soluble inorganic phases), and
- to determine the residual value of phosphate applications. These four-year experiments are designed to allow comparisons between P of different ages in the soil and enable the parameterization of a time-dependent model of residual P.

Dynamic phosphorus pools.
Organic P pools in soils represent important pathways of P cycling in soil-plant systems and their manipulation to improve P-use efficiency could play an important role in the sustainability of production systems on savanna soils. Manipulation at the system level could occur through appropriate management of crop residues and the inclusion of green manures, covers, intercrops or leys, as hypothesized in the Culti-core project. Investigations by a Swiss-financed PDF of the effects of improved pastures on P dynamics in savanna Oxisols compare soils under long-term pasture experiments with native savanna soils at Carimagua, and improved pastures sown under rice with mono-cropped rice soils at Matazul Farm. Measurements include estimation of microbial P and determination of various inorganic and organic P pools using methods developed at the University of Saskatchewan (Canada).

Results show the importance of the microbial P pool in P cycling and availability especially in grass-legume pastures, which appear more efficient at cycling P through labile P pools compared to grass-only pastures, native savanna or rice monocultures. This work will be extended to the Culti-core experiment to determine whether short-term rotations with grain legumes and green manures have similar effects to the pastures. Sequential P fractionation data such as these form the basis of the P sub-model in the CENTURY soil organic matter model developed to simulate the dynamics of C, N, P and S in temperate grassland soils. Preliminary evidence from these studies indicates that critical C:P ratios which determine the partitioning and rates of P fluxes to different soil P pools may require modification for tropical soils. Modification and application of CENTURY (and other simulation models) will be to assess the net effects of different interacting processes on resource sustainability.

On-farm studies on rice-pastures
The history of this project in the llanos of Colombia was briefly mentioned in the introduction. A range of contrasting systems and practices were investigated in long-term experiments: continuous rice mono-crop, pasture associations sown under rice both for pasture establishment and for recuperation of degraded pastures, crop rotations, planting, fertilizer and methods of land preparation. Rice could be undersown with pastures without reducing rice yields, and pasture establishment was faster than using traditional methods. The pastures were higher quality because of the residual effects of the fertilizer applied to the rice and gave higher cattle weight gains.

The findings have valuable implications from the point of view of both preservation of the soil resource and economic viability. Farmers could produce good rice crops, avoid continuous cropping, establish good quality pastures at minimum cost, and economically recuperate degraded pastures before environmental damage takes place.

Since then the Program has concentrated more on strategic research, not only on rice-pastures but also on other crops such as maize, soybeans, sorghum, and new pastures (grasses and legumes) that have been released for the acid savanna soils. These activities are in Colombia and Brazil and are starting in Venezuela and Bolivia, both on research stations and on farmers' fields with the farmers' participation. Cross sectional studies on farmers' lands are being carried out across representative parts of the selected study areas.

Research in farms of the Meta region of Colombia
Experimental sites were chosen as representative of the land system characterized by well-drained lands with slopes of less than 8%, and haplustox soils of intermediate to heavy textures. This area covers 424,000 ha of the llanos which mostly have good roads and it is where intensification of farming is starting to take place.

Continuous cropping is the traditional practice by farmers on oxisols of the savannas, and it has sometimes had devastating consequences eg. soybeans in some areas of the Brazilian Cerrados. The initial hypothesis was that yields decline in continuous cropping on Oxisols, and the soil degrades.

At Matazul Farm from 1989 to 1992 there was a linear decline in rice yield of nearly 400 kg/ha/yr (r^2=0.96), from 3.8 to 2.6 t/ha, despite fertilizer inputs being adjusted yearly to maintain appropriate nutrient levels and balances. In 1993, the experiment was modified to test whether better agronomy could counteract the declining yields. There was an improvement of about 800 kg/ha, but not to the original levels. There has also been a significant decrease of the aggregate stability despite using minimum tillage practices. The soil is chemically much improved by the application of fertilizer, so that yield losses appear to be more related to weeds and perhaps to deteriorating soil physical properties. From 1994, herbicides were included to try to increase yields further, while still maintaining the soil chemical balance. This work will continue for several more years.

In contrast, also from 1989 in Matazul farm, a long-term, large (9 ha) rice-grass/legume pasture experiment was establshed as a prototype agro-pastoral system. Rice yields averaged 2 t/ha, were the same with or without the pasture and gave excellent pasture establishment. Liveweight gains of the cattle grazing the pastures were high in the first two years (630-700 g/animal/day, 1.75 animal units/ha), but when in 1992 the legumes had almost disappeared, gains declined to levels typical of traditionally established pastures. In 1993 the 1 ha plots were split between continued grazing and recuperation by planting rice and legumes. Rice yields were 3 to 4 t/ha and excellent grass-legume pastures were obtained, which are again being grazed.

Fertilizer was applied only with the rice crops in 1989 and in 1993 whereas it was applied each year to the continuous rice. By the end of 1992, soil nutrient levels in the rice-pasture treatments had fallen to the same as the original native savanna. Soil physical properties, such as aggregate stability, remained almost unchanged in contrast to the continuous cropping experiments.

The above two experiments are part of a group of short- and long-term trials covering a range of systems and some other strategic issues of agro-pastoral systems research for savannas. They were chosen here to illustrate both the contrast between a traditional and a new production system and some of their implications in the longer term.

Adoption of the crop-pasture technology

Under ideal management conditions the crop-pasture technology increases economic returns, reverses soil degradation and acts as a carbon sink (see later in this report). Its adoption is being analyzed to understand how the process works in different socio-economic environments, and to identify an appropriate niche for the technology within an overall strategy for sustainable development of the savanna. In Meta, Colombia, the area sown to improved pastures has increased by 14% annually between 1979 and 1992. At present 17% of the area of sample farms is planted to improved pasture, of which only 18% includes legumes, while 1.5% is planted to the rice-pasture technology. There are major differences between farmers' practices and those recommended by the technology developers.

The area sown to improved pasture is positively associated with highly capitalized farms, with secure tenure and proximity to markets, but absentee ownership did not impede adoption. Cash flow of the rice-pasture technology was no better than that of improved pastures or mono-cropped rice, so that a key advantage of the technology is being eroded under current economic conditions in Colombia. As infrastructure improves, native pasture is likely to be increasingly replaced by improved pasture. However the technology as practiced on-farm is very different from the concept technology developers had in mind. The ecological implications of this, requires modifications in the technology, and alternative technological options with greater adoptive potential will be explored.

Cerrados of Brazil

Characterization work conducted by CIAT and EMBRAPA during the last two years indicated the urgent need to halt or revert trends in soil degradation and declining soil productivity of the current production systems in the Cerrados. Among available technologies, the combination of crops and pastures in space and time (agro-pastoralism) is one of the best options. This technology can not only increase overall productivity and enhance soil fertility but also may contribute to improve socio-economic conditions of farmers.

The National Center for research on Rice and Beans (EMBRAPA-CNPAF) has demonstrated the value of rice-pasture systems for the reclamation of degraded pastures in its "sistema Barreirão". Further crop options are also being tested such as maize, sorghum and soybean. The Tropical Lowlands Program in cooperation with CIAT's forage program and the University of Uberlandia, is testing the feasibility of introducing other forage grasses and legumes into these crop-pasture systems. Of the 19 grasses and 21 legumes "best bets" with some tolerance to the dry season include the grass *Brachiaria decumbens* BRA4308 and the legumes *Arachis pintoi* and *Stylosanthes mineirao*. Legume compatibility studies with grasses and crops indicate that grasses are more competitive with the legumes than crops and that *Stylosanthes* and *Arachis* establish well with *Paspalum spp.* and *Brachiaria brizantha*. At the University of Uberlandia one ha plots of *Stylosanthes mineirao* and *Arachis pitnoi* have been established in order to provide seed for large scale testing in the future. Further seed production plots of *Paspalum atrattum* 9610 and *S. mineirao* will be harvested this year from two farms.

Dynamics of farming and regional systems in theBrazilian savanna
Continuing development of the Brazilian savannas (Cerrados) can reduce pressure on the Amazon rain-forest by absorbing capital and providing employment. However, many current production systems degrade the environment, so there is a need for ecologically sound technologies to replace them. Because the new technologies must also be economically viable, they must be developed within a comprehensive strategy based on sound socio-economic research.

The nature and extent of trade-offs among conflicting uses of resources in three sites at contrasting stages of development in the Cerrados is proposed using multiple objective programming. Analysis of secondary information identifies the forces that drive socio-economic processes to develop strategies both to prevent and to reverse resource degradation. Data at the farm level will be linked to the watershed and regional level for extrapolation to the whole Cerrados.

Strategic studies on nitrogen fixation and recycling
Nitrogen is one of the most limiting nutrients for agricultural production in tropical acid soils and Latin America is the center of origin of many legumes especially forage legumes. CIAT has been active in the collection of both legumes and rhizobium genotypes since the mid 1970s. The CIAT collection of over 4000 Rhizobium spp. remains within the Tropical Lowlands Program and inoculants and ampoules are routinely prepared and sent out to research institutes throughout the region. In total over 100 requests are serviced per annum. When required rhizobium strains are collected for new legumes with promising potential such as *Arachis pintoi* in cooperation with the Tropical Forages Program.

There remains a need however to develop appropriate technologies to exploit biological nitrogen fixation via a thorough understanding of the fixation process and the transfer of fixed N from legumes to crop and animal products. An examination of the N cycle in tropical pastures revealed that under relatively lax grazing the majority of N recycling occurs via plant litter rather than animal excreta. Therefore a major research effort was initiated to characterize and quantify litter production and decomposition in pastures, followed by decomposition of crop residues in crop-pasture systems. Large differences in rates of decomposition and nutrient release patterns were observed between six forage legumes and four grass species with some legumes decomposing at rates up to twice as fast as grasses. Others decomposed at similar rates to grasses but release of nutrients was greater owing to a greater initial concentration of nutrients in legume litter compared with the grasses. The lignin:N ratio was the best compositional indicator of decomposition rate. Neither litter particle size nor ease of access of macrofauna had major effects on the rate of litter decomposition. There was no synergistic or inhibitory effects of mixing litters of different qualities, such as a grass and legume. Decomposition data were successfully fitted to the CENTURY model currently the data are being tested in more recent versions of the model.

In the long-term "Core" grazing trial in collaboration with the Tropical Forages program at Carimagua, litter production has been monitored in stocking rate, establishment fertility and soil type treatments. In general there was little effect of stocking rate on litter production on either soil type. Higher establishment fertility, however, increased litter production with increasing plant biomass. Litter production over the 3 years ranged from 1.1 to 5.2 kg DM/ha/year. Nutrient contents in the litter were low, especially after the disappearance of the legume component during the first two years of the experiment.

The recycling of N via animal excreta is also being studied. Preliminary experiments with ^{15}N-labeled urine suggest a recovery of about 10% by herbage 9 weeks after application. Losses from the soil-plant system over the same period amount to some 30%.

Field experiments indicate the proportion of legume-N derived from fixation is consistently greater than 80% on varying soil types and with different rates of fertilizer at pasture establishment. Such findings, if widespread, suggest that a measure of legume dry matter production may be sufficient for estimating amounts of N fixed in pasture systems. This would greatly simplify efforts to quantify N fixation inputs into the N cycle.

Soil physical properties under legume-based and pure-grass pastures
Generally, research on the causal element in pasture degradation focusses only on its chemical aspects, as savanna soils are strongly acidic, have a low nutrient status, a high aluminum saturation and a high P-fixation capacity. There are few data on the short- or long-term trends of the soil's physical condition under pastures that replace native savanna.

The physical properties of the soil were measured in two long-term pasture experiments with different grass and legume species and different stocking rates. The soils under improved pasture generally had a lower hydraulic conductivity (*K*) compared with native savanna at given value of the volumetric water content or, stated differently, were wetter at a given value of the hydraulic conductivity. This implies that after a given amount of rain, soils under improved pasture are more susceptible to damage by animal trampling or tillage than the savanna. On the other hand, adding a legume to the pasture increased *K*, which should reduce runoff. Differences in soil physical characteristics appear to be due to differences in root systems between the two types of pastures, and to differences in biomass and/or composition of soil fauna, especially earthworms.

Microbial biomass
The soil microbial biomass plays a key role in the maintenance of soil fertility maintenance because soil nutrient cycling is tightly linked to the turnover of microbial biomass. The formation and stabilization of soil aggregates depends strongly on the production of microbially-derived polysaccharides, which glue soil particles together, and on the entanglement of soil particles in fungal hyphae. As microbial biomass responds rapidly to changes in soil management compared to total SOM, it may serve as a sensitive indicator of quality and quantity of soil organic matter .

A study was carried out to determine how the soil microbial biomass responds when native savanna (whose organic matter content may be expected to be at equilibrium level) was brought under mono-crop rice compared with the rice-pasture rotational systems described earlier. A greater fraction of the soil microbes was active in the pastures, especially with a legume component, than under continuous rice. This is likely to be related greater and more continuous input of organic matter under pasture compared with the crop. Although the amount of microbial biomass C per gram of soil did not vary much among treatments, the N content of the microbes and the contribution of microbial-N to total soil organic N was much lower under rice monocrop than in the pastures. Estimating microbial turnover time at 0.5 to 1.5 years, nitrogen cycling through the microbial biomass is 44 to 166 kg ha^{-1} yr^{-1}. Values under 5-years' rice mono-crop were about half the value calculated for the pasture treatments. These data clearly indicate a decline in soil organic matter quality under rice mono-crop and a build-up in quality under grass-legume pasture.

Modeling organic matter turnover and nutrient cycling

The CENTURY model was originally developed for simulating the organic matter dynamics and nutrient cycling in natural grasslands of the north-American Great Plains. Over the years, its use has been gradually extended to other eco-systems and other climate zones, and the model now has been adopted for the tropics by the Tropical Soil Biological and Fertility network and by the alternatives to slash and burn project.

In contrast to most temperate ecosystems, P is generally the nutrient limiting plant production in the tropics, because the soils are low in P and have a strong P fixing capacity. Our work in the Colombian savannas showed that C/P ratio's in plants are very much higher than the ranges presently assumed in the CENTURY model. Although the option exists in the model to modify these ranges, using it for conditions of such extremely low P availability stretches the model's use beyond the limits of reliability. Recent work in our group on P-fractionation in savanna soils indicated that the soil-P chemistry section of the model may need to be modified for the conditions of low-P soils. Given the wide adoption of the CENTURY model for use in the tropical ecosystems, this calls for caution against injudicious use of the model for such soils. Using data from above- and below-ground litter decomposition experiments in the savanna and from soil-P fractionation, the phosphorus chemistry section of the model is presently being analyzed and will be adapted where necessary.

Strategic studies on carbon budgets

At Matazul farm on the eastern side of the Colombian llanos, a three-year-old *Andropogon gayanus/Stylosanthes capitata* pasture, sown with a rice cover crop in 1989, and grazed for three years at 2 head ha^{-1}, had 50 tons carbon ha^{-1} carbon more than an adjacent untouched savanna. Most of the difference was in the layer 20-100cm. A *Brachiaria dictyoneura/Centrosema acutifolium* pasture sown at the same time had 28 tons C ha^{-1} more than the savanna, while a *B. dictyoneura* alone pasture had 20 tons C ha^{-1} more.

Confirmation of the finding was sought in nine-year old pastures based on *Brachiaria humidicola* at Carimagua. Pastures oversown with *Arachis pintoi* in 1987 and grazed at 3 head ha^{-1} for five years had accumulated 70 tons C ha^{-1} more than the savanna in the top 80 cm, while a pasture of *B. humidicola* alone, grazed at the same stocking rate pasture had 26 tons C ha^{-1} more. Here again, most of the difference was in the layer 20-80 cm. It is noteworthy that the difference from the savanna in these pastures was undoubtedly underestimated, as the differences between the savanna and the grass-based pastures in the deepest layer (70-80 cm) showed no signs of lessening.

The implications of the ability of introduced grass-based pastures to fix large amounts of carbon have important implications for the stabilizing of the global carbon cycle. If similar amounts of C are fixed in the introduced pastures that occupy 35 million ha of the cerrados of Brazil, then from 100 to as much as 507 million tons of C are being fixed annually, which could account for a substantial part of the so-called missing global sink for carbon. Moreover, most of the fixation is below the plough layer, so that it should not be affected by a cropping cycle in crop-pasture systems. Indeed it should be possible to crop these soils in agro-pastoral systems, and still have them fix carbon.

As a point of reference, a large automobile produces 1 ton of carbon in about 8,500 miles of motoring, so we could be talking about sequestering each year the carbon produced in that year by more than 215 million large cars, each of which covers 20,000 miles. As another comparison, a mature tropical forest contains about 130 tons of carbon ha^{-1}, so the amount sequestered each year could be equivalent to the carbon lost when 3.9 million ha of rainforest is cut down.

This discovery shows that CIAT technologies not only have the possibility to increase production of the savanna lands of the neotropics, but to have very large positive externalities. Thus the individual farmer and the broader community both benefit from CIAT's technological innovations.

Institutional relations and collaborative research projects

From an institutional point of view, we recognize that the Program's strategies and research initiatives are only a part of the activities required to achieve sustainable agricultural development of the savannas and forest margins of Latin America. The Program is therefore developing active collaboration with numerous national, regional and international research and development institutions that have comparable interests. In this context, the International Fertilizer Development Center, IFDC, outposted a senior soil chemist to CIAT in late 1992 who is an integral part of the research team. Similarly, the savanna plant ecologist of the French IEMVT-CIRAD, who was previously assigned to the former Tropical Pastures Program, transferred to the Savannas Program.

With respect to national programs, close links have been forged with CORPOICA, Colombia, at both the Carimagua and La Libertad experiment stations, with the establishment of a number of collaborative trials. In other different fields of activities, active collaboration has been established with the Department of Biology of the National University, Bogotá, with the Technological University of the Llanos, Villavicencio, with the Secretariat of Agriculture of the Meta Department, with FEDEARROZ, and with the Colombian National Geographic Institute (IGAC), Bogotá.

In Brazil, one scientist is outposted to EMBRAPA-CPAC and has established a number of on-station and on-farm experiments in collaboration with the station's scientists. In addition, we have established regular contacts with other EMBRAPA Centers: CNPAF, the rice and beans center; CNPGC and CNPGLC, the beef and the milk centers; CNPMS, the maize and sorghum center; and CNPS, the soybean center and CNPAB, center for agrobiololgy. In the savannas of Venezuela, we have established close links with the Experimental University of the Llanos, UNELLEZ and with FONAIAP. A number of joint research projects have been prepared with several of these institutions for submission to various national and international donors. We learned recently that one of these projects based at Uberlândia, Brazil, has been accepted for funding by the German agency, BMZ. Another scientist is outposted to EMBRAPA-CPAF to participate in the global slash and burn project.

In an effort to consolidate and standardize research methodologies, a network of workers in agro-pastoral research is being established that incorporates several of the institutions named above plus the Center for Research in Tropical Agricultural, CIAT, in Santa Cruz, Bolivia. So far, two workshops financed by Inter-American Development Bank have been held in Villavicencio, Colombia in 1992 and in Goiânia, Uberlândia and CPAC, Brazil in 1993 and a third will take place in September 1994 in Venezuela.

At the second of these workshops the NARS requested that CIAT undertakes 1) the coordinating role for collating information on agropastoral research and facilitates the rapid dissemination of this information throughout region, 2) training new researchers in agropastoralism and organizes specific courses with identification of training sites, 3) long-term research of a strategic nature into the key processes, mechanisms and themes involved in the sustainability of agropastoral systems, 4) support to NARS in identifying and obtaining funds for research, 5) the development and testing of models suitable for agropastoral systems and 6) improves the methodology for on-farm research.

In late 1993 the Program organized an international workshop on tropical acid soils, attended by 32 representatives from five US and two German Universities, CATIE, CPAC-EMBRAPA, ICA, the Universidad Simón Bolivar, Venezuela, IFDC. At the workshop, the participants decided to create a research consortium named MAS (management of acid soils) to develop a joint research agenda for acid soils based on common sites in the forest margins, the hillsides and the savannas. Since then the consortium has been joined by representatives from ICFRAF, ORSTOM and IBSRAM. The consortium will emphasize strategic research, integrating soil and water management with improved germplasm to generate prototype environmentally benign technologies for sustained agricultural production within a framework of appropriate socio-economic and policy considerations.

In December 1993 the program hosted a workshop to develop a project on the transfer of technologies for improved agropastoral production systems for savanna ecologies of S. America jointly with UNDP/FAO/NARS. This event paralleled an initiative taken by PROCITROPICOS to develop a project on the regeneration and sustainable management of degraded soils in the savannas and program members attended PROCITROPICOS meetings in May and June 1994 in Brazil. In July 1994 the program participated in a PROCITROPICOS meeting held at CIAT headquarters to discuss the regeneration project and it was decided that both this project and the UNDP/FAO project could be combined. This effort is currently continuing with PROCITROPICOS and NARS representatives with the aim of finalizing the project before CG centers week this year.

In June 1994 the program participated in and co-organized a workshop on land quality indicators for the lowland savannas and hillsides of tropical America with the World Bank and representatives from CIMMYT, IBSRAM, IICA, FAO, AG Canada, IFPRI and USDA-SCS. A report on the outcome of this workshop is pending from the World Bank.

FUTURE RESEARCH STRATEGY

- The program will continue emphasis in its three major research areas, the Brasilian cerrados, the Colombian llanos and the forest margins as outlined in the document "Funding request for 1995".

- As part of the MAS consortium and scientific research group on production systems and soils management (PSSM-SRG) new thrusts will be pursued on C sequestration, P acquisition and the integration of inorganic and organic nutrients in lowland and hillside farming systems (see report on PSSM-SRG)

- ***Inter-program collaboration***
  The program is actively involved in inter-program projects which are described under the reports of the SRGs. One major inter-program effort is underway with the hillsides program entitled "Prototype systems for ecologically sound intensification of production in the hillsides". After a series of "planning by objectives" meetings during 1994 the project objectives include the development of sustainable agrosilvopastoral systems that improve soil quality, water management, and efficiency and productivity of labour.

  The general strategy will cover the range from short cycle, shallow rooted monocrops to perennial, deep rooted, and more diverse agro-silvo-pastoral systems. The work is expected to be starting in the field in the next few weeks.

- ***Relation of CIAT projects to CGIAR system-wide programs***
  Projects in the forest margin areas of Brazil are already incorporated into the global slash and burn project and much of the process-orientated and socioeconomic studies in the savannas are relevant to the CGs response to Agenda 21 with respect to soil, water and nutrient management (SWNM). The research program and the development of the MAS consortium fit well into CIAT's efforts as the ecoregional convener for agricultural development in the American lowland tropics (report submitted to TAC August 15, 1994).

- On the basis of the strong core of CIAT's soil-plant relations group within the tropical lowlands program and the MAS initiative, the center has been asked to become the convening center for CG-wide issues on SWNM. CIAT has replied positively to this suggestion and is awaiting a reply from the CGIAR. We are currently a member of the steering committee on SWNM organized by IBSRAM.

SRGs and Units

Scientific Resource Groups

Genetic Diversity
Germplasm Development
Pests & Diseases
Production Systems and Soil Management
Management
Land Management

Scientific Resource Groups

INTRODUCTION

To deliver research outputs effectively through its current program/project structure, CIAT requires a critical mass of scientific, sociological, and technical talent. These disciplinary-based talents are also essential to the future development of the Center's research on commodities and agroecologies.

Now and in the future, it will not be possible for each project area to have an adequate internal critical mass. In addition, CIAT must have the capacity to develop strategic research capacity, which not only cuts across the Center's programs and projects but also strengthens and distinguishes our ability to contribute to joint initiatives with our national partners and other CG centers.

The scientific resource groups (SRGs) have been established to encourage innovation within the various disciplines that contribute to CIAT's mission. Each SRG will also be anchored to a particular research unit. The five groups, their overall objectives, and the associated research units are:

1. ***Genetic Diversity***
   Collect, conserve, analyze, evaluate, and distribute genetic diversity within and among selected species to support germplasm development and help other institutions in Latin America characterize, conserve, and monitor a wide range of plant genetic diversity.

   Associated unit: Genetic Resources Unit

2. ***Germplasm Development***
   Identify sources of useful genetic variability, assemble and recombine this variability into pools and complexes for variety development (using both conventional and biotechnology approaches), devise efficient selection techniques for rapid enrichment with desirable genes, and promote networks for disseminating improved germplasm.

   Associated unit: Biotechnology Research Unit

3. ***Disease and Pest Management***
   Provide tools for detecting and monitoring pests and pathogens, gene complexes that can provide durable resistance, biological control agents, and new knowledge about resistance mechanisms and the dynamic relationships between pests, diseases, natural enemies, and their plant hosts.

   Associated unit: Virology Research Unit

4. ***Production Systems and Soil Management***
   Develop sustainable systems that combine plant species in such a way as to increase productivity, maintain adequate soil cover, cycle nutrients efficiently, and increase soil organic matter.
   Associated unit: Soils Research Unit (to be established)

5. ***Land Management***

Analyze current patterns of land use and develop tools for designing sustainable land management strategies, with a strong emphasis on community action and government policy.

Associated unit: Geographic Information Systems Unit

Because they are new, the SRGs will need to evolve in response to needs and challenges. It is also possible that new SRGs may be developed as a result of increased disciplinary demands (e.g., in economics and sociology).

Each of our principal and senior staff will be a member of a specific SRG. A few staff may belong to more than one SRG.

The SRG are a recent innovation in CIAT's Action Plan and they are in the process of developing center wide strategies and projects that reflect the needs of programs, which cut across more than one program and are highly strategic. Strategic approaches have already been developed for the Genetic Diversity and Diseases SRGs and are included with the profile of these SRGs. For the other SRGs, strategic approaches are under development.

Each of the SRGs have developed a portfolio of new project initiatives, a selection of which is included for each of the five SRGs. For the foreseeable future, and when funded, each of the SRG initiated projects will have an SRG affiliated project leader but will be implemented within one or more programs.

SRG - Genetic Diversity

Genetic Diversity Research and Training

Leader: William M. Roca
Associated Unit: Genetic Resources Unit

Translating biodiversity conservation into economic and social progress, through sustainable agriculture, is a major concern of developing countries. Tackling sustainable agricultural objectives will rely increasingly on the access to genetic diversity and to strategies for genetic enhancement and crop improvement. Utilization of genetic diversity rely on the description of their variability and the genetic differences between species and within agroecosystems where they co-exist. As a consequence of the ratification of the Biological Diversity Convention in 1993, it is imperative that technologies, both traditional and modern, are ready available for member countries to better describe, conserve and use genetic diversity in a sustainable manner.

CIAT Activities in Genetic Diversity

In genetic resources research CIAT has developed considerable capacity for analysis of intra-and inter-specific genetic variability and for *ex situ* conservation of selected crop species. CIAT collects, conserves (field, seed and *in vitro* gene banks have been operational in CIAT); characterizes and evaluates (using both conventional approaches and DNA-based marker analysis); and distributes genetic resources. To meet phytosanitary standards for the international movement of germplasm under CIAT's trusteeship, health status of seed and other planting material is certified.

Through the analysis of genetic diversity and its relation to agroecosystem variation, we gain an understanding of the principles governing the structure and distribution of genetic resources at micro and macro regional levels, and use such knowledge for developing improved strategies in conservation and utilization.

1. Species Coverage

1.1 Food Crops:

- Cassava (*Manihot esculenta*) and wild *Manihot* relatives.
- Beans (*Phaseolus*, *vulgaris*, *P. acutifolius*, *P. coccineus*, *P. polyanthus*, *P. lunatus*) and wild *Phaseolus* relatives.

1.2 A range of forage legume and grass genera:

- *Arachis*, *Calopogoninum*, *Centrosema*, *Chamaecrista*, *Desmodium*, *Pueraria*, *Stylosanthes*
- *Andropogon*, *Brachiaria*, *Panicum*, *Paspalum*, *Urochloa*

1.3 Soil Biota: *Rhizobium*, *mycorrhiza*

1.4 Related species: diversity within CIAT mandated agro-ecoregions.

2. Major Research and Training Topics

Technologies steaming from traditional and modern morpho-taxonomy, genetic, cellular and molecular biology are integrated with agro-ecological and geographic information systems (GIS) data to develop, evaluate and promote strategies to secure species diversity and genetic variability in CIAT mandated crop genetic resources, and plant/biota species relevant to the agroecological regions of competence.

2.1 Characterization and analysis of genetic diversity

- Spatial distribution of diversity including population dynamics, gene flow between wild and cultivated forms, and evolution
- Relationship between *ex-situ* collections and *in-situ* diversity
- Comparative genome mapping of crop species

2.2 Conservation

- Rationalization of *ex-situ* collections through:
  - Development of core collections
  - Identification of duplicate genotypes
- Conservation approaches
  - *ex-situ*: field gene banks, seed gene banks (active and base), research on cryopreservation.
  - *In-situ*: Initiating studies to develop strategies for wild species and land races *in situ* conservation.

2.3 Broadening genetic base

- Gene introgression from related species and wild relatives
- Gene transfer from alien sources through transformation

2.4 Exchange of genetic resources and enhanced germplasm

2.5 Training, communications, and institution development

- Collaborative research with developing and developed country institutions
- Degree-oriented theses, advanced courses and seminars/workshops
- Data bases for genetic resources, catalogs, maps, search - diffusion of relevant literature.

3. Areas of competence

3.1 Plant genetics:

- Acquisition, collection and exchange of plant genetic resources of mandated crop species and their wild relatives.
- Genetic systems of sexually and asexually reproducing species.
- Description of diversity at the morphological and genetic levels.
- Conservation strategies to maximize genetic diversity in core collections.

3.2 Cell biology and cell genetics:

- In vitro methods of genetic conservation.
- Wide hybridization for alien gene transfer.
- Transformation techniques to introduce foreign genes.
- Diagnostics and protocols to ensure dissemination of clean planting material.

3.3 Molecular biology and moelcular genetics:

- DNA isolation, characterization, and sequence analysis.
- Recombinant DNA technology.
- Molecular probes and markers to analyze DNA sequence variation and develop molecular maps.

3.4 Agronomy:

- Procedures for the evaluation of diversity in tropical legumes and grasses for use in agro/silvo/pastoral systems.

3.5 Training:

- Training and workshops on conservation, description, handling, and dissemination of genetic resources.
- Molecular and cellular technologies to analyze species diversity for designing conservation strategies.

4. Infrastructure

CIAT genetic diversity activities utilize modern, well equipped, facilities and infrastructure, comprising:

4.1 In the Genetic Resources Unit: Complete seed storage facilities, *in vitro* conservation laboratory, seed health testing lab, glass houses and screen houses.

4.2 In the Biotechnology Research Unit: Tissue culture, molecular genetic markers and molecular biology laboratories

4.3 In the Virology Research Unit: virology and immunology laboratories

4.4 In the Geographic Information Systems Unit: Geographic information facilities, and electronic mapping and data bases equipment

4.5 In the Commodity Programs: Laboratories, experimental greenhouses and field plots located across CIAT agroecosystems in several countries

Title: CGIAR System-wide initiative on Latin American agrobiodiversity of major food crops: The integration of conservation approaches ex situ and in situ for improved utilization of genetic resources.

Background:The CGIAR centers based in Latin America have long established *ex situ* collections of germplasm in relation to their crop improvement efforts. Large segments of germplasm exist as land races in farmers fields, and many wild relatives occur in natural habitats along the crop species major centers of diversity. There is scientific theoretical and practical interest to understand the dynamics of diversity within and between gene pools and in farmer's fields vis-a-vis the diversity maintained in the *ex situ* collections. The suitability of *in situ* conservation of genetic resources and its relation to *ex situ* collections need assessment.

Although widely seen as an important conservation method, the experience about *in situ* conservation is limited to a few case studies, and methodologies and criteria need to be assessed and validate to operate and link *in situ* with *ex situ* conservation.

Answer to these questions can partly be provided by *ex situ* conservation. CIAT has conducted research of the genepools of their mandate crops and can already indicate where unique fractions of genetic diversity are located. CIAT has established capabilities for the use of DNA marker technologies to study genetic diversity, on computerized basis, covering continental Latin America.

The proposed research would involve the CGIAR centers of the region; address issues of strategic and global nature and involve selected national institutions.

Approach: Development of GIS, mapping of natural populations, assessment of genetic diversity with molecular markers, and the conservation of wild relatives of crops of American origin will be the main activities of the project.

Outputs: Indications of where particularly variable and unique fractions of genetic diversity for wild relatives of crops are actually located, or are likely to be;

- foresee where *in situ* conservation facilities could accordingly be established;
- indicate where endangered populations should be collected as priority for *ex situ* conservation; and predict where, and under which conditions, such *in situ* sites can be operated at the local level.

Project: Integration of research in genetic diversity with research on agroecosystem diversity for more efficient conservation and utilization of crop genetic resources.

Crops: *Phaseolus, Manihot, Arachis* (CIAT) with implications for *Oryza* (CIAT, IRRI), *Teosinte* (CIMMYT), *Imopoea* (CIP).

Approach: Analysis of genetic diversity of wild relatives and cultivated forms with molecular markers and etnobotanical descriptors will be matched with agroecological information and geographic information systems (GIS) data; information from *ex situ* collections with *in situ* diversity will be related.

Outcomes: Understanding of evolution of crop species and their wild ancestors; rationalization of conservation of genetic resources, and more effective strategies for breeding programmers.

Collaborator: BRU, GRU, Cassava/Bean/Rice/Tropical Forages Programs, (CIAT), IRRI, CIMMYT, CIP

Project: Endowment for linking academics, agricultural research centers and non-governmental organizations for using DNA-based technologies in agrobiodiversity research: case of Colombia.

Crops: IARC's mandated and other priority crops in LAC

Approach: Identification of trainees and crops of interest to Colombian institutions (universities, NGO's, NARI, private sector); organize workshops and training program and lab. manual; repeat (updated) workshop one/year for 3 years.

Outputs: Develop lab. facilities in two key Colombia Universities for work with molecular markers in cooperation with NGO's and CORPOICA; a core curriculum in biotechnology and agrobiodiversity will be develop for future training of national/regional scientists; developed collaborative projects in agrobiodiversity and biotechnology.

Collaborators: BRU, GRU (CIAT); Univ. de los Andes, Univ. del Valle, CORPOICA, Colegio Verde, FES, Fundacion Natura (Colombia).

Project: Molecular and GIS Characterization of the Bean and Cassava Core Collections

Approach:

- Study the ecogeographic distribution of collected cassava and bean germplasm and their diversity by linking germplasm databases with GIS information databases. Identify gaps in collections based on ecogeographic representation.

- Intensify germplasm characterization for reaction to key pathogens, photosynthetic capacity, and tolerance of low soil phosphorus and potassium. Analyze the distribution of these agronomic characters in the collections.

- Strengthen national research capacities through training and practice in germplasm management.

- Develop a complementary collection of cassava, beans, and their wild relatives.

- Determine the relationships between (a) genetic groups identified through analysis of molecular markers, (b) the distribution of economic traits in the germplasm, and (c) the agroecological parameters of the sites of origin.

Outputs

- Understanding of the genetic structure of bean and cassava gene pools, and of the genetic distribution and ecogeography of important sources of agronomic variation (which will provide a basis for developing strategies to collect, conserve, and use germplasm)

- Methodologies relevant to similar concerns for the germplasm of other crops

- National program scientists trained in germplasm conservation and evaluation

Collaborators

INTA (Argentina), INIA (Peru, Ecuador, Colombia)

GENETIC DIVERSITY SRG

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Conservation of Genetic Resources: CIAT'S Role in Germplasm Research

Document prepared by
The Genetic Diversity Scientific Resource Group

CIAT, July 1994

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Conservation of Genetic Resources: CIAT'S Role in Germplasm Research

EXECUTIVE SUMMARY

1. As the CG Centers embark on ecoregional-oriented research in natural resource management, genetic resources will play an even broader role. This brings a broader challenge as specified in the Convention of Biological Diversity (CBD) and Agenda 21. The Centers' outputs should now contribute not only to increased crop productivity, but to the conservation of the natural resource base. The CG centers must bring their traditional strengths to bear on new challenges, particularly in their work on plant genetic resources conservation. CIAT sees this work as consisting of three interdependent activities: conservation, research, and utilization. Progress in all three requires close integration of various disciplines, techniques, and approaches, including modern biotechnology, conservation biology, plant breeding, geographic information systems (GIS), integrated pest management (IPM), anthropology, ethnobotany, and farmers' participation. In house capacity in the fore-going areas exist in CIAT and other CG Centers, and is not duplicated elsewhere in the same balance and with the same potential for interaction of disciplines.

2. Within an interdisciplinary approach, plant breeding forms one link in a complex chain of activities, stretching from molecular genetics to land use analysis. An important challenge in this work is to improve our understanding of biodiversity at the molecular level, relating *ex situ* with *in situ* conservation, while also identifying traits of agronomic or industrial value that open up opportunities for developing new end products.

3. By integrating the CG centers' traditional role in commodity research with their role as ecoregional centers, they and their developing country partners can generate information that is critical for establishing a new, system-wide approach to genetic resources work. Such an approach will require the centers to apply more vigorously their existing capabilities in modern biology, database management, and GIS through intercenter collaboration in research and training for key ecoregions. The ecoregional approach may be one rational criterion by which the scope of the CG centers can be broadened beyond their mandate crops.

4. Through training, scientific visits, and networks, we can share the results with developing country partners who are evaluating their own germplasm or receiving accessions from the world collections maintained in the CG Centers. Thus the Centers become a critical backup to national institutions in germplasm and information, and for strengthening their activities to monitor, preserve, characterize and utilize genetic resources, which is a top a priority of the CBD.

5. In developing a new agenda for genetic resources work and a unified strategy for pursuing it, the CG centers should consider establishing a network that coordinates certain activities to better integrate their work on genetic resources, and communicates

its accomplishments and benefits to the community. The participating institutions and individual genetic resources units would remain under the auspices of their centers. An administrative structure that fits an expanded role for the centers is also needed. The CG centers' activities on genetic resources must pursue the integration of approaches and activities such as geographic information systems, plant breeding, modern biology, farmer participation, and ethnobotany, within each center and around important research themes at the regional level. These activities would involve: (i) Coordination of Centers' contributions to studies on genetic resources and to *in situ* and *ex situ* conservation within particular agroecologies; (ii) Close partnerships with NGOs, national research institutes, and universities; (iii) Restricted core funding for conservation of genetic resources in each center to provide the continuous support this activity requires; (iv) An endowment fund to support genetic resources activities with priority on conservation independently of the centers' core and complementary budgets; (v) A stronger role for the Intercenter Working Group on Genetic Resources in guiding research and monitoring progress across centers. The chair of this group should be rotated among members, with IPGRI providing a permanent secretariat; (vi) A central role for IPGRI in mobilizing long-term financial support, in shaping policy (e.g., on intellectual property rights), and in maintaining public awareness and links with other organizations working on genetic resources.

INTRODUCTION

The need for change

CIAT and other CG centers have contributed to agricultural development largely through research on major food commodities. By exploiting key features of these crops and tackling production constraints, the IARCs have helped farmers satisfy food needs under a wide range of socioeconomic conditions in the developing world. The gene banks of the CG centers, together with their capacity for helping improve production under different socioeconomic conditions, are vital for maintaining the world's food security. But as the centers embark on more comprehensive programs aimed at an ecoregional approach on research in natural resource management, genetic resources will play an even broader role.

Our challenge now covers much more ground, as spelled out in the Biodiversity Convention and Agenda 21. From now on the information and technology components we develop and disseminate must contribute not only to increased crop productivity but to conservation of the natural resource base. Without abandoning important tasks for which the centers were created, we must bring our traditional strengths to bear on this new challenge.

A central part of this challenge is to improve the conservation and management of plant genetic resources. At CIAT we see genetic resources work as consisting of three interdependent activities: conservation, utilization and research. In the past the first two received most of our attention. But now we see a growing role for research that impacts on both conservation and utilization.

Plant breeders, until now the main clients of the germplasm facilities, will be joined by many others interested in using genetic resources of the world's major crops. Breeding will be recognized as one link in a complex chain of activities, stretching from the use of biotechnology for germplasm characterization to the analysis of land management. Many aspects of this latter activity, including farmer participation, the development of environmental databases, and GIS applications will help identify requirements in crop improvement.

The key to success will be integration of disciplines, including biotechnology (molecular and cellular), virology, geography, pathology, entomology, plant breeding, anthropology, and other social sciences. This is essential for expanding the focus of genetic resources work beyond conservation and for transforming it into a more dynamic scientific endeavor. In addition to routine storage of seeds and other plant parts, we will need to formulate and test hypotheses on major themes in genetic resources research. In taking up this approach, we will have to reorient current activities, looking more horizontally to involve the relevant disciplines in understanding genetic diversity. Most of the necessary expertise is already available to the CG centers, and many of the interdisciplinary activities are already underway. The accompanying Table illustrates the complex nature of genetic resources work at CIAT in which virtually every Unit, Program and Section has invested significantly.

TECHNICAL ASPECTS : APPLYING NEW TOOLS IN GENETIC RESOURCES RESEARCH

The realization of our vision of germplasm research requires that we have the necessary infrastructure and interdisciplinary teams for engaging in the whole continuum of genetic resources activities. It requires that we actively employ GIS databases (describing ecological variation both within and between environmental niches), the tools of modern biotechnology, analysis of farming systems and the identification of areas for the conservation of germplasm of landraces and wild ancestors.

The powerful tools of biotechnology

Most CG centers working on major commodities, including CIMMYT, IRRI and CIAT, have acquired a significant capacity for genetic analysis at the DNA level. At CIAT we are engaged in molecular genetic analysis of relevant traits and/or of genetic diversity, in beans, cassava, rice and tropical forages, in addition to certain pests and microorganisms associated with these crops. This is one of our most powerful tools for assessing and conserving genetic diversity. The use of techniques, such as *in vitro* culture and molecular markers, are required for two other tasks: those of introgression of traits from wild relatives into domesticated species, and genetic transformation for enrichment of gene pools. *In vitro* culture is also useful for *ex-situ* conservation and exchange of genetic resources. Acquiring the capacity to do this required a major financial commitment to develop facilities and cover the cost of the equivalent of four senior staff positions. Most projects that rely on these facilities involve collaboration with universities, national programs, or other agencies and provide excellent opportunities for training, scientific visits, and other contacts aimed at strengthening or complementing our partners' capacities.

To supplement their own capacity for molecular analysis, some CG centers have helped establish biotechnology research networks. These provide a framework for partnerships between laboratories in the industrialized countries and institutions in the developing world. International networks now exist among scientists working in cassava and beans, and CIAT participates actively in the international rice network. Such networks can be a powerful means for the centers to promote better conservation and use of genetic resources.

Biotechnology offers another rational link between our work on mandate crops and research on other species, specifically those whose diversity has not been characterized at the molecular level. Approaches such as comparative genome mapping show considerable promise for extrapolating present results on major crops to related but minor species and thus facilitating the evaluation and use of genetic resources. The application of these strategies can provide a rational basis for expanding the array of crops on which we work to include some minor species.

New opportunities with geographic information systems

Several CG centers are now introducing an ecoregional orientation into their agricultural research and development programs. CIAT was originally conceived as an ecoregional center. In fulfillment of this responsibility, CIAT has developed Latin America's most complete GIS database for resource management studies including soil classification and quantitative description of climatological and topographical parameters. It can readily be adapted for the purposes of new work on genetic resources. Our climate database, for example, contains data from more than 18,500 climate stations in the tropics. We continuously update this information and distribute it freely to other centers and institutions, including UNEP/GRID in Nairobi. Over the years we have acquired considerable expertise in applying the climate database to environmental classification and comparison. Other important sources of information are the FAO map of soils of the world and the UNESCO map of world vegetation, both with a scale of 1:5,000,000. In the near future CIAT will increase the nominal precision of its data on soils, land forms, and land uses to 0.5-1 km, at least for Latin America, if finance is available.

GIS opens up numerous opportunities for a wide range of specialists. Biotechnologists can use it to evaluate distribution of genes and molecular data, taxonomists to study phenotypic variation, land use analysts to explain the consequences of human intervention in the environment, and agricultural geographers to identify variation in crop distribution and adaptation. These data can help us determine the environmental range of species and, once their niches have been identified and described, provide the basis for phenotypic and genetic analysis of populations. These tools can also help us identify environments where well-targeted germplasm collection is needed.

The technique enables us to evaluate the wild relatives of major crops more consistently and conserve these materials more effectively, both *in situ* and *ex situ*. As we better understand the ecoregional distribution of genetic diversity, we can foresee a day when large central gene banks will no longer be as necessary for conservation as was envisaged in the 1950s. When that happens, the CG centers will need to concentrate more on mapping and describing ecosystems in support of local efforts to conserve and use the developing world's germplasm heritage.

Mapping genetic diversity in ecoregions is essential for in situ and ex situ conservation and effective use of this resource. It helps us identify sites of valuable diversity and design strategies to protect them. It is also an important step toward acquiring representative germplasm samples. Finally, mapping helps orient procedures for *ex situ* conservation and identify locations for germplasm evaluation that match the ecological conditions where the material was originally collected.

As the CG centers move to an ecoregional approach in research on natural resource management, they should broaden their interest in biodiversity to include not only crop germplasm, but its pests, pathogens, vectors, and the interactions between them. This is one more reason why CIAT must pursue an interdisciplinary approach that ties germplasm curatorship to other areas of research on major agroecologies. The ecoregional approach may be one rational criterion by which the scope of the CG centers can be broadened beyond their mandate crops.

DATA MANAGEMENT

The basis for effective data management

Data management is central to germplasm research. The centers have already made a considerable effort (which at CIAT can be measured in hundreds of person-years) to characterize the germplasm collections under their care. The results are now available in complex databases, which are linked to databases containing agroecological information and the results of agronomic evaluation. However, will be valuable to standardize the databases somewhat in order to make their contents more widely available.

Scientists at every center conducting commodity research generate data that are relevant to the center's genetic resources unit. The scientists who collect and use these data are best positioned to update and revise them. This task remains linked to the germplasm collections to which the data pertain. It is essential to maintain the vital links between the germplasm and the scientists working on all its aspects in order to preclude degradation of the databases. CIAT is no exception to this rule.

Synthesizing information across disciplines

Integrating disciplines implies synthesizing information. Traditionally, data on genetic resources have been generated and used within the confines of particular disciplines. One consequence is that we have not fully appreciated the importance of data on environmental conditions at germplasm collection sites. The lack of a common approach to describing farming systems and environments has made it difficult to predict or target germplasm diffusion and utilization.

As already indicated, the CG centers, particularly those with ecoregional mandates, are making good progress toward providing environmental and land use data in a consistent, widely usable form. CIAT is most probably the lead centre. These data are being collected primarily for studies on crop adaptation and resource management. But increasingly, the information is also being used for basic germplasm research, integrated with the work of plant breeders as well as soil scientists, geographers, climatologists, and other specialists in resource management. These data will be essential for establishing criteria by which to gauge the conservation of genetic resources and their utilization in applied germplasm research.

As we look toward closer integration with CG sister centers and other institutions, we must still recognize that it is not practical to standardize databases across crops, because different types of data are available for each species. Even so, it is possible and beneficial to standardize the form in which information is exchanged or at least to make the CGIAR systems more compatible. This would facilitate the exchange of information between databases, such as the wealth of biochemical and molecular data becoming available for particular crops and increasingly for groups of related crops.

One option is to form a metadatabase, which indicates where to obtain data, how to retrieve them, and how reliable they are. A Gopher setup on Internet will be ideal for this. The CG centers do not pretend to hold all the germplasm data available, even on their mandate commodities. A central function of IPGRI or another central agency can be to manage a metadatabase that helps scientists in the centers and elsewhere find the information they need. IPGRI can also help the centers distribute data, just as GRID in Nairobi provides data on tropical environments. Unlike GRID, however, we don't need centralized storage of data, unless a center is unable to provide its data on request. We in CIAT are pursuing the possibility of putting data onto a CGNET server in California.

OUTPUTS

Core collections

Several institutions have assembled core collections, which contain a manageable number of representative samples from the complete world germplasm collections. The purpose of core collections is to facilitate characterization of genetic resources and their utilization in breeding and to orient the conservation of additional useful diversity. The collections are dynamic, since they form the genetic base of applied breeding programs and change as the complete collection is improved through germplasm exploration.

To ease the exchange of germplasm with our partners, we need more data on the performance of accessions in the core collections. The evaluation of this material should be closely tied to the development, evaluation, and distribution of elite germplasm, containing a high concentration of desirable alleles and allele combinations. Linking the two activities gives us a means of evaluating progress and changes in the structure of our active gene pools. Through training, scientific visits, and networks, we can share the results with partners who are evaluating their own germplasm or receiving accessions from the world collections.

Recent experience at CIAT illustrates the complexity of CIAT's interdisciplinary approach to research on genetic resources. For example, germplasm curators, biotechnologists, and agricultural geographers have formed a core collection of *P. vulgaris*, relying on GIS and biochemical tools. A simple agroecological classification (based on growing season, soils, rainfall, and photoperiod) enabled us to assure that the genetic resources contained in the collection represented germplasm from the full range of bean-growing environments. Using molecular markers, we will further analyze genetic variation between and within certain environments.

In situ conservation

In situ conservation of landraces and wild species presents a formidable challenge for research, which becomes more urgent as habitats are altered or lost. Our task is to conserve the diversity of gene combinations in domesticated and wild populations and maintain a reservoir of individual genes as a component of the natural resource base. For this purpose we need, not only to examine the diversity of phenotypes and genotypes occurring in specific environmental niches, but to understand the place of these niches within the species' full range of environmental adaptation. The collections held by the CG centers are a good place to start, since we are already accumulating considerable knowledge about the diversity of particular species and their wild relatives, both within ecoregions and at the molecular level. Effective models developed for *in situ* and *ex situ* conservation of these crops can then be applied to a broader spectrum of biodiversity.

Germplasm collections in the CG Centers, a back-up to national institutions

The International centers have assembled germplasm collections, which were either directly donated by national programs or collected in geographic centers of domestication and/or diversification in collaborative efforts with national organizations. Different percentages, ranging from low to high of such germplasm collections are not represented in their countries of origin due to several reasons (lack of adequate facilities or losses in the management process). These circumstances make the CG Centers a critical back up to national institutions, both in terms of germplasm and information. There is a great need to develop regional systems for *ex-situ* collections on a species by species basis, and their linkages to *in-situ* conservation.

Research on conservation and utilization will be developed to respond to needs of national institutions for strengthening their activities and capabilities to monitor, preserve, characterize and utilize genetic resources. CIAT has routinely devolved duplicates of germplasm collections to several national programs, and a comprehensive program for germplasm evaluation, characterization and duplication of national collections by NARS scientists in collaboration with CIAT is being proposed.

INSTITUTIONAL RELATIONSHIPS

An ambitious program of institutional development

Gene banks and the data they generate through germplasm evaluation will contribute to agricultural development only if they are linked to networks of national institutions. In many places these institutions have only limited capacities. To strengthen them, the centers must embark on an ambitious program of institutional development that includes training and information support.

To form the entire team of researchers needed to conduct the chain of activities envisaged, CG centers must establish new partnerships with national governments, NGOs, and farmers within each particular ecoregion. CIAT is well placed for this. Our center's challenge will be to promote efficient utilization of genetic resources by integrating disciplines, synthesizing information, and seeking the full participation of every partner. The team will need to develop, not only a thorough understanding of the existing biological diversity in particular places, but a clear idea of the demand for end products and the consequences of generating them. To do this they will need to take into account the ecological as well as economic aspects of genetic resources, focusing particularly on the identification of traits with agronomic and industrial value.

Partnerships and a unified strategy

With regards to non-agricultural species and some minor crops in Latin America NGOs have already taken the lead or are participating in preserving plant genetic resources and associated indigenous knowledge on many fronts. But these organizations lack facilities for conducting molecular analysis and applying GIS to generate information that could help them design and implement conservation strategies. To remove this obstacle, universities, IARCs, and NGOs can jointly establish a forum for organizing training and research on biodiversity. The role of the CG centers and their partners will be to help universities develop the necessary infrastructure and capacity for giving NGOs access to new tools. Such an arrangement will strengthen research on species that have significant economic and social value but are not targeted by any of the centers.

Interdisciplinary training

Training in conservation biology and technology must be maintained and expanded. Additionally, many scientists have already received or provided training in molecular and cellular biology techniques, although skills in interpretation of molecular data must be improved. We must also give special emphasis to training in the application of GIS and mapping techniques to research on genetic diversity. Many developing countries are gradually acquiring these new techniques, and some agencies are using remote sensing to map environmental resources and land use. However there is little contact between those agencies and national institutions engaged in germplasm conservation and management. It is therefore especially important that the CG centers vigorously apply their own GIS expertise to these activities in cooperation with partners in developing countries. CIAT is well placed to assume this responsibility for Latin America.

The interdisciplinary work of many centers on the genetic resources of major crops offers abundant opportunities for practical in-service training and should serve as a sound model for other institutions. We have a critical role in strengthening institutional capacity and identifying partnerships that are complementary to accomplish regional needs. Under no circumstances should CIAT weaken its direct links with partners in germplasm research and conservation, since they will then lose their capacity to share expertise with other members of the germplasm management community.

CIAT'S RELATIONSHIP TO THE CGIAR SYSTEM

A need for coordination

As the CG centers make new commitments to new partners, their work will require international coordination. An expanded role for the centers in genetic resources work justifies integration of research but does not require central management of activities CIAT should maintain communications with the international community and national systems. We need to strengthen our role at the regional level, relying on support from IPGRI as a central clearing house.

Until now each of the CG centers has worked largely independently of the others toward similar goals. There is great potential for research integration, particularly where our expertise and activities overlap with respect to crops, farming systems, agroecologies, or strategies. Through cross-center germplasm projects, we can better coordinate the collection and exchange of environmental data. We can also join forces to conserve wild relatives of our mandate crops and other species, where these are found in the same regions or ecosystems. Often, centers cooperate independently with the same national programs, while pursuing their own objectives according to their own styles. The centers should at least find ways to consolidate their activities in such areas.

We must seek a unified strategy for our work on genetic resources and communicate our joint accomplishments more effectively. By doing so we can become more accountable to the individuals and groups who expect us to expand our work beyond conservation and use of genetic resources for the purposes of plant breeding. We must play a broader role in research, drawing on CIAT's unique array of combined strengths.

An administrative structure for the new research agenda, the CIAT view.

Along with a new agenda for genetic resources research, the CG centers need an administrative structure that meets the requirements of the research. In our view the network approach for coordinating work on genetic resources across the CG system can work.

We endorse the model adopted at the 1994 MidTerm Meeting of the Center Directors to develop a system-wide program in genetic resources. Specifically, the CIAT stance would involve the following:

- Individual genetic resources units remain under the auspices of their centers but with major changes aimed at promoting integrated multidisciplinary research. Most staff working in genetic resources research will remain members of the center's staff. Inter-center projects can provide a means to share new staff costs.

- Conservation of genetic resources in each center should be supported with restricted core funds, since it is essential that this activity receive continuous support.

- The Intercenter Working Group on Genetic Resources (ICWG-GR) should have a stronger role in guiding research across centers. The chair of this group should be rotated among members, with IPGRI providing a permanent secretariat.

- IPGRI should play a central role in fund raising and policy making (e.g., on intellectual property rights), and public awareness.

The main role of a central body, such as IPGRI, should be to represent other centers and help them identify gaps in their genetic resources work. For example, it can address concerns about minor crops not dealt with by other centers through regional partnerships. As a representative of other centers, IPGRI may also be the logical candidate for designing mechanisms to assess the impact of genetic resource work. Impact information will be vital for maintaining public awareness and accountability. As new agencies get involved in genetic resources work with us, it will be especially important that each member of the network understand the comparative advantages of others as well as the scope and results of their work. To further smooth the way for cooperation, we will also need centralized documentation of the geographical, ecological, methodological, and biological dimensions of conservation projects worldwide. Through its active role the Secretariat of the ICWG-GR, IPGRI would be linked to the operations of each center, which will ensure effective representation. Finally, IPGRI could coordinate a centralized effort to secure long-term financial support for conservation and for research on conservation biology and methodology.

Center image

In addition to making changes internally, the centers need to alter the external image of their genetic resources activities. This should be an important function of IPGRI in close coordination with the other centers. Our image and our actions must fit a new, more synergistic role, and our accomplishments must be more visible to the international community. For the latter purpose, we need to identify clear indicators of the success (or failure) of our genetic resources work. Specifically, we should document the use of collected germplasm in new varieties; the replacement of lost collections; the genetic diversity of traditional versus modern agriculture; the amounts of diversity threatened, compared to that protected; and the amounts conserved *ex situ*, as compared to *in situ*. CIAT will dedicate itself to serve these ends.

Securing long-term financial support

Another function that clearly lends itself to centralization is fund raising. As the CG system moves to a more unified strategy in its work on genetic resources, the centers will enter into new long-term commitments. We cannot fulfill these under ephemeral funding arrangements or through scattered efforts that give rise to internal competition for continued support. We must define a role for ourselves that convinces the donor community of our strong commitment to genetic resources and our special place in this work. On that basis the CG system should be better placed to secure long-term financial support for relevant research on conservation biology and methodology. More specifically, we recommend that the system seek endowment funds and that in administering these funds it give first priority to supporting conservation of genetic resources.

CONCLUSION

The centers must communicate with one another about their activities and priorities in genetic resources to identify specific opportunities for cooperation. At the same time we need to interact more effectively with national institutions to ensure that our activities are consistent; each center must maintain its own direct contacts with research partners. There is some room for central coordination of methodologies. But each center should have ultimate responsibility for the procedures involved in maintaining the *ex situ* collections (i.e., acquisition, management, evaluation, and exchange) and for designing and operating the germplasm databases. All centers should take an active part in research on methodologies for *ex situ* conservation as complement to *in situ* conservation, in developing analytical tools to measure diversity, and in monitoring the preservation of genetic resources.

The IARCs are a unique and invaluable global resource for conserving genetic diversity of the world's major food crops. The measures we propose here should better enable the centers to fulfill this vital responsibility and even expand their work to impact on a range of other species.

CIAT has at least 20 years experience in managing germplasm of its mandated crop species. The environmental databases and the necessary know-how on the integrated use of modern biological tools are in place. Development of these to a scale useful for genetic resources characterization/analysis and conservation is a matter of time and cost.

Illustration of the genetic resources complex at CIAT

Germplasm Activity	HOST PROGRAM AT CIAT					
	GRU	VRU	BRU	COMMODITY PROGRAM	LAND MANAGEMENT	SPECIAL PROJECTS
Collection/acquisition				BCF	BCF	
In vitro conservation	CF					
Field conservation	F			C	BCF	
Seed conservation	BCF	B		F		
Research on conservation methods	CF		C	C	BCF	
In vitro distribution	CF					
Seed distribution	BF			C		
Database management	BCF			C	BCF	
Agronomic evaluation current tools				BCF		C
Development of new evaluation tools		CF	BCF	BCF		
Germplasm enhancement				BCF		
Devpt of strategies for development				BCF		C
Devpt of crop potential (utilization)				BCF	BCF	C
Eval gen diversity target/associated spp	CF	BC	BCF	BCF	CF	
Health testing/quarantine	BC	BCF		BCF	BC	
Research of safe movement/risks		BCF	CF			
Training	F	BCF	BC	CF	BCF	

B= Beans
C= Cassava
F= Forages

Genetic Resources Report For The 1994 EPMR

1. Executive Summary

The period 1990-94 could be considered as a stage of restructuring and consolidation for the GRU. However, two sub-stages can be visualized: the first two years as of a high input to reinforce and upgrade of GRU responsibilities, followed by three subsequent years affected by the global CG centers constraints; the latter stage held down the initial impulse and put it on a kind of standby.

Overall goal. The Unit's goals are to assemble, conserve and characterize all critical germplasm resources in *Phaseolus* beans, *Manihot* (cassava) and several key genera/ species of tropical forages, and to research those collections, thus ensuring fuller use by international and national programs. GRU late major change has been in the organizational structure: the three sections are now incorporated into the SRG Genetic Diversity Area and its projects nested within the respective megaproject commodity program.

History of overall program activities (1990-94). The new GRU gene bank facilities were operational by mid 1991, and also, a new organizational GRU administration was permitted for improving conservation and management of the germplasm collections. For Beans: at present the GRU handles all the stages of germplasm management. For Tropical Forages: those stages of management that were under the program control, were passed to the GRU. For Cassava: the in vitro bank management was forwarded to the GRU from the BRU. Reassignation of responsibilities were done with the agreement of the respective commodity programs. Two new labs. for Electrophoresis and Seed Health Testing were established at the GRU in this period. The main drawback after the initial impulse has been the drastic personnel reduction affecting the three sections; however, three curators were appointed for the management of beans, tropical forages and cassava, which will improve the quality of management and help on the better coordination of join activities unit-program.

Major clients, collaborators, partners and regional impacts. The GRU is both a service-oriented and germplasm management unit. It must know who its clients and partners are and their demands in order to be relevant. Such partners and clients are CIAT scientists, NARS and national genetic resources programs, experimental biologists, IPGRI (formerly IBPGR), and other CG centers in the near future. CIAT's scientists help the unit in four aspects: germplasm acquisition, evaluation and documentation of the collection, better understanding of the genetic diversity, and improved methodology for germplasm conservation, characterization and distribution. NARS and national genetic resources programs (which are usually part of NARS), mainly from Latin America, are the principal clients and partners for the CGIAR system, they can collaborate in the following ways: acquisition of germplasm, shared ex situ conservation, and in situ conservation. Regarding the experimental biologists, although they are not target clients they produce information which contributes significantly to a better understanding and use the germplasm. As for the sister center IPGRI, there are four major areas which can contribute to the GRU mission: germplasm expeditions, strengthening national programs, conservation biology research, and linkage with other organization inside and outside the CGIAR system.

Historical Assesment 1990-94

Conservation of Agrobiodiversity of *Phaseolus* Beans: 2,225 new accessions added to the collection, which has reached now 27,434 accessions. A new quarantine house was built for ICA in Bogota to expedite germplasm introduction. A new high altitude location was identify for multiplication and production of good quality seed. Two core collections were assembled for *P. vulgaris*: one of cultivated and one of wild forms; clean seed ready for distribution. Documentation was high priority that enriched the database. A new database on ORACLE software was implemented. A new curator was appointed. A total of 16,120 accessions distributed to 42 countries and 46,734 to the bean program. The main constraints are: Resources for the adequate management of other cultivated species. Lack of a policy for conservation and management of wild non cultivated species. Linkage with other germplasm banks. Need of practical and routine biochemical molecular characterization techniques. Collection has reached a size that present personnel and resources are the minimum for just maintenance. Lack of a facility for germination. Poor data on origin of germplasm from secondary centers.

Conservation of Agrobiodiversity of Tropical Forages: This unique collection consisting of 150 genera and 700 species, reached about 21,000 accessions: 90% legumes and 10% grasses. Acquisition of more variability for *Arachis, Cratylia, Desmodium, Paspalum, Panicum Sesbania* and other MPTS was done through collection and exchange. Phytosanitary procedures were established for a more efficient introduction of germplasm. The reference herbarium was completely reorganized, including new space and equipment. Special taxonomic studies on *Brachiaria* and *Galactia* helped to better understand variability. Documentation was also high priority, which permitted the full implementation of the database on ORACLE software; also, catalogs by species and/or countries published. Biochemical characterization of *Stylosanthes, Centrosema,* and *Arachis* provided an appraisal of their variability. A total of 16,735 accessions were distributed to more than 30 countries. The appointment of a new curator has been implemental on the organization of the collection. The main constraints are: Shortage of resources to speed up the multiplication and duplication. Need for a cool temperature room for temporary storage. Inability to initiate research in in vitro conservation. Insufficient knowledge of seed physiology.

Conservation of Agrobiodiversity of Cassava species: a new in vitro bank was established at the GRU. The collection grew from 4,344 to 5,491 accessions; germplasm introduced in this period were collected in South America, Caribbean, and Asia. A core collection of cultivated cassava was assembled by using geographic origin, morphology , and biochemical characterization. A model for identification of possible duplicates has been developed; it uses morphology, biochemical characterization, and a DNA probe. Promising results are now available for cryopreservation which may imply the availability of a long term storage alternative for cassava. An international workshop assigned the secretariat to CIAT for coordinating a global *Manihot* Genetic Resources Network. Morphological and biochemical characterization has been completed. Efforts have been done to assemble a collection of wild *Manihot* species. A total of 1,126 accessions have been indexed for the main cassava viruses; mainly of core and elite materials. A data base for the management of the in vitro bank was implemented on ORACLE software. A total of 1,684 accessions were distributed to 34 countries. A curator was appointed which will strengthen network secretariat and seed production research for cultivated and wild species. The main constraints are: Addition of more cultivated and of wild *Manihot* germplasm makes collection size surpassing the capacity of the storage room, thus, expansion is needed. Identification of an institution willing and capable to accept a duplicate. Lack of knowledge of seed physiology. Lack of variability representation within wild species. No representation of cultivated *Manihot* germplasm from Africa. Lack of Quarantine procedures for continental exchange.

Seed Health Lab: Its responsibility is to test the seed health status of germplasm of CIAT's commodities. During 1990-94 a total of 11,466 were analyzed for shipments to Africa, Asia, North and South America.

Training: The GRU had a dynamic activity on training professionals of NARS from Latin America. During the last five years 33 professionals from 17 countries were trained on germplasm management. Two international courses were carried out: in vitro management and documentation. There is a continuous increase trend of requests for training.

Future Research Strategy: The three worldwide collections held at the GRU, convey CIAT to a closer involvement in a global scenario. Several forces are pressing CG centers collections to play leading role in the world concern for bioconservation. CIAT has been studying this issue intensively and as a result a document has been proposed by the Genetic Diversity Scientific Resources Group to envision the future on germplasm research. The summary of this document is proposed as the future research strategy, as well as its role.

2. Introduction

(a) Overall goal and objectives and changes since 1990.
The Unit's goals are to assemble, conserve and characterize all critical germplasm resources in *Phaseolus* beans, *Manihot* (cassava) and several key genera/species of tropical forages, and to research those collections, thus ensuring fuller use by international and national programs (NARS). Within the network of the CGIAR Centers, CIAT has global conservation responsibilities toward the three groups of germplasm, as follows:

For tropical forages, CIAT has assumed specific international responsibility for 18 species of nine genera.

For *Phaseolus* beans, the five cultivated species, namely, *P. vulgaris*, *P. coccineus*, *P. polyanthus*, *P. lunatus* and *P. acutifolius* are of global mandate to CIAT. The former IBPGR gave the National Botanical Garden of Belgium to form the base collection of wild *Phaseolus*.

For Cassava, within the CGIAR System, CIAT has accepted global responsibility for conserving cultivated and wild cassava (*Manihot* spp.) germplasm.

The different activities needed to meet above goals and mandates were somehow scattered among the GRU and the commodity programs. After the 1989 EPR, there were several decisions and agreements for assigning full responsibility to the GRU for the management of the germplasm of the three groups of species that CIAT is responsible for. The taking over of those responsibilities was greatly enhanced by the completion in 1991 of new seed bank and in vitro bank facilities. In addition to the management per se of the above collections, two labs. were set up as support to GRU activities: the seed health testing lab. and the electrophoresis lab. Therefore, the period 1990-94 can be considered as one of restructuring and consolidation, brought by new responsibilities, new facilities and an increased emphasis in germplasm research.

Since 1989 to 1991 there was a noticeable input to reinforce and upgrade the GRU responsibilities. However, during 1992-1994 the GRU was also affected by the global CG constraints; a cut down of about 30% budget for the GRU held down the initial 89-91 impulse and put it on a kind of standby, until the situation becomes more favorable. A late major change has been in the organizational structure: the three sections of germplasm collections are now incorporated into the SRG Genetic Diversity Area and its projects nested within the respective megaproject commodity program.

(b) History of overall program activities (1990-94)
b1. Responsibilities: In terms of responsibilities for managing the three collections, there has been historical changes in the three sections.

Beans, since its creation the GRU has been in charge of all stages of germplasm management for beans: acquisition, increase, multiplication, characterization, conservation, data management, and distribution; evaluation to major pests and diseases has been under the responsibility of the Bean Program. At present the GRU continues with the same responsibilities.

For tropical pastures, the GRU was mainly in charge of rejuvenation, conservation, and distribution up to 1989. After this year, most of the management responsibilities that were carried out by the Tropical Forages Program were transferred to the Unit. Thus, the GRU now handles acquisition, initial multiplication, characterization, documentation, regeneration and distribution.

For cassava, the GRU was in charge of the in vitro bank management, since its creation until 1985. When the Biotechnology Research Unit (BRU) was created, the in vitro cassava collection was temporarily handed over, until all the needed research on establishing a routine methodology for the proper management of such a collection was completed. Based on the recommendations of the 1989 EPR, the collection was then returned to the GRU in 1990. The Cassava Program manages the field germplasm bank and characterization, while the GRU is responsible for in vitro cassava germplasm management, particularly in three aspects: germplasm conservation, production of disease free clones in collaboration with CIAT's Virology Research Unit (VRU) and germplasm exchange.

Briefly, during 1990-1991, CIAT reassigned the responsibilities managing tropical pastures and cassava germplasm, with the agreement of the respective commodity programs. Most stages of germplasm management, from introduction to distribution, will be under the GRU's control. The above responsibilities have not change much over the years in the conceptual sense, except for the finding and adoption of new technologies applicable to meet those goals. However, the major changes in terms of responsibilities occurred in the organizational structure, in fact, the three sections of the GRU, i.e. beans, tropical forages, cassava, are now incorporated into the genetic diversity area and its projects nested within the respective commodity program.

b2. Facilities: Successful gene bank management depends on the availability of specialized and centralized facilities. By 1985, because of increasing size of the three collections, it became obvious that new and more adequate facilities were essential to cope with all the responsibilities inherent to germplasm management. With CIAT funds and a donation from the Italian Government additional facilities (refrigeration equipment and modules for cold-rooms) were built by 1991. These facilities included two cold rooms (short- and long-term storage), each capable of storing 100,000 accessions; a drying room with low relative humidity for drying seeds, and a tissue culture laboratory with a storage room for holding the in vitro cassava collection. In addition, CIAT set up a new and well-equipped seed health testing laboratory. With these new facilities, the GRU's physical areas were reorganized, thus freeing space for a new room for the herbarium. In addition, the former seed-testing laboratory was converted into an electrophoresis laboratory. At present the GRU is equipped with adequate seed storage facilities, electrophoresis and seed health laboratories, office, greenhouse and screenhouse space. However, there is the need of a cool temperature room for temporary storage of materials coming from the field, also, the implementation of a Laboratory for quality analysis of seed is an urgent facility because of the increasing number of problems found with the wild forms of the cultivated species and of several species of tropical forages, and of *Manihot*.

b3. Personnel: In 1989 the GRU had two scientists at Ph.D. level, namely, the head of the Unit, and a postdoctoral fellow who managed the tropical forage germplasm. A total of 54 local staff worked for the Unit. Additionally, the GRU had three staff supported by an IBPGR-CIAT special project and one worker supported by USAID grant for bean seed increase. In 1988, the GRU had 31 staff, including the head; thus, more than 20 positions were added to the Unit since then. The increase of the GRU's personnel was mainly due to addition of new responsibilities. Ten of the positions came from the Tropical Pasture Program's Germplasm Section of when the GRU assumed complete responsibility for pasture germplasm management. Another four came from the tissue culture laboratory in accordance with the GRU's new responsibility for in vitro cassava germplasm. Two persons who had worked for the Cassava Program in cassava fingerprinting now work at the GRU's electrophoresis laboratory.

Major changes occurred since 1989 regarding personnel. During 1990 and 1991 there was a real increase of support personnel mainly due to additions of new responsibilities for the tropical forages and cassava germplasm collections. As a means of comparison, the chronological history of the number of GRU personnel shows the following figures: 42 people for 1984, 43 people in 1989, 54 people in 1991, and 40.5 people in 1994. This trend reflects the initial support provide to the GRU after 1989, but also the tremendous effects of CIAT's budgetary crisis of 1992 and 1993, as seen in 1994 when the GRU has presently the lowest number personnel, 40.5 people, after the drastic cuts of these years. Another unfortunate event was the resignation of the Head of the Unit just in the peak of the budget crisis; CIAT had to wait for the crisis to settle down before the appointment of a new Head could be initiated; CIAT is now looking for his replacement.

However, two positive major changes were the appointment of 3 curators for the management of the beans, tropical forages and cassava germplasm collections, and of a senior scientist on genetic diversity. The three curators are at the GAS level position. On the other hand, as part of a join effort between CIAT and IPGRI a senior scientist on genetic diversity was appointed in 1994 in order to provide input and coordinate the development of a Latin American consortium on plant genetic resources and agrobiodiversity. Although the quality of management and research of the collections has been improved, the actual support personnel barely meets the operational maintenance of these big size collections and, thus, limiting the possibilities for needed research and the challenge of additional global responsibilities in the near future.

(c) Major clients, collaborators, partners and regional impacts
The GRU is both a service-oriented and germplasm management unit. It must know who its clients are and their demands in order to be relevant. To carry out the immense task of germplasm management the Unit must effectively link and closely cooperate with important collaborators and partners who are often their clients as well. Such partners and clients are CIAT scientists, NARS and national genetic resources programs, experimental biologists, and IPGRI (formerly IBPGR).

c1. CIAT scientists: CIAT scientists are by far the biggest users of the collections, which they consider as their principal source of genetic diversity. They use the collections as basic building blocks for developing, in collaboration with national programs, enhanced germplasm. CIAT's new Genetic Diversity Area will continue to use the collections in this sense and, moreover, will require new groups of germplasm for the strategic germplasm enhancement programs now being restructured. As its most vital set of collaborators, CIAT's scientists have worked with GRU in four important aspects:

- *Germplasm acquisition.* CIAT scientists have been instrumental in acquiring germplasm. They have conducted a good number of germplasm expeditions. They have also assisted GRU in identifying valuable germplasm conserved by national programs, resulting in subsequent introductions of that germplasm to CIAT's collections.

- *Evaluation and documentation of the collection.* CIAT is responsible for characterizing and evaluating its collections in order to enhance their value through documentation for effective use. Collaboration with Program scientists has been and will continue to be critical for achieving this objective.

- *Better understanding of the genetic diversity.* A sound understanding of the genetic diversity of our mandated germplasm is essential for effective conservation and use. CIAT scientists have contributed significantly to this understanding and, given CIAT's new strategic objectives, will increase this type of research.

- *Improved methodology for germplasm conservation, characterization and distribution.* Cryopreservation, molecular fingerprinting and virus indexing are just a few examples of critical technology that GRU needs for its mission and which are being developed at CIAT. Continuous effective collaboration with BRU, VRU, and other sections of CIAT is essential to GRU's mission.

c2. NARS and National Genetic Resources Programs: National Agriculture Research Systems (NARS), mainly from Latin America, are the principal clients for the entire CGIAR system. Traditionally, GRU's contribution to the NARS has been done indirect, that is, CIAT's Programs have used the collections to develop advanced germplasm useful to the NARS. CIAT's programs have also developed international networks for germplasm distribution and evaluation, thus functioning as intermediaries between GRU and the NARS. Although this arrangement will continue to function successfully, more direct interactions between NARS and GRU will also take place in future. National genetic resources programs, GRU's important clients, are also vital partners who can help its mission in the following ways:
- *Acquisition of germplasm.* CIAT's collections need to be improved for coverage of genepool genetic diversity by strategic acquisition of germplasm from specific regions (termed "hot spots"), as well as new groups of germplasm. This can be done only through collaboration with national programs.

- *Shared* ex situ *conservation.* Safe conservation of germplasm needs the integration of different methods and institutions. Strong national programs can share the huge burden of CIAT's germplasm conservation responsibility. Possible scenarios are CENARGEN in Brazil, FCRI in Thailand, accepting responsibility for duplicating the cassava germplasm through in vitro or cryopreservation techniques; CATIE accepted a duplicate of the *P. vulgaris* germplasm.

- In situ *conservation. In situ* conservation is an important method that complements the *ex situ* conservation approach. Some groups of germplasm can be better conserved *in situ*, for example, forage germplasm, because of its constituting wild species. For effective conservation of multipurpose forage trees and shrubs (MPFTS), *in situ* conservation is an essential component. CIAT considers *in situ* conservation to be the direct responsibility of national authorities and as better executed by national programs. In the near future, beyond providing technical assistance on request where possible, GRU will therefore not often be directly involved. However, because GRU is concerned with a whole genepool of mandated germplasm, it will need to monitor the activities of national programs for *in situ* conservation.

c3. Experimental biologists: The GRU often receives germplasm requests from experimental biologists, who are, typically, researchers at universities from developed countries. They use CIAT's germplasm for basic or strategic research in areas, such as crop origins, biochemical mechanisms for insect resistance and wide crosses. Although they are not our target clients within the CGIAR's definition, they produce information which contributes significantly to a better understanding and use of the germplasm, thus facilitating CIAT in its mission to help developing countries. CIAT's recent emphasis on strategic research puts some of CIAT's scientists in this category. Increasingly, there is a demand for specific types of germplasm, such as genetic stock collections and wild germplasm.

c4. IPGRI (formerly IBPGR): The International Plant Genetic Resources Institute (IPGRI) is a sister center which specializes in international plant genetic resources management. At present, it is developing a strategic plan on how to collaborate with the CGIAR's commodity centers. With a new structure and strategic plan, the IPGRI will continue to be an important partner in CIAT's efforts. Additional professional staff has been allocated to the regional office of the americas located at CIAT. This is a substantial increase from the past level of two professional staff, and enhanced the capability of the Regional Office, making IPGRI a more effective partner in GRU's efforts. There are four major areas in which IPGRI will play a major role as GRU's collaborator.

- *Germplasm expeditions.* IBPGR was a major external financial source for germplasm collection expeditions for species under CIAT's responsibility. Although IPGRI is now decreasing its expenditures on germplasm collection expeditions, GRU will, with IPGRI's support, continue to look for opportunities for collecting germplasm of mutual interest through field expeditions.

- *Strengthening national programs.* CIAT helps national programs in aspects directly related to CIAT's mandated germplasm, whereas IPGRI provides a general service in strengthening national genetic resources programs. Because the same group of people are targeted by both centers, there are many common interests shared by IPGRI and CIAT for institutional building. An in vitro training course held in October, 1992 and another on documentation of genetic resources in June, 1994 are examples of effective collaboration between CIAT and IPGRI.

- *Conservation biology research.* IPGRI does not have its own laboratory or research fields. It collaborates with other research groups to generate relevant information and methods for better conservation of germplasm. Because CIAT has an in-depth knowledge on germplasm management and significant research capability, this center has been and will continue to be an effective collaborator for IPGRI.

- *Linkage with other organization inside and outside the CGIAR system.* Because of recent concern in biodiversity, there is an increased number of players in the area of germplasm conservation. IPGRI is expected to play a key role in acting as a bridge between the CGIAR's Commodity Centers and outside organizations, such as FAO and NGOs, for general aspects of germplasm conservation. IPGRI also plays a catalytic role in the establishment of crop-specific germplasm networks, for example, an international workshop, involving IPGRI, CIAT, IITA and NARS, was held in August, 1992, for cassava germplasm; in addition IPGRI has stimulated the creation of Latin America regional networks for genetic resources purposes. GRU aims to collaborate on those networks and other germplasm groups, when needs arise.

3. Historical Assessment

Genetic Diversity. Project UG01:
Conservation of Agrobiodiversity of *Phaseolus* Beans

- A wealth of genetic diversity of *Phaseolus* beans have been assembled, both for cultivated and wild species. About 2,225 accessions were added to the collection since 1990, reaching now a total of 27, 434 accessions. This includes cultivated and wild forms as follows: *P. vulgaris* (89.5%), *P. lunatus* (5.6%), *P. coccineus* and *P. polyanthus* (3.2%), *P. acutifolius* (1.0%), and 22 wild non-cultivated species (0.7%). This germplasm was introduced through a more selective procedure to fill gaps in the collection. Most of the materials were a result of collecting expeditions to primary centers of domestication and diversification: Mexico, Peru, Colombia.

- Acquisition and introduction of germplasm is now more expedite thanks to the construction of a quarantine greenhouse for ICA in Bogota, which was built with japanese funds. A protocol is already operational for the introduction of germplasm using this facility.

- A new high altitude location (2,000 m.a.s.l) was found and rented for multiplication purposes. Environmental conditions of this location (cool-dry) makes it an excellent place for production of good quality seed.

- Two core collections were assembled: one for cultivated *P. vulgaris* of about 1,100 accessions, and another for the wild forms of the same species. These two groups will help researches to know where best to look for useful genes, and, to find multiple sources of a trait. Evaluation to drought tolerance and low phosphorus has been undertaking. Distribution of nurseries has been initiated. This assembling has been a good example of complementarity among disciplines, units, and programs.

- Multiplication and "cleaning" from pathogen of the core collection was carried out. Good quality seed is ready for distribution.

- Biochemical characterization using proteins and isozymes has been established for groups of particular interest, mainly from primary centers of domestication and or diversification.

- A new procedure was set up for accelerating the transfer of germplasm to long term storage. This will increase the number of materials stored per year under these conditions.

- A curator was appointed for the management of the beans germplasm who will help to better coordinate join activities unit-program.

- Major emphasis was placed on the documentation of the beans germplams originated in the primary centers of domestication and/or diversification, i.e. Mesoamerica and Andean South America. In fact, the effort on compiling existing passport data for beans was of a high importance for assembling the core collections. Implementation of the database under ORACLE software is almost finished. In addition catalogs with relevant data for *P. lunatus*, *P. vulgaris* and wild forms of *P. vulgaris*, were published and distributed to national programs and researches.

- Availability of germplasm has been a key activity in the period 1990 to 1994. Thus a total of 16,120 accessions of beans were distributed to more than 42 countries. Likewise, 46,734 accessions were distributed to the Bean Program and the BRU within CIAT; they were used for evaluation, selection and biochemical molecular studies purposes.

Constraints: a) Need of resources for the adequate management of other cultivated species of *Phaseolus* different from *P. vulgaris*. b) Lack of a policy for conservation and management of wild non cultivated species, since they require special location and facilities. c) Need for effective linkage with other germplasm banks. d) Need of routine biochemical-molecular characterization techniques that can furnish a general overview of the real genetic variability in a rather short-medium term. e) The collection has reached a size that present personnel and resources are the minimum for just the maintenance of the collection without possibilities of dedication to needed research. f) Lack of a facility for germination tests for monitoring viability. g) Poor data on origin of germplasm from secondary centers of diversity, i.e. Africa and Europe.

Genetic Diversity. Project UG02
Conservation of the Agrobiodiversity of Tropical Forages
- A unique germplasm collection of tropical forages of wild and undomesticated species with a wide genetic variability has been assembled. This collection has about 21,000 accessions consisting of 150 genera and 700 species; they are predominantly legumes (90%), but also grasses have been incorporated (10%).

- Concerning acquisition of new germplasm for increasing the variability of important genera as *Arachis*, *Cratylia*, *Desmodium* and *Pueraria* were obtained from collections in Brazil and Vietnam. Likewise, additional germplasm of *Paspalum*, *Panicum*, *Sesbania* and other MPTS were received by exchange.

- As for the conservation of the germplasm, acceptable phytosanitary procedures have been established which permits a more efficient introduction flow of materials. Also, an active program of seed increase for renewal and long term storage was set up.

- The reference herbarium was completely reorganized. Specimens are now stored in alphanumerical order, and all samples are inventoried by computer. A new laboratory was inaugurated with sufficient space for all cabinets and adequate storage conditions.

- Special taxonomic studies were carried out in collaboration visiting scientists and thesis works on *Brachiaria* and *Galactia*. This helped a great deal to better understand the variability of those genera.

- High input was given to documentation. The database for the management of the tropical forages collection was completely implemented on ORACLE software. Also an inventory of species stored in the bank was published, as well as specialized catalogs by genus, countries, or regions i.e. *Centrosema*, Colombia, Venezuela, Central America.

- A biochemical characterization using proteins and isozymes have been carried out in *Stylosanthes*, *Centrosema* and *Arachis* as a complement to the morphological characterization. This approach provided a more broader view of their genetic variability.

- The Working Group on Tropical and Sub-Tropical Forage Genetic Resources was reactivated. A workshop was held in 1994 at CIAT with the participation of Australia, Brazil, CIAT, IPGRI and ILCA.

- Distribution of germplasm is also a continuous demanding task. In fact, during the last five years a total of 16,735 accessions were distributed to more than 30 countries.

- The appointment of a curator as replacement to the postdoc position for the tropical forages collection has been very implemental in the management and organization of this germplasm bank.

Constraints: a) Shortage of resources to speed up the multiplication, duplication, and safe storage of the collection. b) The need for a cool temperature room for temporary storage of seed waiting processing. c) Inability to initiate research in in vitro conservation of non-seeding species like some species of *Arachis*. d) Insufficient knowledge of seed physiology with respect to long term storage.

Genetic Diversity. Project UG03
Conservation of Agrobiodiversity of Cassava species
- A *Manihot* collection, comprising cultivated and wild species in now assembled and maintained, both as a field in vivo collection and as in vitro bank; the latter being established at the GRU since 1990. The world cassava collection has increased in its holdings from 4,344 to 5,491 accessions during the past five years, largely through national or international collecting missions in Brazil, Argentina, Paraguay, Cuba, China and Thailand.

- The definition of a core collection for cassava, accomplished since 1991, took advantage of extensive characterization data collected on accessions of the world collection. The definition of the core was based on the parameters of geographic origin (passport data), diversity of morphological characters, diversity of á ß esterase banding patterns, and a *priori* considerations in favor of particular genotypes. The core collection of 630 accessions is a manageable size which is actively used to assess genetic diversity in cassava for characters which require specific, expensive evaluations and may be difficult to apply to the base collection.

- A model for the identification of duplicates in the collection has been developed and implemented in the past five years. The procedure consists of three steps in which the data base of morphological and isozyme characteristics is first consulted to identify accessions with identical descriptors. Next, putative duplicates are observed side in the same year, and compared morphologically. Accessions still appearing as duplicates are then subject to molecular fingerprinting using an M13 DNA probe. To date 35 groups of putative duplicates at the morphological and isozyme level have been evaluated with M13.

- Research in the methodology of cryopreservation of cassava shoot tips has continued toward the application of this conservation method to a broad range of genotypes.

- International workshops/conferences have helped to set research and support priorities in *Manihot* genetic resources. An international workshop held at CIAT in 1992 to address needs in the area of cassava genetic resources, recommended the establishment of a *Manihot* Genetic Resources Network. CIAT was nominated as secretariat for this network. Participants represented national programs, IBPGR, IITA and CIAT.

- In 1993, CIAT organized a two week training course in in vitro germplasm management with IBPGR, CIP and CATIE in which 15 scientists from 13 Latin American countries participated.

- While the workshop held for the formation of the *Manihot* Genetic Resources Network helped to prioritized needs of various institutions concerned with germplasm and genetic diversity, staffing at CIAT in the area of genetic resources has not been adequate to meet our commitment as network Secretariat. The recent appointment of a Cassava Curator promises to strengthen CIAT networking capacity regarding genetic resources of cassava.

- Morphological and isozyme characterization of the base collection has also been completed, but will continue to be required for new acquisitions.

- In the past, conservation and evaluation efforts have concentrated on cassava, with limited attention being paid to *ex situ* conservation and characterization of the crop's wild relatives. A broader conservation strategy is now envisioned, considering thoroughly both the genetic diversity of the primary gene pool and valuable genes and gene complexes in other *Manihot* species as targets of conservation. To this aim, efforts were done to assemble a collection of wild species, which at present has samples of 29 species.

- A total of 1,126 accessions were indexed for CCMV, CsXV, CALV, CCSpV and FSD. About 45% of this germplasm corresponds to Brazilian materials, and 55% to core and elite materials, which are the most requested.

- Special effort was placed to implement the database for the management of the in vitro bank. This database is fully operational on ORACLE software, and it includes mainly conservation and indexation data.

- Germplasm distribution has been a key and time demanding activity due to the fact that all requests of *Manihot* have to be met as in vitro form, not only for basic germplasm but also for improved materials. A total of 1,684 accessions were distributed to 34 countries during 1990-94.

The appointment of a curator for the management of the cassava germplasm is a positive change that will strengthen CIAT networking capacity and the research related to seed production of cultivated and wild species.

Constraints: a) With the introduction of new cultivated *Manihot* germplasm and the addition of wild *Manihot* species during the last five years, the collection grew to a size that is surpassing the capacity of the storage room, thus, expansion is needed for storage and working area. b) Identification of an institution willing and capable to accept a duplicate of the collection in vitro form. c) lack of knowledge of seed physiology and biology in wild *Manihot* species for multiplication and storage purposes. d) Lack of variability representation within wild species. e) No representation of cultivated *Manihot* germplasm from a very important secondary center of diversity such as Africa. f) Lack of Quarantine procedures for continental exchange of in vitro germplasm; i.e. Africa to America and vice versa.

Seed Health Laboratory

Background and Objectives: The Seed Health Laboratory (SHL) was originally established by CIAT in 1983, in response to the FAO-sponsored meeting, "Consultation on germplasm exchange and phytosanitary activities of international centers", held at CIAT on 15-17 June, 1982. The SHL, initially focused its objectives on checking the seed health of bean germplasm for CIAT's East African Regional Bean Project, with a modest facility for processing a limited number of bean seeds intended for international exchanged. On april 1991, CIAT provided new space and the SHL was well equipped and expanded to include other commodities (rice, cassava). The SHL is administratively supported by the head of the GRU. Technical supervision is provided by the Seed Health Working Group (SHLWG) which consists of virologists and pathologists from CIAT's commodity programs.

The SHL's main responsibility is to test the seed health status of germplasm (beans and tropical pastures) intended for international export. The ICA Plant Quarantine Officer, stationed at CIAT, carries out field and greenhouse inspections and issues ICA's Phytosanitary Certificate (which accompanies all out-going germplasm from Colombia), based on that inspection and results of the seed health status obtained by the SHL. The SHL also collaborates to improve the phytosanitary standards of GRU's germplasm bank.

During the last five years the SHL analyzed 11,466 samples from different sections of CIAT with an annual average of about 2,300 samples. The intended destinations of the analyzed samples were to Africa, Asia, Central America, North America and South America.

Training

Training of professionals from National Institutions (NARS) is a very frequent request for the GRU. During the period 1990-94, a total of 33 professionals from 17 countries were trained on different activities of a genebank management. Also 13 B.Sc. and 2 M.Sc. thesis works were carried out at the GRU in collaboration with several local Universities.

Part of the training consisted of join efforts with other institutions. Two international courses were carried out in collaboration with IPGRI. The first on in vitro germplasm management techniques with the participation of 15 professionals from 13 countries in collaboration with IPGRI, CIP and CATIE. The second, on Documentation on genetic resources with the participation of 16 professionals from 10 countries in collaboration with IPGRI and CIAT.

Likewise, in the last two years there has been an increasing demand for short periods of training on biochemical-molecular techniques and for different species i.e. *Capsicum, Saccharum, Trichantera, Passiflora, Aracea.* The seed health testing lab has also frequent requests for training. During the period 1990-94, seven professional from Tanzania, Brazil, Bolivia, Ecuador, Venezuela and Colombia were trained to learn the routine techniques used by the SHL for germplasm seed health testing.

4. Future Research Strategy

The three worldwide collections held at the GRU, convey CIAT to a more closer involvement in the global scenario. Several forces are pressing CG centers collections to play leading roles in the world concern for bioconservation. CIAT has been studying this issue intensively, and as a result a document has been proposed by the Genetic Diversity Scientific Resources Groups to envision the future on germplasm research. The summary of this document is proposed as the future research strategy and its role.

Conservation of Genetic Resources: CIAT's Role in Germplasm Research. Summary
4.1. As the CG Centers embark on ecoregional-oriented research in natural resource management, genetic resources will pay an even broader role. This brings a broader challenge as specified in the Convention of Biological Diversity (CBD) and Agenda 21. The Center's outputs should now contribute not only increased crop productivity, but to the conservation of the natural resource base. The CG centers must bring their traditional strengths to bear on new challenges, particularly in their work on plant genetic resources conservation. CIAT sees this work as consisting of three interdependent activities: conservation, research, and utilization. Progress in all three requires close integration of various disciplines, techniques, and approaches, including modern biotechnology, conservation biology, plant breeding, geographic information systems (GIS), integrated pest management (IPM), anthropology, ethnobotany, and farmers' participation. In house capacity in the fore-going areas exist in CIAT and other CG Centers, and is not duplicated elsewhere in the same balance and with the same potential for interaction of disciplines.

4.2. Within an interdisciplinary approach, plant breeding forms one link in a complex chain of activities, stretching from molecular genetics to land use analysis. An important challenge in this work is to improve our understanding of biodiversity at the molecular level, relating *ex situ* with *in situ* conservation, while also identifying traits of agronomic or industrial value that open up opportunities for developing new end products.
4.3. By integrating the CG centers' traditional role in commodity research with their role as ecoregional centers, they and their developing country partners can generate information that is critical for establishing a new, system-wide approach to genetic resources work. Such an approach will require the centers to apply more vigorously their existing capabilities in modern biology, database management, and GIS through intercenter collaboration in research and training for key ecoregions. The ecoregional approach may be one rational criterion by which the scope of the CG centers can be broadened beyond their mandate crops.

4.4. Through training, scientific visits, and networks, we can share the results with developing country partners who are evaluating their own germplasm or receiving accessions from the world collections maintained in the CG Centers. Thus the Centers become a critical backup to national institutions in germplasm and information, and for strengthening their activities to monitor, preserve characterize and utilize genetic resources, which is a top a priority of the CBD.

4.5. In developing a new agenda for genetic work and a unified strategy for pursuing it, the CG centers should consider establishing a network that coordinates certain activities to better integrate their work on genetic resources, and communicates its accomplishments and benefits to the community. The participating institutions and individual genetic resources units would remain under the auspices of their centers. An administrative structure that fits an expanded role for the centers is also needed. The CG center's activities on genetic resources must pursue the integration of approaches and activities such as geographic information systems, plant breeding, modern biology, farmer participation, and ethnobotany, within each center and around important research themes at the regional level. These activities would involve: (i) Coordination of Centers' contributions to studies on genetic resources and to *in situ* and *ex situ* conservation within particular agroecologies; (ii) Close partnerships with NGOs', national research institutes, and universities; (iii) Restricted core funding for conservation of genetic resources in each center to provide the continuous support this activity requires; (iv) An endowment fund to support genetic resources activities with priority on conservation independently of the centers' core and complementary budgets; (v) A stronger role for the Intercenter Working Group on Genetic Resources in guiding research and monitoring progress across centers. The chair of this group should be rotated among members, with IPGRI providing a permanent secretariat; (vi) A central role for IPGRI in mobilizing long-term financial support, in shaping policy (e.g. on intellectual property rights), and in maintaining public awareness and links with other organizations working on genetic resources.

Germplasm Development SRG

Leader: Bill Scowcroft
Associated Unit: Biotechnology Research Unit

CIAT applies its strong capacity for genetic improvement of plants strictly to its mandate commodities. In this research we have traditionally concentrated on improving the adaptation of higher yielding germplasm to a broad range of environments, particularly in Latin America, Africa, and Asia. This is a four-stage process.

First, we identify sources of genetic variability to overcome constraints on production imposed by plant pests and diseases and by abiotic stresses, to enhance yield, to improve nutritional or processing quality, and to sustain crop productivity.

Then we assemble and recombine useful genetic variability into gene pools and complexes for variety development. This includes conventional crossing and recombination, novel wide hybridization for interspecific and intergeneric gene transfer, and molecular technology for introduction of defined alien genes and associated regulatory sequences.

The third major component is development of efficient selection strategies for rapid accumulation of desirable genes and gene complexes into adapted genotypes and populations. Conventional selection techniques are now being complemented by biochemical and molecular marker-based selection technologies to speed up the process of selection.

Finally, we foster and promote appropriate networks for effective dissemination of improved germplasm to national plant breeding and variety development programs.

Increasingly, we are taking into account the effects of our mandated crops and their management on the resource base. In so doing our aim is to improve, or at least maintain, production within the context of sustainable agricultural development. This objective will be supported by research aimed at identifying gene complexes associated with efficient use of soil nutrients, water, solar radiation, and which improve soil quality and are compatible with integrated cropping systems in keeping with our agroecological approach to resource management and sustainability.

In addition, we will employ our capacity in plant genetics and improvement to modify the quality traits of the mandated commodities to improve nutritional value and to enable others in developing countries to readily add value through postharvest processing and product development.

Across this whole range of activities, we will extend our pioneering efforts to employ molecular biology to make conventional germplasm development more efficient and diverse.

Expertise Needed

Core competence	Complementary competence	Project area
Genetics/Breeding		Beans - Andean
Genetics/Breeding		Beans - Mesoamerica
Breeding		Beans - East SSA
	Breeding/Agronomy	Beans - South SSA
	Breeding/Agronomy	Beans - Central SSA
Breeding		Cassava
Breeding		Cassava - Asia
Breeding/Agronomy		Cassava - SSA
Breeding		Tropical forages
Breeding		Rice - Upland
Breeding		Rice - Lowland
	Breeding	Rice - Upland/lowland
Biochemistry		Various crops
	Biotechnology	Cassava
	Biotechnology	Rice
	Biotechnology	Beans
Agronomy (GxE)		Tropical forages
Agronomy (GxE)		Beans - LA
	Agronomy	Beans - LA
	Agronomy	Tropical forages - Asia
Physiology (plant)		Cassava - LA
Physiology (crop)		Rice
	Physiology (roots)	Rice
Physiology		Beans
Product processing		Cassava
	Product processing	Cassava
	Product processing	Cassava
	Product processing	Cassava
Economics		Cassava
Biometry		Various crops

Competence Descriptors

Genetics:
- Inheritance of agronomically useful traits at the monogenic and polygenic levels.
- Protocols to maximize phenoypic expression of useful genetic variability.
- Mating systems, reproductive biology, and polyploidy.
- Application of biochemical and molecular technologies to identify and isolate useful genetic variability.

Breeding:
- Identification and assembly of genes and gene complexes carrying useful genetic variability.
- Novel hybridization and recombination protocols.
- Selection design, protocols, and their implementation.

- Statistically robust evaluation of breeding material at differing stages of development.

Biochemistry/physiology
- Physiological basis of stress response.
- Biochemical basis of gene action for defined useful traits.
- Development of biochemical selection protocols.

Biotechnology:
- DNA markers and molecular maps for gene identification.
- DNA-based protocols for rapid and efficient selection and to pyramid gene complexes.
- Tissue culture and micropropagation.
- Embryo culture to rescue interspecific hybrids.
- Development of genetic transformation protocols.

Agronomy:
- Field evaluation and validation trials with NARS of gene pools and advanced breeding material.
- Genotype x environment interaction in major target areas.
- Adaptation of forages to various farming systems.
- Determination of factors influencing relations among plants and changes associated with soil and crop/pasture management.

Product processing:
- Postharvest intermediate stage processing of crops.
- Prototype development of low-cost conventional and novel products.
- Identification of genetically controlled postharvest quality traits.

Economics:
- Economic assessment and impact of changes in varieties, production, and postharvest processing.

Networks:
- Foster and promote germplasm exchange, research coordination, training and information transfer in Latin America, Africa, and Asia for mandated crops.
- Assist national programs in matching gene pools with farming systems to increase sustainable productivity.
- Integrate with resource management research to achieve sustainable productivity in agroecologies where CIAT works.

Staff List - September 1994

COMPETENCE	STAFF MEMBER
Genetics/Breeding	J. Kornegay
"	S. Singh
"	H. Gridley
"	V. Aggarwal
"	W. Youngquist
"	C. Iglesias

"	K. Kawano
"	J. Miles
"	E. Guimaraes
"	C. Martínez
"	M. Chatel
"	M. Winslow
Biochemistry	J. Mayer
Biotechnology	W. Scowcroft - Leader
Agronomy	P. Argel
"	O. Voysest
"	W. Stur
"	R. Lépiz
Physiology	M. El-Sharkawy
"	K. Okada
"	J. White
"	G. O'Brien
Product Processing	R. Best
"	D. Dufour
"	D. Jones
"	B. Ospina
Statistics	M.C. Amézquita

Germplasm Development Project Profiles

1. Tagging and Cloning the Apomixis Gene in *Brachiaria*

Purpose: To open the way for development of apomictic crops by locating and starting to clone and manipulate the apomixis gene in *Brachiaria*

Rationale: Apomixis is a potent mechanism for propagating heterozygous (i.e., hybrid) genotypes just as easily as we multiply inbred lines of self-pollinating crops. Apomixis occurs naturally in many tropical forage grasses (e.g., in the genera *Brachiaria*, *Panicum*, *Pennisetum*, and *Cenchrus*).

CIAT improves *Brachiaria*, using an induced tetraploid, sexual *B. ruziziensis* developed in Belgium and obtained from EMBRAPA. The evidence available as well as theoretical considerations suggest that apomixis is under simple genetic control.

Expected Benefits: Cloning and manipulating the apomixis gene and transferring it from *Brachiaria* to other crop species could have an enormous payoff. Millions of farmers would gain a convenient, inexpensive way to multiply their own true seed of hybrids and other superior genotypes rather than purchase this input from government or commericial seed producers.

Expected Outputs:
- Molecular markers linked to the apomixis gene
- A *Brachiaria* map
- Fine mapping of apomixis
- Significant progress toward cloning the apomixis gene

Activities:
- Develop mapping populations and embryo sac and screen F1 plants.
- Screen RAPD markers, with bulk segregant analysis and in the whole population.
- Conduct linkage analysis.
- Screen rice-mapped clones as a first step toward comparative mapping.

Research Partners: EMBRAPA (Brazil), ORSTOM (France)

Scientists at EMBRAPA are studying the genetics of apomixis and developing sexual *Brachiaria* compatible with the *B. humidicola/B. dictyoneura* species complex. ORSTOM has the necessary expertise and facilities for cloning and manipulating the apomixis gene. CIAT is uniquely positioned to provide leadership in this research, since it is already working with a naturally apomictic species and has the expertise and infrastructure needed for all steps up to fine mapping.

Potential Donor: World Bank

Funding: $2.5 million; **Time Frame:** 5 years

CIAT Project Officer: Joe Tohme

2. A Molecular Map of Cassava and DNA Fingerprinting of Cassava and its Wild Relatives

Purpose: To develop a genetic map of cassava, based on RFLP and RAPD markers, that provides genome-wide markers to monitor introgression of useful traits from exotic germplasm into cassava

Rationale: CIAT holds the world's largest collection of cassava germplasm and a representative collection of the various wild *Manihot* species. The collection is well-characterized for diseases, insects, agronomic traits, and quality factors, but the genetics of cassava and its ploidy level are not well understood. While classified as a tetraploid, cassava seems to behave as a true diploid species. Few simple inherited traits have been identified; most of the important traits identified are of a quantitative nature. Such traits are difficult to screen for and to manipulate in a breeding program.

Expected Benefits: The construction of a detailed genetic map of cassava will contribute significantly to the understanding of cassava genetics. The map will be used to analyze the genomic structure of cassava and its wild relatives, to estimate the level of variability and heterozygosity within and between gene pools, to understand the evolutionary relationships between the various species of *Manihot*, to facilitate introgression of genes for target traits from wild to domesticated species, and to tag agronomically important traits. The map will eventually be used to isolate and clone cassava genes.

Expected Outputs:

A better understanding of cassava genetics
A molecular map
Markers for gene tagging and DNA fingerprinting
A understanding of species relationships based on molecular data
Molecular characterization of gene pools

Activities:

Construct and screen cassava genomic libraries.
Generate mapping populations and evaluate for agronomic traits.
Linkage analysis of RAPD and RFLP data.
Implement nonradioactive labelling.
Screen the core collection of cassava with molecular markers.

Research Partners: CENARGEN (Brazil), CORPOICA (Colombia), CIF (Colombia), University of Georgia and Washington University (USA), IITA

Proposed Donor: Rockfeller Foundation

Funding: $300,000; **Time Frame:** 3 years

CIAT Project Officer: Meredith Bonierbale

3. Novel Genetic Strategies to Improve Quality of Cassava Starch

Purpose: To increase the genetic variability of the amylose and amylopectin ratio in cassava, thus expanding the industrial use of its starch and markets for cassava as a cash crop

Rationale: Low variability in the amylose and amylopectin ratio of starch in cassava germplasm limits its potential use in industry. Many industrial applications require amylose-free starch, which cassava lacks but is found in waxy maize and potato genotypes. Some developing countries must import large amounts of waxy maize and potato to satisfy local needs. Cassava genotypes that produce starch with varying ratios of amylose and amylopectin would increase small farmers' revenues and reduce dependence on starch imports. CIAT works on isolating and cloning two genes that could affect the amylose/amylopectin ratio. The genetic transformation of cassava at CIAT is underway, and a protocol applicable to important genotypes should be available soon.

Expected Benefits: This research will increase the attractiveness of cassava as a cash crop for small-scale cassava farmers and will widen use of cassava starch by the industrial sector. The project will offer genotypes with higher starch quality to national programs.

Expected Outputs:

New sources of genetic variability for amylose and amylopectin in cassava starch

A methodology for producing transgenic cassava which will also be useful for introducing other traits

Activities:

Establish a reproducible genetic transformation protocol for cassava.

Clone the genes encoding the starch-branching enzyme isoforms and the granule-bound starch synthase isoforms.

Manipulate these genes for high expression in cassava roots.

Test transgenic plants that produce various amylose/amylopectin ratios.

Research Partners: CORPOICA (Colombia), EMBRAPA (Brazil), FONAIAP (Venezuela), national programs of Indonesia and Thailand

Proposed Donors: Rockefeller Foundation, private sector (cassava starch industry in Brazil, Indonesia, Thailand)

Funding: $600,000; **Time frame:** 5 years

CIAT Project Officer: William Roca

REPORT 1989-94 FOR THE EPMR'94

Biotechnology Research Unit

Sept/94

CONTENTS

Biotechnology Research Unit Report 1989 - 94 for the EPMR'94

Executive Summary

The Biotechnology Research Unit (BRU) was established in 1985 in response to a recommendation by the Panel of CIAT's Second External Program Review of 1984, to perform as a scientific bridge for developing applications of modern biological methods for increasing the efficiency of CIAT strategic research in germplasm development and natural resource management. The BRU's work of the last 5 years has involved: (i)analysis of genetic diversity using molecular markers and identification of useful genes by genetic mapping; (ii)studies of plant-stress interactions at the molecular level and identification of points for genetic manipulation; (iii)gene transfer from alien sources using cellular and molecular biology techniques, and the conservation of genetic resources by *in vitro* techniques.

Major highlights of the period 1989-94 include:

1. Molecular markers (RFLP, RAPD, SCAR, SSR and AFLP) and genomic maps of rice and beans have been used for: understanding *Phaseolus* genetic variability and crop evolution, identification of genotype duplicates in the cassava germplasm collection and for tagging of *Brachiaria* apomixis gene, and resistance genes to rice blast fungus. Construction of the cassava molecular linkage map is well advanced at CIAT.

2. Biochemical-molecular approaches have been used to search for resistance factor(s) to bean bruchids, to characterize amylolytic bacteria from cassava sour starch fermentation, and for the analysis of the plant-pathogen interactions as in the case of common bean with *Colletotrichum* and *Phaeoisariopsis*.

3. Embryo rescue and particle bombardment-, and *A. tumefaciens*-, mediated transformation, and plant regeneration techniques have been used for *Phaseolus* interspecific hybridization, production of transgenic *Stylosanthes* and rice plants, and development of transformation methods for cassava and common bean.

4. Anther culture has been used for the production of doubled haploid rice lines and incorporation into rice breeding; meristem/shoot tip culture has been utilized for the conservation of cassava genetic resources; more recently, successful cryopreservation of cassava shoot tips was achieved.

5. The BRU has been involved in establishing 12 formalized research links (i.e. through external project support) and 15 non-formalized cooperations with advanced research institutes in the U.S., Europe, Australia and five developing countries.

6. The BRU has contributed to the creation/functioning of international biotechnology research networks for cassava and common beans, and has been an active member of the rice biotech program of the RF. The networks have provided an effective means of linking developed with developing country biotech research.

7. Throughout the last five years, the BRU has developed and transfered seven working technologies and biotech activities for implementation and use in CIAT Programs and Units;

Biotechnology Research Unit Report 1989 - 94 for the EPMR'94

1. INTRODUCTION

CIAT's involvement in biotechnology research should be viewed as sharing the responsibility of bridging between advances made in developed countries and the application to priority challenges in tropical, developing countries. In its long-term plan for the 1980's CIAT anticipated its involvement in monitoring and applying biotechnology. In fact, work in tissue culture for the conservation and micropropagation of cassava germplasm in CIAT had begun in 1979. This work was followed in the early 1980's by the use of anther culture in rice breeding schemes of CIAT. The Biotechnology Research Unit (BRU) was established in 1985 as a response to a recommendation by the Panel of CIAT's Second External Program Review of 1984.

1.1 BRU Goal, Strategies and Outputs

Objective. The BRU is designed to perform as a scientific bridge to develop applications of modern biological methods for increasing the efficiency and cost-effectiveness of CIAT strategic research in germplasm development and natural resource management.

Strategy. To achieve its objective the BRU: (i) strives to integrate biotechnology with other strategic research at CIAT. (ii) contributes to develop crop-specific biotechnology networks; (iii) contributes toward strengthening the biotechnology capacities in developing countries. CIAT's bridging role with the NARS of developing countries involve: cooperative research projects; training of developing country scientists; and organization of special workshops; stimulation of awareness on topics such as biosafety and IPR are also included.

Outputs. In the last few years, the BRU has focused on three inter-related activities across CIAT germplasm research, with the following outputs:

(i) DNA-based methods and techniques for the characterization and analysis of genetic diversity of plants and microorganisms.

(ii) Molecular-biochemical methods and techniques to identify points for genetic nanipulation in selected plant-stress interactions.

(iii) Molecular and cellular techniques for gene transfer and conservation of genetic diversity.

(iv) Strengthened partnerships in biotechnology research with developing countries.

1.2 History of Overall Unit Activities (1989-94)

The BRU's work in the last 4-5 years has involved the following components of CIAT's strategic research: (i) the characterization and analysis of genetic diversity through the use of molecular markers and the identification/tagging of useful genes by genetic mapping; (ii)studies of plant-stress interactions at the molecular level and the identification of critical points for genetic manipulation; (iii)broadening the available crop genetic base by gene introgression and transfer from other sources using cellular and molecular biology technologies, and the conservation of genetic resources by *in vitro* techniques, including cryopreservation.

Throughout the past few years, the BRU has successfully developed biotechnology applications which have been transferred to various users in CIAT programs and units, and the NARS of developing countries.

A sizable portion of biotechnology research activities at CIAT has involved special projects, supported by complementary funding.

Most of the research activities highlighted in this report have been carried out in close cooperation between the BRU staff and CIAT Programs/Units scientists, and the participation of national program scientists.

Table 1 shows the range of activities engaged by the BRU in the period 1989 - 94, with attention paid to the research topics, the tools/technologies developed and utilized for approaching selected challenges, and the CIAT organism involved, e.g. crops, pathogens, etc.

Staffing of the BRU in the period 1989-94

Senior Scientists

· Tissue culture/genetic transformation	1	core
· Molecular mapping	1	core
· Molecular biochemistry	1	core

Post-Doctoral Scientists

· Molecular biology	1	complementary - Beans
· Molecular genetics	2	complementary -Cassava
· Cell biology	2	Complementary - Beans and Rice

1.3 Major Clients and Regional Impact

- **At CIAT**. CIAT Programs and Units scientists have been the immediate clients of the BRU research. BRU's research products (methodologies, techniques, genomic maps, DNA probes, etc) have been made available to CIAT scientists as an important step in integrating biotechnology with CIAT research. The BRU has organized workshops involving scientists of each commodity program and continuously trains programs/units technical staff in specific techniques. The BRU supports Programs/Units efforts to implement lab. facilities and equipment for conducting research using biotechnology.

Table 1. Overall Activities of the BRU in the Period 1989 - 1994

Research topic	Methodology and Tools	Organism
1. Germplasm conservation and characterization	• In vitro culture/cryopreservation • DNA fingerprinting	Cassava Cassava, Beans
2. Genetic structure of pathogens	• DNA fingerprinting	Pyricularia, Xanthomonas, Colletotrichum
3. Identification/tagging of resistance genes	• Molecular genetic maps	Bean, Rice, Cassava,
	• Gene tagging	Rice blast, RHBV, Apomixis, BCMV
4. Plant-stress mechanisms and geneproducts	• Molecular biochemistry	Beans, Cassava, Tropical Forages
	• Gene Cloning	
5. Broadening genetic base	• Inter-species hybridization	Beans
	• Genetic transformation - Plant regeneration - Gene transfer	Rice, Stylosanthes, Cassava, Beans
6. Cooperation with developing and developed countries	• Biotech research networks	Cassava, Beans (Rice)
	• Capacity building - Training	Cassava, Beans, Rice (LA), Tropical Forages

• **In the NARS**. The institutions involved in biotechnology research in Latin America and the Caribbean (LAC) include Universities and advanced research centers and the classical NARIs. Roughly, four levels of development in biotechnology can be recognized in Latin America and Caribbean countries. The first group includes Mexico, Brazil, Cuba and Argentina where intermediate-to-advanced labs and high quality scientific personnel exist. The second group includes Costa Rica, Venezuela, Colombia, Uruguay and Chile where well trained , but limited in #, personnel is present, and good laboratory infrastructure is developing. The third group includes Ecuador, Guatemala, Bolivia, Panama, Jamaica and Peru where some human resources exist, as well as some laboratory facilities. Finally, the fourth group includes countries from the Caribbean region, El Salvador, Nicaragua, Honduras and Paraguay where interest in biotechnology exists.

In our view, the main constraint to efficient development of agrobiotechnology in the LAC region is the the lack of integration of biotechnology tools with ongoing agricultural research/development, especially plant breeding, i.e. the research activities are often out of context in terms of crops, research constraints and socioeconomic realities. The role of CIAT has been to share with LAC scientists its philosophy and operational activities for integrating biotechnology tools with agricultural research relevant to the crops and research challenges of the region.

2. HIGHLIGHTS OF ACHIEVEMENTS SINCE 1989

The BRU research has focused on cassava and wild *Manihot* relatives, common bean and related cultivated *Phaseolus* species and wild relatives, rice for Latin America and selected species of tropical forages (*Brachiaria, Arachis, Stylosanthes*), and deals with three inter-related activities: (i)molecular characterization, analysis and identification of useful genetic diversity; (ii)characterization of plant-stress interactions and identification of points for genetic manipulation; (iii)gene transfer and conservation of genetic resources.

2.1 Molecular Characterization, Analysis and Identification of useful Genetic Variability.

DNA-based maps and markers have been developed and used for more accurate analysis of genetic diversity, for the identification of gene pools/ populations and useful genes, and to facilitate a more efficient utilization of genetic resources.

Table 2 shows the range of molecular markers implemented with CIAT crops, as well as the molecular genetic maps and the number of probes available at CIAT. While the rice molecular map was obtained from Cornell University, through the RF Rice Biotech Program, and the common bean map was obtained from the Univ. of Florida, Gaineville, the cassava molecular map is being entirely constructed in CIAT.

2.1.1 Understanding Crop Genetic Diversity

Studies with wild relatives and cultivated landraces of *Phaseolus vulgaris* from Colombia, Ecuador and Peru, using the seed protein phaseolin and RAPD markers have demonstrated: (i)that wild beans are much more variable than cultivated beans; that there is a reduction of genetic diversity in the common bean gene pool ("founder" effect.), implying the existence of still large genetic diversity in the wild populations that need to be adequately conserved and utilized; (ii)that there is natural gene flow between wild forms and primitive cultivars in regions like Apurimac and Cusco (Peru), with the development of intermediate "weedy" types *in situ*; (iii) a core collection of common bean was formed using agroecological data and molecular markers.

Matching of molecular information with agroecological and geographic information systems (GIS) data is being pursued in order to obtain information on distribution of wild *P. vulgaris* diversity and sites for future collection and conservation.

2.1.2 Identification of duplicates in germplasm collections

Ex situ conservation plays a major role in the preservation of genetic diversity of cassava. Using passport, morphological and isozymes characterization, 20-25% of duplicates were identified. Such high level of duplication makes it more expensive to maintain and manage the existing collection. A collaborative project on DNA fingerprinting between the BRU the GRU, and the Cassava Program, was initiated in 1992 to use DNA fingerprinting for enhancing the power of morphological description and isozyme fingerprinting for characterization and duplicate identification.

Table 2. Molecular Markers and Genomic Molecular Maps Implemented at CIAT in the Period 1989 - 94 for Genetic Diversity and Plant Breeding Applications

Technique (Year)*		Institution**	CIAT Crops
1. RFLP:	Restriction Fragment Length Polymorphism (1985)		Cassava, Rice, Beans
2. RAPD:	Random Amplified Polymorphic DNA (1991)		Cassava, Rice, Brachiaria, Beans
3. SCAR:	Sequence Characterized Amplified Regions (1992)		Brachiaria, Rice
4. SSR:	Minisatellites, Simple Sequence Repeats (1992)		
5. AFLP:	Amplified Fragment Length Polymorphism (1993)		Beans, Rice, Brachiaria
•	Rice molecular genetic map and 400 probes	Cornell Univ.	Rice, Brachiaria
•	Common bean molecular genetic map and 300 probes	Univ. Florida	Common bean, tepary bean
•	Cassava molecular genetic map in progress and a library of 1000 clones	CIAT	Cassava

* Approximate date of first use in plant genome studies worldwide.
** Institution where the molecular map has been constructed.
1. Endonuclease restriction, southern blotting, hybridization
2. DNA amplification with random primers
3. DNA amplification with specific primers
4. DNA amplification with primers flanking sequence repeats
5. Endonuclease restriction, DNA amplification

DNA fingerprinting, using the gene for the protein III of the bacteriophage M13 (DNA minisatellite) was applied to a group of 85 clones comprising 34 groups of possible duplicates (as defined by morphological and isozyme fingerprinting criteria). Analysis of the fingerprints confirmed that 27 groups were indeed duplicates (80% of the initial population) while the other 7 groups were identified as distinct from each other.

The technique will be applied in the GRU to all the cassava clones suspected of being duplicates (about 1000 clones).

2.1.3 Genome mapping and identification/tagging of useful genes

- **Construction of a molecular linkage map of cassava.** The construction of the cassava molecular map at CIAT has progressed significantly. The map is being drawn from F1 segregation data of RFLPs and single dose polymorphism of RAPD markers. The work utilizes an F1 population of ninety plants derived from a cross between two elite cassava lines, MNG2 (TMS 30572), possessing resistance to the African Cassava Mosaic Virus (ACMV) disease and (CM 2177-2) (ICA - Cebucan) possessing high photosynthetic rates. A total of 12 linkage groups have so far being identified containing 200 RAPD and 100 RFLP markers; we expect that the first map framework will be available by the second semester, 1994. The availability of the map will allow to increase the efficiency of introgression of specific chromosome fragments from exotic germplasm into various genetic backgrounds, and the localization of genes of interest in cassava improvement schemes.

- **Tagging of *Brachiaria* apomixis gene(s) with RAPD markers.** A molecular genetic marker closely linked to the apomixis gene would permit identification of reproductive mode of *Brachiaria* individuals in segregating progenies, prior to flowering, thus improving the efficiency of *Brachiaria* breeding.
  An induced tetraploid sexual *B. ruziziensis* clone was used as a female parent in crosses with a natural tetraploid apomictic *B. brizantha* accession. To date 500 RAPD primers have been screened using the bulk segregant analysis. Two hundred fifty polymorphic primers were observed between the parental genotypes and between F1 bulks. Of these, 20 primers produced bands which were associated only with the apomixis phenotype both in parents and in the F1 bulks. One primer was identified at 10 cM from the apomixis gene. SCARs for the RAPD marker are being obtained by sequencing the relevant fragment. The polymorphic primer along with mapped clones of rice (Cornell clones), maize (CIMMYT clones) and wheat (John Innes clones) are also being used to construct a *Brachiaria* map. Preliminary screening indicates good homology between rice and *Brachiaria*. Our goal is to fine map the apomixis gene to improve the efficiency of *Brachiaria* breeding and to eventually clone and transfer this gene to other crops.

- **Analysis of pathogen genetic diversity and mapping of resistance genes to Colombian rice blast families.** "Blast", caused by the fungus *Pyricularia grisea* is the most widespread and damaging disease of rice in the tropical and temperate zones. The fungus expresses a large number of virulent pathotypes and farmers control the disease by heavy pesticide applications. Most improved varieties, initially resistant, become susceptible within a few seasons after release. A probe, consisting of cloned fragments of repeated DNA was isolated from the fungus and used by collaborators at Purdue University to develop an understanding of the structure of fungal populations and to reduce races to "families" with similar genetic background. CIAT scientists found that pathotypes within families attack only certain rices, conversely rice varieties were identified that resist specific blast fungal families. Fingerprinting also allowed CIAT to relate each parental line component to corresponding blast families.

  Doubled haploid lines, generated by anther culture, from the IRAT 13 (resistant) x Fanny (susceptible) cross were screened with blast isolates belonging to six MGR lineages and RFLPs markers from the rice molecular map. RFLPs and RAPDs markers were identified to be linked to a cluster of resistance genes isolated from two lineages SRL-1 and SRL-6. RAPDs fragments of the tightly linked primers

have been cloned and sequenced to develop sequenced characterized amplified regions (SCARs) to facilitate future PCR based screening.
Another RFLP marker was found to be linked to a resistance gene for an Altillanura isolate belonging to lineage ALL-7. Fine mapping of the gene is progressing. Screening of the IRAT 13 x Fanny mapping population with isolates from the remaining lineage is near completion. The data will be used for linkage analysis to detect genes of resistance to most of the lineages in Colombia. The relationship between the tagged genes and MGR lineages resistance, and its implications for durable rice blast breeding, are being pursued.

2.2 Characterization of Plant-stress Interactions and Identifications of points for Genetic Manipulation

Gaining an understanding of the molecular/genetic processes that underly plant/stress interactions is a necessary step for the identification of points for genetic manipulation. Identification of specific factors (e.g. proteins) and cloning of the correspondent genes have been two research activities utilizing a range of techniques, from extraction to separation and analysis at the biochemical-molecular levels.

2.2.1 Molecular analysis of host plant-pathogen interactions

A first step in developing a biotechnological approach to this challenge includes an assessment of the pathogen genetic diversity and population dynamics in order to relate to the molecular evolution of virulence. This work is underway at CIAT in the case of two pathogens: *Colletrotrichum lindemuthianum* (CL) and *Phaeoisariopsis griseola* (PG), the causal agents of anthracnose and angular leaf spot in common beans, respectively these diseases are widely distributed and cause serious economic losses.

Analysis of CL shows the existence of very close genetic relationship between several pathotypes; other pathotypes show high genetic homology to some, but not so to others. Analysis of PG indicates high regional pattern conservation among isolates, thus he Mesoamerican cluster can be clearly separated from the Andean cluster; furthermore, pathotypes with different virulences spectrum are also subdivided by RAPD analysis within clusters. Future work in this project will correlate the molecular diversity data of the complete CL and PG collections, with pathotyping data, and later molecular markers linked to avirulence genes will be sought as a step towards the cloning of these genes.

2.2.2 Searching for resistance factors to the bean weevil

Transfer of resistance to the bean weevil, *Acanthoscelides obtectus* by cross breeding has not been successful. We have identified ad inhibitory factor to the bruchid in acetone-soluble fractions from wild *P. vulgaris* resistant accessions. Polyclonal antibodies are being prepared using these protein fractions for screening cDNA libraries in expression-vectors. On the other hand, the technique of differential mRNA expression is being utilized to identify DNA library for the correspondent resistant genes. The cDNA library will be also used in expression vectors for screening with the polyclonal antibodies, as refered to above.

2.2.3 Characterization of amylolytic lactic acid bacteria from cassava sour starch fermentation

Sour cassava starch is a naturally fermented product of economic importance in the food industry, especially in Colombia and Brazil. The product has a high potential for broader industrial applicability. 75 amylolytic lactic acid bacterial isolates (ALAB) from the fermentation mass and from natural inocula have been collected and further characterized. We have grouped 60 purified isolates according to their protein profiles on denaturing polyacrylamide gels. Using HPLC analysis we are in the process of quantifying the organic acid production of our ALAB collection.

Selected isolates were compared to a *Lactobacillus plantarum* strain (AG) isolated in Africa and characterized by ORSTOM, that has been reported to be a great amylase producer. ALAB1 showed higher amylolytic activity than AG. We have sequenced ribosomal DNA amplified by PCR, of the most promising ALABs. This information was used to classified the isolates, into related groups as a first step toward the production of specific probes for strain identification and monitoring during the fermentation process.

2.3 Gene Transfer and Conservation of Genetic Resources

In the last few years, we have utilized *in vitro* culture and molecular-genetic techniques for gene transfer with CIAT crops. While hybrid embryo rescue and culture have been applied to inter-specific *Phaseolus* crosses, genetic transformation followed by plant regeneration has been successfully applied to rice (biolistic technique) and *Stylosanthes* (*A. tumefaciens* vectors), and methodologies are being developed with cassava (*A. tumefaciens*) and beans (biolistics).

2.3.1 <u>Inter-specific gene transfer.</u> Barriers to gene flow increase as one departs from *P. vulgaris*, to *P. coccineus* and *P. polyanthus*, to *P. acutifolius* and to *P. lunatus*. The tepary bean (*P. acutifolius*) is a source of important traits such as high level of resistance to bacterial blight and bruchids, tolerance to leaf hoppers and tolerance to drought which are not found in wild, weedy and cultivated forms of (P. vulgaris). Attempts to transfer such traits to common bean have generally failed due to early embryo abortion, hybrid incompatibility and sterility. Recent work at CIAT has shown that an improved embryo culture technique allowed to produce large numbers of hybrid plants for evaluation. Seed protein electrophoretic patterns and hypervariable DNA probes served to monitor gene transfer through successive backcross generations. The goal is to develop an interspecific gene pool for ready transfer of tepary traits to other genotypes.

2.3.2 <u>Genetic transformation.</u> Genetic transformation offers a direct means to introgress genes into plants from other species, genera, taxa, or artificially made gene constructs.

• **Gene transfer for resistance to pathogens:** *Rhizoctonia solani* and *Colletotrichum lindemuthianum* are two important fungal pathogens of rice and *Stylosanthes* in Latin America, respectively. All rice varieties are susceptible and there is no known source of natural resistance. In the case of anthracnose, levels of resistance are low and not easily accessible. The barley ribosome-inactivating protein gene (rip) is a candidate gene for a transgenic antifungal approach. Work at CIAT to modify the *rip* construct (obtained from the Max-Planck Institute, Cologne) is underway; the objective is to try both constitutive and wound-inducible expression of the gene using appropriate promoters.

Work at CIAT with **rice** transformation is well advanced; using the biolistic method, plasmids harboring marker genes have been introduced into immature zygotic embryos and panicles; proliferating cells with strong expression of the *gusA* gene were selected, and regenerated plantlets carrying the selectable marker gene *hyg* have showed resistance to the antibiotic hygromycin. Work is underway to incorporate the *rip* gene into important Latin American *indica* rice genotypes.

A protocol for transformation of ***Stylosanthes guianensis*** was developed at CIAT using *Agrobacterium tumefaciens*, and transgenic plants already exist expressing marker genes. Current work will utilize this transformation technique for expressing the *rip* gene in *S. guianensis* genotypes important to Latin America.

Another important rice pathogen in Latin America is the Rice Hoja Blanca Virus (RHBV) for which a transgenic approach will contribute to minimize outbreaks of the disease by incorporating new sources of resistance. Two strategies are being attempted: coat protein-mediated cross protection and antisense RNA. CIAT Virology Research Unit has developed constructs with the RHBV coat protein and antisense RNA genes, and the biolistic transformation technique is being utilized in the BRU for transformation.

• **Gene transfer to improve quality**. Improving the quality of **cassava** starch would open new market and industrial opportunities for the crop; this in turn would increase the demand for cassava production at the farm level. The range in amylose/amylopectin ratios in cassava starch is too narrow. Collaboration with advanced labs engaged with the cloning/manipulation of starch genes of cassava (Agricultural Univ. of Wageningen, The Netherlands) is an essential component of this project.

CIAT has progressed towards developing a transformation protocol for cassava. We used a CIAT *A. tumefaciens* strain in conjunction with the plasmid pGV1040 containing the nptII, gus and bar genes; the explants were cotyledonary leaves from young somatic embryos of cv. M. Peru 183. Several basta resistant plantlets were obtained from GUS positive somatic embryos regenerated from these explants. Work is underway to confirm the presence and expression of the foreign genes in cassava plants grown in the greenhouse. So far, some plants have shown tolerance to Basta.

2.3.3 Conservation of genetic resources. Conservation of genetic resources involves both *in situ* and *ex situ* approaches. *Ex situ* conservation comprises a range of approaches, from field gene banks, seed genebanks, to in vitro genebanks: tissue culture banks, DNA banks and cryopreservation.

An *in vitro* active gene bank (IVAG) has been developed at CIAT which maintains more than 5500 clones. This collection is maintained at CIAT Genetic Resources Unit, under slow growth conditions (reduced temperature and special medium), i.e. sub-culture interval of 12-18 months, in a $50m^2$ laboratory, which represents one thousandth of the area needed to maintain a similar collection in the field. The IVAG has contributed to make cassava clones widely available.

While the cassava IVAG requires periodic sub-culturing, **cryopreservation** is ideal as it stops cell functions, and thus cell deterioration is avoided to achieve indefinite preservation of the plant genome. CIAT has been engaged in developing cryopreservation of cassava shoot tips since 1989. Recovering of complete cassava plants from shoot tips frozen in liquid nitrogen was achieved in 1991. Since then, the technique was consistently improved to reach over 60% plant recovery rates from a number of genotypes. Main factors contributing to successful cassava cryopreservation include:

tissue dehydrating treatments, rate of cooling and culture media after freezing. A simplified protocol for more efficient and less costly freezing is being developed.

2.4. Advance Research Linkages

From the outset, the BRU has pursued to develop collaborative linkages with advanced research labs. in the USA, Europe, Australia. Twelve of such linkages have been formalized through special projects with external funding; 15 other have remained informal, but still useful. In the case of cassava and beans, CIAT has been pro-active in the formation of biotechnology research networks.

2.4.1 Formalized research relationships 1989 - 94: (i) Univ. of Georgia, Athens (G. Kochert): Cassava genome mapping; (ii) Washingtong Univ, St. Louis (B. Schaal): Cassava DNA fingerprinting; (iii) Purdue Univ; West Lafayette (M. Levy): Rice blast; (iv) Ohio State Univ. (R. Sayre): Cassava Cyanogenesis/gene constructs; (v) The Scripps Research Inst.; La Jolla (L. Fauquet, R. Beachy): Cassava virus resistance/transformation; (vi) Univ. of Florida, Gainesville (E. Vallejos): Bean genome mapping; (viii) Washington State Univ; Pullman (C. Ryan): Cassava insect resistance; (ix) Univ. of Gent, Belgium (M.V. Montagu): Bean gene cloning/transformation; (x) Univ. of Hannover and Univ. of Hamburg (H.J. Jacobsen, F. Wolter): Bean gene cloning/transformation, (xi) Univ. of Tuscia, Viterbo, Italy (J.P. Soressi): Bean transformation; (xii) Univ. of Manitoba, Canada (W. Bushunk): Genotyping.

2.4.2 International Biotechnology Research Networks

Crop-targeted biotechnology research networks have provided CIAT an effective means to promote research collaboration and develop capabilities in developing country institutions.

In the last few years, CIAT has organized the Cassava Biotechnology Network (CBN) and the *Phaseolus* Beans Advanced Biotechnology Research Network (BARN), and has been an active member of the Rice Biotechnology Program of the Rockefeller Foundation.

• **The Cassava Biotechnology Network (CBN).** The goal of the CBN is to stimulate biotechnology research efforts to address identified cassava research priorities that are recalcitrant to other research approaches, and to increase efficiency of classical techniques, while involving end-users and developing country national institutions in setting priorities and conducting research in cassava biotechnology. Appointment of a Steering Committee and a network coordinator have expedited activities in the CBN. The operations and other CBN activities are supported by DGIS, The Netherlands.

Table 3 shows the increasing acceptance of CBN by the scientific community as an effective forum for cassava biotechnology issues. Interestingly in the Bogor Meeting, out of the 40 speakers, 16 were from DCs, 15 from LDCs and 9 from the IARCs.

Table 3. Progress in attendance and scientific participation of developing countries in three consecutive meetings of the Cassava Biotechnology Network (CBN)

Year	Location	No. Participants	No. CountriesLDC/Total	No. Papers
1988*	South America	35	6/13	21
1992**	South America	128	20/30	70

1994***	South East Asia	152	18/28	85

* Founding Workshop at CIAT, ** Cartagena, Colombia, *** Bogor, Indonesia

2.5. Transfer of Developed Technologies for use in CIAT Programs and Units

2.5.1 Operationally, the BRU's role is one of methodology development. Hence, once a given technology has reached maturity in terms of potential usefulness, the responsibility for its utilization is shifted to CIAT programs/units. In the last few years various technologies have been transferred to CIAT programs and units (Table 4).

2.5.2 The BRU has been contributing to train support staff of CIAT Programs and Units in DNA-based techniques (RFLPs and PCR-based) for use in their research projects: Rice pathology, Bean pathology, Bean entomology, Bean microbiology, Tropical forages germplasm, Cassava germplasm, Tropical forages pathology.

2.6. Capacity Building in NARS' Biotechnology

To accomplish its bridging role for biotechnology information and technology transfer with the NARS of developing countries, CIAT has organized cooperative research on mutually beneficial topics; training courses, advanced degree theses, and specialized workshops.

2.6.1 In the last 5 years more than 100 scientists from developing countries have received training at CIAT in a range of biotechnology topics. A number of undergraduate theses, and six Ph.D. and four M.Sc. theses were carried out in the BRU by developing country students. Within Colombia, the BRU has hosted in 1993-94 scientific staff from CORPOICA, CENICAÑA, CENICAFE and several Universities for training in molecular and cellular technologies.

Table 4. Developed technologies shifted to CIAT Programs/Units in the Period 1989-94

Technology	Recipient within CIAT	Year
1. Rice anther culture	Rice Program	1989
2. Cassava *in vitro* gene bank	Genetic Resources Unit (GRU)	1989
3. Cassava *in vitro* germplasm exchange	GRU	1989
4. Isozyme fingerprinting	Cassava Program, GRU	1988
5. Phaseolin markers (beans)	GRU, Bean Program	1988
6. Cassava Biotechnology Network	Cassava Program	1992
7. Molecular markers (research and training)	Center-wide	1993-94

Table 5 shows the activities carried out by the BRU in 1994 aimed at integrating biotech tools in LAC NARS and developing actions for policy decisions in biotechnology.

Table 5. Specialized Biotechnology Workshops and Courses Organized by the BRU in Collaboration with CIAT Programs in 1994 for Latin America and the Caribbean.

Topic	No. Participants: Scientists	Countries	Funding
1. Rice anther culture breeding*	18	9	RF
2. Biosafety: harmonization in the Andean region	25	5	DGIS, USDA
3. Molecular approaches for durable rice blast resist.**	14	5	PROCISUR
4. Biotechnology for conservation of agrobiodiversity	16	6	OEA/ICETEX/FES

* Each participant NARI sent one breeder and one tissue culturist
** Offered to Southern Core countries

2.6.2 In 1991 CIAT established its **Biosafety Guidelines** and **Institutional Biosafety Committee** to oversee and regulate all research with R-DNA in the Center and is serving in consultations with Latin American countries in the development of national biosafety regulatory legislation.

2.7 Special Projects

A sizable part of the research carried out in the BRU in the las 4-5 years has been under special projects, with complementary funding. Table 6 lists the research topics, crops and funding sources of recent special biotech research projects.

Table 6. Special Projects in Biotechnology carried out at CIAT with Complementary Funding in the Period 1989 - 94

Research topic		Crop	Donor
1.	Gene tagging: RHBV, blast	rice	RF
2.	Blast fungal pathogen characterization	rice	RF
3.	Genetic transformation: RHBV, Rhizoctonia	rice	RF
4.	Construction of molecular linkage map	cassava	RF
5.	Biotechnology Network activities	cassava	DGIS
6.	Resistant mechanisms (bruchids)	common beans	AGCD
7.	Molecular linkage map	tepary bean	AGCD
8.	Genetic transformation (methodology)	common bean	BMZ/GTZ
9.	Biotechnology Network meeting	beans	BMZ/GTZ
10.	Transfer anther culture to LAC NARS	rice	RF

3. NEW MAJOR RESEARCH INITIATIVES

The projects contemplated in the BRU's plan for the 1990's fit well into the four project area categories under current involvement. Most of the new BRU project initiatives cut across CIAT commodities and agroecosystems, and others, impinge directly or indirectly upon crops under the mandate of the other IARCs.

1. **PROJECT AREA: Molecular Characterization Analysis and Identification of useful genetic diversity**

1.1 Project: Integration of research in genetic diversity with research on agroecosystem diversity for more efficient conservation and utilization of crop genetic resources.

Crops: *Phaseolus, Manihot, Arachis* (CIAT) with implications for *Oryza* (CIAT, IRRI), *Teosinte* (CIMMYT), *Imopoea* (CIP).

Approach: Analysis of genetic diversity of wild relatives and cultivated forms with molecular markers and etnobotanical descriptors will be matched with agroecological information and geographic information systems (GIS) data; information from *ex situ* collections with *in situ* diversity will be related.

Outcomes: Understanding of evolution of crop species and their wild ancestors; rationalization of conservation of genetic resources, and more effective strategies for breeding programmers.

Collaborator: BRU, GRU, Cassava/Bean/Rice/Tropical Forages Programs, (CIAT), IRRI, CIMMYT, CIP

1.2 Project: Novel approaches for the identification, manipulation and utilization of useful genetic diversity from wild germplasm of *Phaseolus, Oryza* and *Manihot*.

Approach: Analysis of wild and cultivated germplasm for variability at molecular level; QTL mapping and morphagronomic characterization at different sites of transgressive populations, generated by crosses of selected wild germplasm with commercial varieties; markers assisted selection for key traits and acceptable commercial characteristics.

Outputs: High yielding bean and rice cultivars; molecular markers for gene transfer and gene pyramiding in beans, rice and cassava; a novel approach for maximal use of agrobiodiversity thought effective selection of transgressive segregants with minimal linkage drag.

Collaborators: BRU, GRU, Rice Cassava and Bean Programs (CIAT); INIFAP, Mexico; CORPOICA, Colombia; EMBRAPA, Brasil; Cornell Univ, USA.

1.3 Project: Fine mapping, and manipulation cloning of *Brachiaria* apomixis gene(s)

Genera: *Brachiaria*, with implications to cassava (CIAT), rice (CIAT, IRRI), etc.

Approach: Based on recent progress made at CIAT in tagging the apomixis gene using RAPD markers, carry out intensive saturation of the chromosome segments containing the gene, using molecular markers; initiate work on map-based cloning through cooperation with advanced labs; develop gene constructs certaining the apomixis gene(s) and appropriate promoters; test expression in homologous (*Brachiaria*) and heterologous (rice) systems by genetic transformation and plant regeneration.

Outputs: Saturated map of *Brachiaria* chromosome(s) containing the apomixis gene; apomixis gene cloned; transgenic *Brachiaria* and rice plants expressing the apomixis gene(s).

Collaborators: BRU, Tropical Forages Program, Rice Program (CIAT); IRRI

2. PROJECT AREA: Characterization of Plant-stress Interactions and Identification of Points for Genetic Manipulation

2.1 Project: Improving cassava marketability through the minimization of post-harvest deterioration of roots using an integrated genetic approach.

Approach: Following a socio-economic impact analysis, key entry points for genetic manipulation will be identified. Having developed an efficient transformation protocol, genes of interest will be isolated and introduced into plants and their expression analyzed at different levels, i.e. in vitro and field; finally, agronomic performance of plants will be characterized.

Outputs: Cassava clones with increased storage potential; reduced deterioration and losses, increased flexibility of production, processing and marketing aspects, and improved quality, availability of cassava as raw material at rural/village level for food and other products.

Collaborators: BRU, Cassava Program (CIAT); Natural Resources Institute U.K. Center for applications of molecular biology to international agriculture (CAMBIA), Australia; Cornell Univ, USA; FAO, Rome.

2.2 Project: Single chain antibodies (SCABs) and phage antibodies (PHABs) for detection of viral diseases in plants.

Crops: Cassava, beans, tropical forages and rice

Approach: The Peanut Mottle and Guineagrass Potyviruses will used as a model. Variable regions of Ig G will be amplified using PCR on DNA from immunized anice and cloned into SCAB constructs or for display on filamentous phage surface protein. Combinational libraries will be screened using ELISA and the best constructs selected.

Outputs: Development of SCAB technology for viral diagnostic purposes across CIAT crops.

Collaborators:BRU, VRU, Cassava/beans/tropical forages/Rice Programs, GRU.

3. PROJECT AREA: Gene Transfer and Conservation of Genetic Resources.

3.1 Project: Novel genetic strategies for improving cassava starch quality

Approach: As part of this project, the establishment of a genetic transformation technique for cassava will be continued; this work is now under way at CIAT and several other labs. Available cloned genes encoding for isoforms of the starch branching enzyme and the granule-bound starch synthase will be acquired for research purposes with cassava (expression in roots); transgenic plants expressing these genes will be tested at various developmental stages.

Outputs: Additional sources of genetic variability for amylose/amylopectin in cassava starch; a methodology for producing transgenic cassava with increased starch quality.

Collaborators:BRU, Cassava Program (CIAT); Agricultural Univ. Wageningen; EMBRAPA, Brazil; CORPOICA, Colombia; FONA: \P, Venezuela.

3.2 Project: Rice genetic transformation for resistance to sheath blight (*Rhizoctonia solani*).

Approach: Available, cloned anti-fungal genes (chitinases, rip) will be acquired and put in to transformation cassettes under the control of 35S or Act 1 promoters, or the wound inducible promoter from the proteinase inhibitor potato gene; transgenic rice plants will be produced by the biolistic technology developed at CIAT expressing the anti-fungal genes; transgenic plants will be tested at various stages under certainment, and eventually in the field.

Outputs: Availability of a source of genetic resistance to sheath blight for indica rice genotypes adapted to LAC.

Collaborator: BRU, Rice Program (CIAT); INTA, Argentina; IRGA, Brazil; CORPOICA, Colombia; INIA, Uruguay; FONAIAP, Venezuela

3.3 Project: A pilot base gene bank for cassava under cryopreservation

Approach: Standarize the technique being developed at CIAT for a wide range of cassava clones; simplify the protocol to achieve a quick and low cost process; test the logistical and operational aspects of running a base gene bank under cryopreservation; implement the technology in CIAT GRU.

Outputs: A technology for long-term conservation of cassava genetic resources (base gene bank) under cryopreservation; provide service to NARS for conservation of cassava collections.

Collaboration:BRU, GRU, Cassava Program (CIAT); IPGRI, Rome; CORPOICA, Colombia; CENARGEN, Brasil; IITA, Nigeria.

4. PROJECT AREA: Institution Building in Biotechnology

4.1 Project: Biotechnology of tropical plants: integration of biotechnology tools with agricultural research. An advanced training program for LAC scientists.

Crops: IARC's mandated commodities and other crops of regional interest.

Approach: The program will be offered to teams of scientists comprising biotech specialists and plant breeders from each participating institutions/ country; eight LAC countries will be involved in the program. The program will involve an initial workshop followed by three-year-on-the-job training/research and a final wrap up workshop.

Topics for the workshops and the research phase of the program will be selected based on ex-ante survey of priorities in the region, both research topics and techniques.

Outputs: Strengthened capacity of NARS for effective integration of biotech with agricultural research objectives; an efficient updating mechanism for LAC scientist in modern biotechnology and applications; development /strengthening of collaborative links between the NARS of the region, IARCs and advanced research labs.

Collaborators:Countries of the LAC region

4.2 Project Endowment for linking academics, agricultural research centers and non-governmental organizations for using DNA-based technologies in agrobiodiversity research: case of Colombia.

Crops: IARC's mandated and other priority crops in LAC

Approach: Identification of trainees and crops of interest to Colombian institutions (universities, NGO's, NARI, private sector); organize workshops and training program and lab. manual; repeat (updated) workshop one/year for 3 years.

Outputs: Develop lab. facilities in two key Colombia Universities for work with molecular markers in cooperation with NGO's and CORPOICA; a core curriculum in biotechnology and agrobiodiversity will be develop for future training of national/regional scientists; developed collaborative projects in agrobiodiversity and biotechnology.

Collaborators:BRU, GRU (CIAT); Univ. de los Andes, Univ. del Valle, CORPOICA, Colegio Verde, FES, Fundacion Natura (Colombia).

4. THE WAY AHEAD: Genetic Diversity, Crop Improvement and Biotechnology

4.1 CIAT's Action Plan calls for achieving agricultural growth while maintaining, or even enhancing, the natural a resource base, through the application of strategic research to crop commodities in agroecosystems settings. Tackling this challenge will depend to large extent on the ready access to useful genetic diversity and the application of effective strategies of crop germplasm enhancement and improvement. Crop genetic resources are a critical part of global biodiversity, comprising wild relatives, weedy forms, primitive cultivars, modern varieties and advanced lines within a species.

For the foreseeable future, CIAT biotechnology research will increasingly contribute towards more accurate and precise characterization, measurement and conservation of genetic diversity. It will also contribute to develop broad-base gene pools and more efficient screening and breeding methodologies.

4.2 Cooperation through research projects that cut across CIAT, with other IARCs, and the NARS of developed and developing countries will be emphasized. The objective being a more efficient use of cooperative advantages, capabilities and resources.

4.3 As a cost-effective strategy, the BRU will continue acting as a center of gravity for methodology research and development, based on the availability of more sophisticated equipment and targeted external funding. CIAT scientists will continue to be the immediate users of biotechnology tools at CIAT, with the cooperation of the NARS of developing countries.

Biotechnology Research Unit
List of the most important planning conferences, internal reviews and expert meetins: 1990 - 1994

Title	Date, Place	Participants
1. Planning for a Bean Advanced Biotechnology Research Network (BARN)	Sep. 1990, CIAT, Colombia	50 scientists from USA, Europe, Latin America and Africa
2. Biosafety meeting for preparing CIAT guidelines	June, 1990, CIAT, Colombia	CIAT scientists from different programs and units
3. Experts meeting on cassava post-harvest deterioration	Dec. 1991, Rome, Italy	Scientists from FAO, CIAT, IITA, CAMBIA and NRI
4. First Scientific meeting of the Cassava Biotechnology Network	Aug. 1992, Cartagena, Colombia	128 scientists from 29 countries
5. In depth review of the Biotechnology Research Unit,	Dec. 1992, CIAT, Colombia	Dr. G. Persley, from the World Bank as external

1988-1992		reviewer with Drs. M. Wolfe, and R. Flavell from the CIAT Board of Trustees

Title	Date, Place	Participants
6. Expert meeting on International Rice Blast Effort	April 28-29, 1993 Santa Rosa, Colombia	Scientists from CIAT, IRRI, Purdue Univ., Cornell Univ., DUPONT Co.
7. First International BARN workshop	Sep. 1993, CIAT, Colombia	100 scientists from 16 countries
8. Latin American Workshop on Anther Culture for Rice Breeding	Feb. 1994, CIAT, Colombia	18 scientist from 9 Latin American countries
9. Andean region biosafety meeting organized with IICA, USDA, CORPOICA, and Dutch Goverment	June, 1994, Cartagena	30 scientists from 5 andean countries, USA, Holland, Colombia, and other Latin American countries
10. Progress review of the Biotechnology Research Unit by CIAT BOT members	July, 1994, CIAT	Drs. R. Flavell and M. Wolf
11. Second Scientific meeting of the Cassava Biotechnology Network	Aug. 1994, Bogor, Indonesia	150 scientists from 28 countries

Disease and Pest Management SRG

Leader: Anthony C. Bellotti
Associated Unit: Virology Research Unit

This area of competence in CIAT has expanded beyond its traditional role of supporting plant improvement, to include biological and cultural control practices and IPM. The key features of this area are to:

Produce suitable diagnostic tools that research institutions in developing countries can employ to detect and monitor the presence of causal agents of major biotic stresses.

Identify gene complexes for durable resistance to pests and diseases augmented by conventional breeding, molecular biology, or genetic engineering techniques.

Identify and deploy biological control agents as an alternative to the use of hazardous chemicals, and compliment plant resistance.

Generate knowledge about the interactions between host plants and their pests and pathogens, the environment and cropping system.

Generate knowledge about the evolutionary dynamics of pests, diseases, their natural enemies and host plants.

Provide knowledge on crop management options, such as intercropping, rotations, crop sanitation, etc. that can reduce pest and pathogen populations.

Design novel strategies in pest and disease management such as pheromones, insect hormone analogues, genetically engineered micro-organisms, etc.

Identify plant traits for germplasm development with enhanced competitiveness against weeds.

Study weed dynamics; characterization of weed populations shifts resulting from different cropping practices.

Our expertise in strategic and applied research will generate basic knowledge that will result in the development of technology components. This provides a strong foundation for collaboration with other institutions to find more effective methods to manage and control the impact of pests, diseases, and weeds particularly through IPM. IPM contributes to increased, stable and sustainable production, maintenance of biodiversity, and conservation of the natural resource base, while minimizing human health risks associated with chemical pest and disease control.

Expertise Available

Core Competence	Complementary Competence	Project Area
Pathology		Rice
Pathology		Cassava
Pathology		Beans
	Pathology	Beans - SSA
Pathology/Molecular biology		Forages
Entomology		Beans/Rice
Entomology		Beans - SSA
Entomology		Cassava
	Entomology/IPM	Cassava-Brazil
	Entomology (Insect Popl. dynamics)	
Entomology		Rice/forages
Virology		Beans/forages
Virology/Molecular biology		Cassava/rice
Weed science		Various crops
		Cassava IPM

Competence Descriptors

Pathology:

- Identification and assessment of genes for durable disease resistance.
- Epidemiology of pathogen diversity and prediction of virulence change.
- Development of screening protocols for pathogen resistance.
- Development of disease resistant transgenic plants.
- Genetic diversity of pathogens and population dynamics.
- Development of conventional and molecular detection tools for plant pathogens.

Virology:

- Detection, characterization, and epidemiology of viral diseases.
- Development of screening procedures for host plant resistance and genetic studies on the interaction between viruses and susceptible plants.
- Development and implementation of sensitive virus detection methods, including serology and DNA-based techniques.
- Molecular characterization of viruses to develop transgenic virus resistant plants.

- Virus indexing methods to produce virus-free plant genetic resources.

Entomology:

- Identification of pest complexes.
- Identification and assessment of host plant resistance.
- Assessment of biotype diversity in insect pests.
- Identification, collection, rearing, and dissemination of natural enemies of pests, diseases, and weeds of mandated crops.
- Evaluation of effective cultural control methods for specific pests.

Weeds:

- Development of yield loss functions from weed competition.
- Development of non chemical weed management strategies.
- Identification, biology and competitiveness of noxious weeds.
- Detection, characterization and monitoring of herbicide resistance buildup in weed populations.

IPM:

- Integrated participatory assessment for problem diagnosis and development of control strategies.
- Integration of adapted varieties resistant to pests and diseases as key components of IPM.
- Integration of pathogen diversity characterization as a key IPM component.
- Development and pilot scale implementation of biocontrol methods and strategies.
- Development of prototype integrated pest control systems, including agronomic practices.
- Development of action thresholds to minimize pesticide use, reduce contamination, and human health problems and encourage natural biological control.
- Monitoring protocols to sustain use and modification of IPM strategies.
- Collaboration and training involving national programs to assemble

components and implement strategies for integrated control.

- Identification of constraints to adoption of pilot IPM strategies.
- Economic assessment of IPM pilot strategies.

Scientific Resource Group
Pest and Disease Management

Anthony C. Bellotti (Leader) Entomologist (Cassava)

Cesar Cardona Entomologist (Beans)

Lincoln Smith Entomologist (Biological Control Cassava)

Steve Lapointe Entomologist (IPM/Cassava Brazil)

J. Kwasi Ampofo Entomologist (Beans/Africa)

Fernando Correa Pathologist (Rice)

Marcial A. Pastor-CorralesPathologist (Beans)

Segenet Kelemu Pathologist (Tropical Forages)

Robin A. Buruchara Pathologist (Beans/Africa

Francisco Morales Virologist (Beans/Tropical Forages)

Lee Calvert Virologist (Cassava/Rice)

Albert Fischer Weed Science (Rice)

A position paper on CIAT's regional initiatives for integrated pest management in Latin America and the Caribbean has been formulated.

CIAT's Activities in IPM

CIAT has traditionally contributed to IPM primarily through the development of component technologies, placing particular emphasis on resistant germplasm of beans, rice, cassava and tropical forages. In addition successful methods of biological and cultural control have been devised on certain crops.

CIAT is presently involved in working with National Programs to develop and implement IPM strategies. The rice program during the mid 1980's initiated an IPM program with growers in Colombia and Venezuela to reduce the high, unnecessary use of pesticides. Pilot project studies in the Tolima valley Colombia, show a reduction of 70% in the total volume of insecticides applied between 1980 and 1990, and almost 30% of farmers apply no insecticide. The volume of fungicide was reduced by almost 50%, the number of applications to about on-fifth, and the percentage of farmers not applying has risen from 22.7% in 1980's to 42.8% in the 1990's. Funding was provided by FEDEARROZ, ICA and CIAT.

The problem addressed on beans is also the excessive use of pesticides, especially in the Andean zone (Colombia, Ecuador, and Peru). One hundred percent of the farmers spray, nearly all on a weekly basis, a mixture of insecticides and fungicides. An average 8 to 16 applications are used each growing cycle. A pilot project study in Colombia, financed by IDRC, has reduced insecticide application by 62% and fungicides by 36%, while yields have remained constant. This project is ready to enter into the second phase, the implementation of IPM with numerous growers across ecosystems. Funding is being sought for this phase.

A UNDP funded project initiated during 1993 in cooperation with EMBRAPA/CNPMF will focus on a wide range of arthropod pests and diseases in cassava based systems in Northeastern Brazil. The rationale is that cassava yields are low in this region (the lowest in Brazil) due to the complex of pests and diseases attacking the crop. The four year project will rely heavily on farmer participatory methods to introduce, evaluate, validate and measure the impact of IPM technologies, especially host plant resistance, biological and cultural control. Initial activities include diagnostic surveys, site selection, farmers participatory technology testing and adaptation, and training of researchers, extensions and farmers.

CIAT is a pioneer in the development of methods in farmers participatory research. Through its active involvement in IPM, CIAT can contribute importantly to sustainable agricultural development in Latin America.

Integrated Pest Management in Latin America: What Role for CIAT?

Curbing the Threat of Indiscriminate Pesticide Use

- Pesticide use is rapidly increasing in Latin America under the pressure of powerful demographic and economic trends. By the year 2000, the region will be spending US$3.97 billion a year on chemical control measures. This represents a sizable drain on farmer's scarce resources and a significant hazard to human health and the environment. The only hope for curbing excessive and indiscriminate use of chemicals is integrated pest management (IPM). This approach shows strong potential in Latin America, having already lowered the use of pesticides in cotton and sugarcane pest management in Colombia.

The Heavy Demands of IPM

- IPM relies on several control measures, including resistant germplasm, biological control, cultural practices, crop monitoring, and properly timed pesticide application. Based on extensive knowledge of pest biology and of farmer's agronomic practices and socioeconomic conditions, interdisciplinary teams of scientists assemble these components into broad-based strategies aimed at keeping major pests below economically significant levels in an environmentally sound manner.

- Unlike chemical controls, which developing country farmers can take straight from the shelves of developed country manufacturers, IPM strategies must be designed and implemented for specific cropping systems through a painstaking research program, in which farmers are key participants. No single organization can accomplish this alone; getting IPM established is invariably a multi-institutional endeavor.

The Four Phases of a Successful IPM Project

1. Plant protection specialists (geneticists, entomologists, plant pathologists, etc.) work closely with agronomists and social scientists to identify major pest problems, gauge farmers' perceptions of these, and suggest possibilities for an IPM strategy. The information gathered at this stage provides the basis for a project proposal.

2. The next step is to acquire or develop resistant germplasm, biological control techniques, and so forth, based on a systematic study of the target pests, their natural enemies, and the interactions of these species in particular cropping systems.

3. The component technologies are assembled into a model IPM strategy. This is evaluated at different sites in a limited area to determine whether it's technically sound and matches prevailing agroecological and socioeconomic conditions in the target cropping system. The results of this pilot study indicate the feasibility of applying the strategy on a larger scale.

4. The IPM strategy is heavily promoted through training and extension provided by public institutions and the private sector. An institutional framework is established for supplying inputs (improved varieties, natural enemies, information, etc.), and policies (such as pesticide subsides) that may hinder successful implementation are reviewed with key decision makers among farmers, in government, and in private companies.

CIAT's Traditional Contribution

- The Center has contributed to IPM largely through the development of component technologies. We've placed particular emphasis on resistant germplasm of beans, cassava, tropical forages, and rice. Increasingly, we've drawing on techniques from molecular biology to enhance the efficiency of resistance selection. For some of CIAT's mandate crops, we've also devised successful methods of biological and cultural control. In the course of this research, we've amassed a substantial amount of information that is essential for further development of control measures.

- Through two recent projects, CIAT has become more closely involved than ever in helping national programs develop and implement IPM strategies. In the first, begun during 1991 with a grant from IDRC, we are working closely with scientists and small-scale bean farmers in the Andean zone of Colombia, Ecuador, and Peru to curb extreme insecticide abuse. In the second, a UNDP-funded project initiated during 1993 in cooperation with EMBRAPA and IITA, the Center will focus on a wide range of pests in cassava-based systems in northeastern Brazil.

- CIAT was a pioneer in the development of methods for securing farmer participation in research. We can make excellent use of this experience in identifying and monitoring pest problems, in supporting the development of IPM strategies, and in helping create the institutional framework needed to make these strategies work.

The Evolution of CIAT's Role

The Center's expertise in developing pest control technologies in a strong base on which to build a more assertive program for actively promoting IPM throughout Latin America. There is no question that this approach can and should be used more widely in the region. But in helping others work toward that objective, is it equally clear that CIAT can and should go beyond its traditional role? Here are four reasons why we think the answer in an unqualified "yes."

1. In the IDRC and UNDP projects, we've already taken the next step beyond developing IPM components. The experience gained through this work will put CIAT in an excellent position for pursuing the same approach in other places and with other cropping systems.

2. After technology, improved research methods are the next important output of centers like CIAT. They are one of the most effective ways in which we can fulfill our international responsibilities, especially in helping deal with problems that require site- or system-specific solutions (as is the case with IPM). There is tremendous scope for CIAT to develop methods that national institutions can use to assess pest problems, fashion technology components into effective IPM strategies, and implement these in specific agroecosystems.

3. Universities in the USA and other developed countries have considerable expertise in IPM and are interested in applying it to the solution of pest problems in the developing world. As an international center, CIAT can provide the institutional common ground on which experts in Latin America can work with their developed country counterparts in all four phases of IPM.

4. If CIAT did nothing else but IPM, it could contribute importantly to sustainable development in Latin America. This work has even greater value as part of our

broader initiative to improve resource management in the region's major agroecosystems. What is the aim of this research if not to help others develop a capacity to manage evolving biological systems without damaging natural resources? On a different scale, that is precisely the goal of IPM.

Project Profile

Integrated Management of Whitefly, A Major Pest and Vector of Viruses of Food Crops

Purpose: To curb excessive pesticide use and reduce crop losses through environmentally safe management of whitefly

Rationale: Whitefly, *Bemisia tabaci*, is considered the most damaging insect pest of food crops in this century. It is also a vector of several important viruses, including the African cassava mosaic virus (ACMV), bean golden mosaic virus (BGMV), and other geminiviruses that attack tropical legumes. Other whitefly species that also cause significant crop losses and transmit plant viruses are *Bemisia tabaci*, *B. tuberculata*, *Trialeurodes variabilis*, *T. vaporariorum*, *Aleurotrachelus socialis*, and *Aleurothrixus aipim*.

Current methods of whitefly control rely heavily on pesticide use. Far from solving the problem, they have generally increased pest damage and environmental degradation. Integrated management would rely on host plant resistance, biological control, cultural practices, natural insecticides, pheromonal and hormonal methods that affect life cycles, and disease forecasting. To implement these measures will require a better understanding of insect population dynamics, the epidemiology of viral diseases, genetic variability for resistance, and host plant selection.

Expected Benefits: Integrated control of whiteflies will reduce environmental contamination by lowering insecticide use, reduce crop losses, and prevent the development of pesticide-resistant whitefly biotypes. This will benefit millions of producers of major commodities (including cassava, beans, tropical legumes, horticultural species, potato, and various fruit crops) throughout the Americas, Asia, and Africa. The project will help national agricultural research systems by:

- Enhancing their research capacity to deal with important pests and diseases of major crops
- Providing them training in nonchemical control methods and development of IPM systems
- Generating information and technologies that can help reduce whitefly populations and virus disease incidence

Expected Outputs:
- Technology components that contribute to effective control of the whitefly and virus
- An IPM system for whitefly and virus control that has been tested and validated with farmer participation in research trials
- Training for national program scientists in whitefly IPM systems
- Manuals and other training materials

Activities:
- Conduct research leading to the development of technology components.
- Test and validate IPM systems in selected agroecologies.
- Organize training events, seminars, workshops, field days, and demonstration plots.

- Develop and implement client-driven research methods.

Research Partners: Escuela Agricola Panamericana (Honduras), INIFAP (Mexico), ICTA (Guatemala), CESDA (Dominican Republic), CORPOICA (Colombia), INIAP (Ecuador), EMBRAPA (Brazil), University of Florida (USA), University of California at Riverside (USA), University of Tel Aviv (Israel), CATIE, IITA, ICRISAT, CIP

CIAT is already working on whitefly control in collaboration with several of these institutions. Currently, we are concentrating on the problem of whitefly diversity in the Americas.

Proposed Donors: USAID, UNDP, FAO, IFAD, BID, Rockefeller Foundation, World Bank

Funding: \$5.0 million; **Time Frame:** 5 years

CIAT Project Officer: Anthony Bellotti

Integrated Pest and Disease Management for Hillside and Lowland Agroecologies in Tropical America

Purpose: To curb excessive pesticide use through IPM strategies and promote sustainable crop production systems

Rationale: Pesticide use in Latin America is increasing at a rapid rate. By the year 2000, the region will be spending about US$4.0 billion on these products. Misuse of pesticides already poses a serious hazard to human health and the environment. The dangers are particularly great in various "hot spots"—many of them in fragile hillside and lowland agroecologies—where excessive amounts of pesticides are applied.

Although IPM has proved effective in solving this problem, it has worked primarily in large-scale production of specific crops. This project will provide evidence that IPM can be implemented on an agroecological basis by small-scale farmers. Much experience has shown that IPM can succeed where farmers are involved in the research at an early stage.

Expected Benefits: This project will primarily benefit farmers caught in the trap of excessive pesticide use. By reducing applications and dosages, IPM strategies will lessen the hazards to these farmers' health and lower their crop production costs. Moreover, by decreasing pesticide contamination of produce, the new strategies will increase its commercial value and make it safer for urban consumers. Since IPM permits reestablishment of the equilibrium between natural enemy populations and pest complexes, it will control pests more effectively.

The project will promote IPM as part of a broader effort to establish sustainable cropping systems in major hillside and lowland agroecologies. National research institutes, NGOs, and farmer groups will be actively involved in developing IPM strategies. Researchers and extensionists will receive practical training in methods for implementing IPM and organizing farmer participation in research.

Expected Outputs:
- Genetic, biological, and cultural methods for controlling major pests and diseases
- Effective methods for implementing IPM
- An expert system for disseminating information about IPM implementation

Activities:
- Conduct surveys and diagnostic studies to identify opportunities for IPM.
- Analyze crop production costs.
- Determine yield losses caused by pests and diseases.
- Calculate action thresholds for selected pests.
- Verify genetic resistance to biotic constraints.
- Determine the effectiveness of technology components in field trials.
- Verify the socioeconomic feasibility of technology components and control strategies with farmer participation.
- Measure rates of technology adoption and impact.

Research Partners: Various national research institutes, including CORPOICA (Colombia), INIAP (Ecuador), INIAA (Peru), EMBRAPA (Brazil), FONAIAP (Venezuela), INIA (Argentina), and CESDA (Dominican Republic); various NGOs, such as FEDEARROZ, FEDERALGODON, and CENICAFE in Colombia; and several international centers, including CIP and CIMMYT.

Nearly all the national programs mentioned here have some experience with IPM. CIAT is currently involved in several IPM projects and has considerable expertise in promoting methods of organizing farmer participation in research.

Proposed Donors: UNDP, USAID, SAF, World Bank, FAO, IFAD, IDRC, DGIS, NGOs

All are currently supporting IPM projects or have indicated interest in them.

Funding: $5 million each for two agroecologies; **Time frame:** 5 years

CIAT Project Officer: Cesar Cardona

A Latin American Training and Research Network for Biological Control of Major Arthropod Pests by Means of Entomopathogens

Purpose: To reduce pesticide use by developing environmentally sound technologies that employ insect pathogens to control pests

Rationale: Pesticide use in Latin America is increasing at a rapid rate. By the year 2000, the region will be spending about US$4 billion dollars on these products. To better manage pest problems and reduce pesticide use will require sustainable control strategies that rely heavily on biological control, among other environmentally safe measures.

Entomopathogens show considerable potential for controlling major pests, including leafhoppers, burrowing bugs, spittlebugs, certain soilborne arthropods, whiteflies, mites, lepidopterous pests, and mealybugs. But before we can fully exploit this potential, the role of entomopathogens in tropical agroecologies must be investigated more thoroughly. Since the tropics are a vast reservoir of beneficial organisms, this work will very likely lead to the discovery of presently unknown insect pathogens that offer an innovative approach to pest control.

Biological pesticides manufactured from these species could become a major component of IPM systems in developing countries. To facilitate their adoption, the project will need to devise ways to improve product quality and deploy biological pesticides more efficiently under tropical conditions. Drawing on biotechnology techniques, it should also find novel ways to use entomopathogens to control insects that have given rise to excessive pesticide application.

Expected Benefits: These materials will primarily benefit producers of several major food and industrial crops in the developing world. But some entomopathogens could also be used as pest control agents in developed countries. Widespread adoption of this approach will reduce environmental contamination by lowering insecticide use, in addition to reducing crop losses caused by pest attack. The project will strengthen national research institutions by enhancing their research capacity to develop and use biological pesticides and by training scientists and extensionists to use entomopathogens in IPM systems.

Expected outputs:
- New arthropod pathogens identified
- Existing arthropod pathogens adapted to tropical conditions
- Advanced techniques for formulating pathogens
- An understanding of pathogen activity on previously unrecorded hosts
- Training in insect pathology for staff of national research institutes
- Stronger links between scientists in developed and developing countries
- New strains of pathogens identified and evaluated

Activities:
- Survey and identify entomopathogens.
- Study the pathogenicity of these species and strains, devise methods to deploy them, and identify and select pathogen strains, using pest colonies already at CIAT.
- Organize workshops, courses, and seminars to train research and extension staff.
- Develop a model pathogen-pest system to serve as a training tool.
- Study entomopathogens on key crops in hillsides, savannas, and forest margins.

Research Partners: Many institutions in Latin America, especially CORPOICA (Colombia) and EMBRAPA (Brazil); various NGOs, such as CENICAFE (Colombia); the Escuela Agricola Panamericana (Honduras); the Boyce Thompson Institute at Cornell University (USA); the Commonwealth Institute of Biological Control (UK).

CIAT has worked on fungal and viral pathogens of pests that attack cassava, beans, and tropical forages programs. CORPOICA, EMBRAPA, and other institutes in Latin America have well qualified personnel and adequate facilities. The Boyce Thompson Institute and CIBC conduct basic and applied research on arthropod pathogens.

Proposed Donors: BID, AID, IDRC, DGIS, ODA, Biotec Industry

These donors have a history of funding projects to develop environmentally safe methods of insect control that reduce pesticide use, improve food security, and can be applied by small-scale farmers.

Funding: $2.5 million; **Time frame:** 5 years

CIAT Project Officer: Anthony Bellotti

A Working Collection of Arthropod Diversity

Purpose: To facilitate the study and use of arthropod species for integrated pest management and other purposes

Background: Arthropods or insects and mites are enormously diverse, encompassing an estimated 30 million species. According to a World Bank study, many are concentrated in the neotropics. Numerous species could be used for biological control or for medicinal purposes, but they must first be accurately identified. Improper identification has often been a serious hindrance to entomology research.

Although various institutions maintain arthropod collections, none has organized a *working* collection that provides a useful service to agricultural and natural resource specialists. Nor has anyone established a collection specifically for the neotropics. Despite the region's immense species diversity, it has few arthropod taxonomists and systematicists. CIAT has established a small working collection of arthropods that affect its mandate commodities. In new research on major tropical agroecologies, the Center will deal with other crops, arthropods, and their natural enemies.

Expected Benefits: A working collection of arthropods will give taxonomists and systematicists ready access to a wide array of species diversity. With this tool specialists in IPM will be able to search more easily for new natural enemies of major pests and will have more accurate knowledge of the pests species involved. It is highly likely that they will identify unrecorded natural enemies that reduce pest damage. This will benefit farmers and society as a whole in both the tropical and temperate zones by reducing environmental contamination caused by irrational pesticide use, increasing crop production, and lowering crop production costs. The working collection will also serve quarantine agencies by generating new information on unrecorded pests. The project will assist national program scientists in developing countries by:

- Providing accurate, rapid identification of arthropod pests and their natural enemies
- Putting these scientists in closer contact with taxonomists in developed and developing countries
- Offering training in arthropod systematics

Expected Outputs:
- A collection of properly identified and conserved arthropod pests and their natural enemy complexes
- Taxonomic services for national research institutes, universities, NGOs, and other organizations
- A centralized database on arthropods in the neotropics
- Specialized training for taxonomists and systematicists
- A network of taxonomists, systematicists, and collection users in developed and developing countries

Activities:
- Collect and conserve arthropods.
- Identify arthropods.
- Form a centralized database on these species.

- Organize specialized training.
- Establish links between taxonomists and collection users.

Research Partners: Taxonomists in developed and developing countries; national agricultural research institutes, universities, and NGOs in tropical and subtropical America; Escuela Agricola Panamericana (Honduras); the Taxonomic Services Unit (TSU) of USDA; CAB International (UK); the Department of Entomology, Smithsonian Institute (USA); CATIE; CIP; CIMMYT ;

CIAT's location in the tropics and contacts with national and international institutions will greatly facilitate its management of the working collection.

Proposed Donors: Smithsonian Institute, NGOs, World Wildlife Fund, American Museum of Natural History, USDA, World Bank

These institutions maintain an active interest in arthropod biodiversity.

Funding: $2 million; **Time Frame:** 10 years

CIAT Project Officer: Cesar Cardona

Beneficial Microorganisms for Biological Control of Plant Diseases in the Tropics

Purpose: To use beneficial microorganisms for environmentally safe management of major diseases

Rationale: The various mechanisms by which microorganisms survive in competitive, hostile microbial communities can also benefit humans and animals. For example, the antibiotics we use to treat infections are derived largely from microorganisms.

Another intriguing option is to employ naturally occurring microorganisms to manage plant diseases. Several *Rhizobium* strains have been shown to reduce diseases significantly in grain legumes. Several other organisms, such as species of *Bacillus* and *Pseudomonas* as well as endophytes, generate products that can be used for disease and insect control.

To further exploit such possibilities will require a major effort to identify, characterize, and conserve a wide range of microorganisms for various uses. Already, we have identified several bacteria with antifungal or antibacterial properties. In characterizing some of these properties, we observed that one or more products of *Bacillus subtilis* isolate I 2 inhibits *Colletotrichum gloeosporioides* (the causal agent of *Stylosanthes* anthracnose) at several stages of its development in vitro. Another beneficial organism, *Erwinia* spp. (isolated from seeds of *Stylosanthes* spp.) shows antifungal and antibacterial properties. CIAT scientists have collected and characterized a number of other beneficial microorganisms as well.

Expected Benefits: Beneficial microorganisms have enormous potential as environmentally safe alternatives for disease control. If properly collected and preserved in a gene bank, these organisms could be distributed efficiently to researchers throughout the developed and developing worlds.

In addition to using live beneficial microorganisms directly, scientists could employ genes derived from bacteria to develop insect and pathogen resistance in transgenic plants. This approach would be particularly useful for controlling pathogens that are highly variable or for which host plant resistance has not been identified. The end result will be higher crop productivity, lower production costs, and reduced pesticide use, which will lead to a cleaner environment and better human health.

Expected Outputs:

- A well-characterized and maintained bank of beneficial microorganisms
- Effective technology components for IPM

Activities:

- Collect, isolate, and identify beneficial organisms.
- Characterize their properties.
- Identify useful products.
- Conserve characterized microorganisms.
- Test them in the laboratory, glasshouse, and field.

Research Partners: EMBRAPA and IAPAR (Brazil), CORPOICA (Colombia), University of Costa Rica, Montana State and Kansas State Universities/EPA (USA), various universities in Japan, and IITA

Proposed Donors: USAID, Japanese government, UNEP, UNDP

All have a strong interest in research aimed at reducing environmental degradation caused by misuse of pesticides.

Funding: $1 million; **Time Frame:** 3 years

CIAT Project Officer: Segenet Kelemu.

Comprehensive Unit Report for EPMR
Virology Research Unit

Executive Summary

Overall goal and objectives. Since its creation in 1988, the main objective of the Virology Research Unit (VRU) has been the identification and control of the viruses that affect the productivity or utilization of the plant genetic resources entrusted to CIAT.
History of overall program activities (89-94). The VRU assists the four commodity programs in the selection and development of virus-resistant germplasm. This collaborative work has resulted in the world-wide distribution of bean genotypes possessing resistance to the main viruses that affect bean production in the world, such as bean common mosaic and bean golden mosaic viruses. The Cassava Program has also received considerable assistance for the identification of known and unidentified viral pathogens that severely limit the production and distribution of improved cassava germplasm. . The Rice Program has received assistance in the development of germplasm that is resistant to RHBV. One of the VRU's major activity area in this period, has been the detection and identification of viruses in the large tropical forage legume and grass collection managed by the Tropical Forages Program.
Major clients and regional impact. The VRU has targeted the clients and regions selected by the commodity programs of CIAT, particularly throughout Latin America but also in Asia and Africa. Active collaborative research projects have also been conducted with advanced research laboratories in the United States and Europe.

Historical Assessment

Achievements and Impacts

Bean Program. Over 90% of the improved lines developed by the Bean Program of CIAT carry resistance to at least one virus, bean common mosaic virus. The deployment of advanced bean genotypes possessing resistance to whitefly-borne geminiviruses in Central America, Mexico, the Caribbean and Brazil, has been the most critical contribution of the Bean Program and the VRU to sustainable bean production in the lowlands of Latin America. All of the viral diseases of beans in Latin America and Africa have been identified and appropriate recommendations have been issued to control theses viruses.
Cassava Program. Frog-skin and Caribbean mosaic diseases are two disorders of cassava that are considered of quarantine significance to national cassava research programs. It was determined that both diseases are cause by the same virus. The pathogen have been identified and suitable diagnostic methods are available to detect infected reproductive material. Considerable progress has been made on the characterization of cassava vein mosaic and cassava common mosaic virus. All major viral pathogens of cassava occurring in the Americas have been identified and effective control stategies for CCMV and FSD have been developed.
Rice Program. One of the most devastating diseases of the rice crop in the Americas is caused by the rice hoja blanca virus (RHBV). RHBV is distributed throughout northern South America, Central America and the Caribbean. The VRU identified and characterized the virus and in collaboration with the Rice Program developed a screening methodology, which is utilized to produce gene pools that are the source of virus-

resistant for commercial cultivars that have been widely adopted by growers in affected rice-producing regions of Latin America.

Tropical Forages. Over 25 different viruses have been detected in tropical forage legumes and grasses since 1989, when the VRU initiated research on the viral pathogens of these species. The viral pathogens of the main tropical forages evaluated by the Tropical Forages Program, Arachis pintoi, Centrosema spp., Stylosanthes spp. and Brachiaria spp. have been characterized and sensitive diagnostic methods produced. The selection of virus-resistant germplasm and production of virus-free propagating material, is an on-going activity.

Constraints

Bean Program. The dismantling of the research networks that the Bean Program created in the last decade, particularly in Latin America and Africa, has greatly hindered further collaborative work and the adoption of technology needed to solve the numerous production problems that continuously arise due to the rapidly changing agricultural environments found in these regions.

Cassava Program. No major constraints have been identified in Cassava Virology other than the difficult nature of this species as a test plant. Also, the quarantine regulations that restrict the exchange of germplasm between Africa and Latin America, have limited the collaboration between the VRUs of IITA and CIAT.

Rice Program. The continuous changes in the focus, size and philosophy of the Rice Program, coupled to the lack of an entomologist, have significantly affected the collaboration between the Rice Program and the VRU.

Tropical Forages. The large number and exotic nature of the tropical forage species introduced by the TFP, poses a special challenge for the VRU, given the limited human and material resources allocated, since all the germplasm introduced into Colombia must be checked for the presence of virus(es).

New components since 1989. A molecular virologist, Dr. Lee Calvert joined the VRU in 1989 to take advantage of the latest technology available in the areas of diagnostics, molecular characterization of plant viruses and genetic engineering.

Future Research Strategy

The VRU will pursue several projects in two major areas of research: 1) the characterization of the plant viruses that affect CIAT's mandate commodities and associated crops in target ecosystems, and 2) the integrated control of the main viral problems area.

Major new projects initiatives

Genetic Transformation of Rice Plants for Resistance to Rice Hoja Blanc Virus. The molecular characterization of RHBV has led to the design of novel virus-resistant strategies to genetically engineer commercially-grown rice cultivar. Control of RHBV by plant transformation is being attempted at CIAT by following the coat protein-mediated cross protection and antisense RNA strategies. This work is being conducted in collaboration with the Rice Program and the Biotechnology Research Unit.

Forecasting the incidence of bean golden mosaic virus in affected beanproduction regions of Latin America. Plant virus disease forecasting has been shown to be a critical component of IPM projects. The purpose of this project is to confirm field observations made during the past 15 years, correlating pre-planting climatological conditions with the incidence of BGMV.

Inter-program project initiatives including SRG led initiatives. By mandate, the VRU has to interact with all of CIAT's research programs. The VRU also collaborates closely with the Genetic Resources Unit, mainly in the area of seed health and germplasm conservation. The collaboration with the Biotechnology Research Unit is centered around the transformation of virus-affected plant species investigated by CIAT. An example is the development of genepools with resistance to African cassava mosaic virus is a project to prepare for the possible extension of the range of a potentially devestative disease. This project will be a collaborative effort between the cassava program, BRU, and GRU.

Relation of VRU's projects to CG system wide projects. The activities of CIAT's VRU can be linked to those currently implemented at other IARC's, such as IITA on cassava viruses; ILCA-ILRAD on viruses of tropical forages; ICRISAT on legume viruses, and IPGRI on the safe exchange of plant germplasm. CIAT's VRU could also play a major role in centralizing virology research in Latin America, considering the unique virology research facilities it has.

2. Introduction

a. Overall goal and objectives.

Since its creation 1988, the main objective of the Virology Research Unit (VRU) has been the identification and control of the viruses that affect the productivity or utilization of the plant genetic resources entrusted to CIAT. The main objective till 1989, was to genetically improve commercial cultivars for their resistance to economically important plant viruses. Since 1990, CIAT has placed more emphasis on the impact of agricultural practices on the conservation of natural resources. As a result, the VRU been investigating integrated plant virus control practices designed to minimize or eliminate the abuse of pesticides to control the insect vectors of plant viruses. Also, the VRU has a critical role in the preservation and distribution of the plant genetic resources entrusted to CIAT. Part of this ermplasm is heavily contaminated with plant viruses, and this hinders its evaluation and distribution world-wide.

b. History of overall program activities (89-94)

The VRU has continuously assisted the commodity programs in the selection and development of virus-resistant germplasm. The Bean Program has greatly benefitted from the collaborative work that has resulted in the world-wide distribution of bean genotypes possessing resistance to the main viruses that affect bean production in the world, such as bean common mosaic and bean golden mosaic viruses. The Cassava Program has also received considerable assistance for the dentificati of known and unidentified viral pathogens that severely limit the production and distribution improved cassava germplasm. The Rice

Program has received assistance in the development of germplasm that is resistant to RHBV. The VRU's activities for the Tropical Forage Program have been the detection and identification of viruses in the large tropical forage legume and grass collection.

The VRU has several major activities that are important across programs. Included in these activities are implementing strict phytosanitary standards at CIAT to regulate the introduction and distribution of plant germplasm. Another major activity of the VRU has been the implementation of advanced molecular virology techniques mainly for diagnostic techniques, characterization, and plant improvement (transformation) purposes. The arrival of a molecular virologist in 1989, greatly expedited the implementation of molecular techniques, such as cloning, development of cDNA probes, sequencing, PCR, and production of transgenic plants. The VRU has recently created a monoclonal antibody production facility for the specific diagnosis of viruses and their pathogenic variants. This laboratory can also produce specific antibodies to antigens of interest to other scientists in various disciplines. The electron and light microscope laboratories are other centralized facilities that are used by scientist throughout CIAT.

c. Major client and regional impacts

As a research support unit, the VRU has targeted the same clients and regions selected by the commodity and natural resource programs of CIAT, particularly throughout Latin America but also in Asia and Africa. These include national and regional programs, NGOs, and other international research centers. Active collaborative research projects have also been conducted with advanced research laboratories in the United States and Europe. Some of the technology developed has been applied to the solution of agricultural problems in these countries. The control of whitefly-transmitted viruses of horticultural crops in S.E and S.W. U.S.A., is a pertinent example.

3. Historical Assessment

a. Achievements and Impacts

Bean Program. Over 90% of the improved lines developed by the Bean Program of CIAT carry resistance to at least one virus, bean common mosaic virus. The deployment of advanced bean genotypes possessing resistance to whitefly-borne geminiviruses in Central America, Mexico, the Caribbean and Brazil, has probably been the most critical contribution of the Bean Program and the VRU to sustainable bean production in the lowlands of Latin America. The identification, control and monitoring of the viruses that infect beans world-wide, has also been a major contribution to sustainable bean production in Africa and Asia.

Cassava Program. The presence of 'virus-like' diseases of cassava had greatly hindered the introduction and distribution of promising cassava germplasm in Latin America, Asia and Africa. Frog-skin and Caribbean mosaic diseases are two disorders of cassava that are considered of quarantine significance to national cassava research programs. It was determined that both diseases are cause by the same virus. The pathogen have been identified and suitable diagnostic methods are available to detect infected reproductive material. The development of sensitive virus detection methods for the major cassava viruses in tropical America and for African and Indian cassava mosaic viruses has finally made possible the safe exchange of cassava germplasm. Considerable progress has been made on the characterization of cassava vein mosaic and cassava common mosaic virus. All major viral pathogens of cassava occurring in the Americas have been identified and effective control stategies for CCMV and FSD have been developed.

Rice Program. One of the most devastating diseases of the rice crop in the Americas is caused by the rice hoja blanca virus (RHBV). The causal agent was first identified at CIAT and the VRU maintains a leading role in the molecular characterization of the virus. The VRU in collaboration with the Rice Program developed a screening methodology in collaboration with the Rice Program, that is utilized to produce virus-resistant cultivars which have been widely adopted by growers in affected rice-producing regions of Latin America. Since the genetic resistance to RHBV in commercial cultivars are from a single source, the current activities are to identify and include into gene pools additional sources of resistance including genetically engineered rice plants.

Tropical Forages. Over 25 different viruses have been detected in tropical forage legumes and grasses since 1989, when the VRU initiated research on the viral pathogens of these species. The viral pathogens of the main tropical forages evaluated by the Tropical Forages Program, Arachis pintoi, Centrosema spp., Stylosanthes spp. and Brachiaria spp. have been characterized and sensitive diagnostic methods produced. The selection of virus-resistant germplasm and production of virus-free propagating material, is an on-going activity.

b. Constraints

Bean Program. The dismantling of the research networks that the Bean Program created in the last decade, particularly in Latin America and Africa, has greatly hindered further collaborative work and the adoption of technology needed to solve the numerous production problems that continuously arise due to changing agricultural environments (economic policies) in these regions.

Cassava Program. No major constraints have been identified in Cassava Virology other than the difficult nature of this species as a test plant. Also, the quarantine regulations that restrict the exchange of germplasm between Africa and Latin America, have limited the collaboration between the VRUs of IITA and CIAT.

Rice Program. The continuous changes in the focus, size and philosophy of the Rice Program, coupled to the lack of an entomologist, have significantly affected the ability to plan long term collaborative research between the Rice Program and the VRU.

Tropical Forages. The large number and exotic nature of the tropical forage species introduced by the TFP, poses a special challenge for the VRU, given the limited human and material resources available, since all the germplasm introduced into and exported from Colombia must be checked for the presence of virus.

d. Components terminated since 1989. None

e. New components since 1989.

A molecular virologist, Dr. Lee Calvert, joined the VRU in 1989 and this has added to the unit the ability to take advantage of the latest technology available in the areas of diagnostics, molecular characterization of plant viruses and genetic engineering.

The VRU has created an immunology laboratory that includes the ability to produce monoclonal antisera. This laboratory enhances the capabilities for CIAT to fulfill worldwide mandates to help assure the safe movement of germplasm, and its diagnostic capacity.

4. Future Research Strategy

a. The VRU will pursue several projects in two major areas of research: 1) the characterization of the plant viruses that affect CIAT's mandate commodities and 2) their control. The characterization of viruses facilitates the exchange, utilization and genetic improvement of plant genetic resources, and it is critical for developing suitable plant disease control strategies that reduce or eliminate the need for pesticides and make possible the implementation of IPM projects. The VRU has a unique advantage in this area since it is an especially well-equipped virology facility which are rare or non-existent in most developing countries. The control of plant viruses can be achieved through crop improvement and by implementing integrated disease management practices. Identifying sources of genetic resistance to viruses in our germplasm banks is the most effective way to reduce pesticide use on food crops, and integrated disease management practices are the most reliable approach to the implementation of sustainable agricultural systems.

Genetic Transformation of Rice Plants for Resistance to Rice Hoja Blanc Virus. The genetics of resistance to rice hoja blanca virus (RHBV) is not fully understood, and it appears to be (virus) dosage-development. Hence, the hoja blanca disease still has the potential to cause severe yield losses since there are still many commercial varieties that are resistant only to the planthopper vector but not to the virus. The molecular characterization of RHBV has led to the design of novel virus-resistant strategies to genetically engineer commercially-grown rice cultivar. Control of RHBV by plant transformation is being attempted at CIAT by following two different strategies: the coat protein-mediated cross protection and antisense RNA strategies. This work is being conducted in collaboration with the Rice Program, the BRU and the VRU.

Characterization of bean cucumoviruses affecting beans worldwide. Cucumoviruses are seed-transmitted and have a worldwide distribution. The cucumoviruses display a broad range of pathogenicity in beans and the diseases they cause are becoming increasingly important. The VRU has begun a project to characterize the different virus isolates and to determine the distribution of cucumoviruses in the main bean bean-producing regions of the world these isolates. This project developed in collaboration with the Institute of applied Plant Virology, Turin, Italy will lead to better control measures for this important disease.

Screening the cassava core collection for resistance to cassava frogskin disease. The VRU has begun a program to search for tolerant or resistant germplasm to cassava frogskin disease. The 630 varieties of cassava core collection will be evaluated for their reaction to cassava frogskin virus. Additionally, other Manihot species will be evaluated for resistance to cassava frogskin virus. This activity will take 3-5 years and will lead to the development of gene pools that are tolerant to cassava frogskin disease.

Ecologically sustainable cassava production. The VRU is part of the UNDP project for Ecologically Sustainable Cassava Production in Latin America and Africa. Cassava vein mosaic virus is a widespread pathogen throughout the semi-arid Northeast of Brazil. The project includes the characterization, development of diagnostic methods, and understanding the epidemiology of this disease. Integrated pest management solutions to control the disease will be tested using farmer participatory research. The duration of the project is 4-5 years.

b. Major projects initiatives

Forecasting the incidence of bean golden mosaic virus in affected bean production regions of Latin America. Plant virus disease forecasting has been shown to be a critical component of IPM projects Yet, there are few examples of forecasting programs currently practiced in the world. The main limitation of previous forecasting projects has been their complexity and reliance on mathematical modelling to understand the epidemiological factors that generate virus epidemics. On the contrary, the initial purpose of this project is to confirm field observations made during the past 15 years, correlating pre-planting climatological conditions with the incidence of BGMV. These observations consistently show that high rainfall and low temperature conditions prior to bean planting suggest considerably time, reduces whitefly vector populations and disease incidence. To confirm these field observations, meteorological data will be collected from weather stations located in or near selected BGMV-affected bean production regions. Additionally, a group of local bean farmers will be selected in each target area to take daily precipitation and temperature data using simple rain gauges and thermometers provided through the project.

Additionally, the dynamics of whitefly (Bemisia tabaci) populations will be monitored at selected locations representative of the different regions selected for this investigation. Growers will be trained as well in simple whitefly monitoring methods to complement on-farm weather data. Satellite imagery will be used to correlate cloud cover to microscale data and to monitor major climatic phenomena, such as tropical disturbances and fronts, which greatly modify the course of BGMV epidemics in Central America and the Caribbean as a demonstration of the potential benefits of satellite weather information for agricultural purposes.

World-wide deployment of resistance to African cassava mosaic disease. African cassava mosaic virus (ACMV) is the most destructive virus that infects cassava. Currently there is a devastating epidemic that is sweeping through Uganda and has eliminated cassava production from a large area of the country. Also for the first time, geminiviruses that cause African and Indian cassava mosaic disease pose a threat to cassava production in tropical America. There are at least three distinct geminiviruses that cause ACM and Indian cassava mosaic (ICMV). Since cassava was introduced from South America to Africa, these viruses undoubtedly moved from other plants to cassava. Currently, there is a new biotype (it has been reported as a new species) of whitefly that is known to colonized cassava. This whitefly is also a vector for geminiviruses. The whitefly is distributed throughout the Caribbean, Central America and the southern part of the United States. The range of the whitefly is expanding rapidly and may already be in parts of South America. Since native geminivirus could move to cassava or a dormant reservoir (ACMV-infected cassava that affected only a single variety since there was no vector) may spread the disease from Africa to tropical America, there is a need for a project to develop a molecular marker to the know resistance to ACMV. This will best be linked to a project that compliments the current efforts to combat the epidemic of ACMV in Uganda. This project will need special project based funding and will take 3-5 years. The objectives will be to develop gene pools and expand the distribution of ACMV resistant varieties to mitigate and prevent losses due to African mosaic disease in cassava.

c. Interdisciplinary initiatives

By mandate, the VRU has to interact with CIAT's research programs. The VRU also collaborates closely with the Genetic Resources Unit, mainly in the area of seed health and germplasm conservation. One of the main joint projects between the VRU and the GRU, is the 'Elimination of Viruses Affecting the Utilization of Plant Genetic Resources Stored at CIAT'. The collaboration with the Biotechnology Research Unit is centered around the transformation of virus-affected plant species investigated by CIAT.

g. Relation of VRU's projects to CG system wide projects

The activities of CIAT's VRU can be linked to those currently implemented at other IARC's, such as IITA on cassava viruses; ILCA-ILRAD on viruses of tropical forages; ICRISAT on legume viruses, and IPGRI on the safe exchange of plant germplasm. CIAT's VRU could also play a major role in centralizing virology research in Latin America, considering the unique virology research facilities it has.

Production Systems & Soils Management Research Group

Leader: Richard J. Thomas
Associated Unit: Soils Research Unit (to be developed)

Rationale and background

As farmers try to increase production for their own needs and in response to new opportunities there is a danger that agriculture will contribute to the degradation of soil and water resources, increased pollution and loss of biodiversity. Agricultural systems are needed which satisfy both the short-term requirements of farmers and the long-term sustainability of their production systems. The task requires an integrated research strategy that blends studies on biophysical constraints with socioeconomic and policy issues. The PSSM-SRG will attempt to ensure that research projects are developed which take into account these goals.

Current production systems tend to mine the soils for nutrients and where cash and export crops predominate the region and even a country can have a negative nutrient balance. Productive and sustainable systems cannot be obtained by mining soils, yet access to large agrochemical inputs is beyond the means of most poor farmers. In addition there is evidence of soil loss, degradation and loss of sustainability within the major cropping areas of Latin America.

The recent report of the CGIAR Task Force which responded to the issues on soils raised by the Agenda 21 documents (Action plan to follow up on UNCED, 1993), proposed that the CGIAR system focuses its soils research efforts towards attaining sustainability on marginal soils. In Latin America and in CIAT's target areas, the majority of the soils are predominantly acid and infertile (oxisols and utlisols) with low amounts of available nutrients especially phosphorus, low levels of soil organic matter and cation exchange capacity and hence are marginal. Although possessing excellent physical qualities for agricultural use these soils are susceptible to degradation and when mismanaged can degrade within 2 to 3 years of being brought into production. Such soils however cover much of the remaining areas of the world which could be brought into productive agriculture. In Latin America these soils cover the 250 million ha of savannas of which some 76 million ha could be brought into production relatively quickly.

If these areas are brought into production the soils need to be managed carefully in order to avoid degradation such as that already occurring in large areas of the Brazilian cerrados after cropping and pastoralism.

The problem requires a changed emphasis away from amending the soil conditions for crop production by use of large amounts of inputs including irrigation, fertilizers and lime, to a system that relies on plant germplasm adapted to prevailing soil constraints, on increased efficiency in the use of on-farm and external inputs and on a maximization of nutrient cycling. Successful implementation of this changed focus requires the participation of farmers, increasing the knowledge of farmers and an increasing awareness of the issues involved by policy makers.

The role of soil science - a new approach
Most soil research has been carried out in temperate regions, which have inherently better soils and which have been used for intensive cropping systems with inputs. Under these circumstances soil research conducted during the last 30 years has fostered and encouraged examination of individual factors and practices, but has not dealt well with integrated systems as a whole. For example, soil tests have been developed based on simple correlations between inputs and outputs, without considering the interaction between inputs and the soil environment, particularly organic matter and soil losses. This picture is no longer valid for sustainable agricultural systems, particularly in the tropics. What are needed are input efficient agricultural systems based on efficient utilization of resources to achieve high productivity while conserving the soil resource.

Unfortunately work on whole systems, or complexes of systems is difficult because of the inherent complexity, which, using conventional methods, leads to much higher research costs. A fundamental rethinking of the present approach to soil-plant research is needed if the inherent difficulties are to be overcome. The interactions between the components of the systems will need an approach quite distinct from "farming systems" research conducted a decade or so ago.

Work on soils in the past has followed four major lines;

- Characterization of the resource base (mapping, morphology, description, genesis and mineralogy)
- Soil chemistry (chemistry of clays and soil/fertilizer interactions)
- Soil physics (hydrology, structural stability, physics of clays, surface stability/ erodability, erosion processes).
- Soil fertility and management based on high inputs of machinery, fertilizers and pest control.

Much of this work has viewed the soil as a static resource, with little attempt to determine the processes that are responsible for soil degradation or conversely are responsible for its maintenance.

In temperate regions, the soils are inherently more fertile, with, of course, some notable exceptions. On these stable soils systems of production evolved based on high input technology, which could afford almost to ignore the role of the soil as a source and sink of nutrients. These systems could be viewed from a strictly industrial viewpoint of inputs and outputs in terms of harvestable plant materials and almost independent of the soil processes. However it is now recognized that this viewpoint ignores the understanding of the interaction between the chemical, cultural and biological aspects of the of the soil-plant-atmosphere, the loss of soil organic matter and environmental pollution from excessive and inefficiently used inputs. Consideration of these aspects is essential for management of natural resources in sustainable systems of crop production.

The major essential difference between temperate and tropical regions is temperature. On average, the tropics are 15°C warmer than temperate regions, and moreover do not have cold winters. This has enormous implications for the rate of production and decomposition of organic matter, and a major influence on the cycling of nutrients in tropical ecosystems.

Rapid and cost-effective progress can only be made by groups of scientists working in collaboration across a range of traditional research disciplines. In any particular agroecosystem, high crop yields, stable in the long term, come from using cropping sequences whereby the nutrients removed in the harvested yield are balanced by chemical and biological inputs.

The term "sustainability" which is increasingly being applied to modern agriculture, requires meeting the challenge to optimize the balance between inputs and outputs of production systems while providing a basis for a continued increases in productivity and minimizing adverse effects on the environment. Agricultural systems have achieved high levels of production by using agronomic practices to modify the natural, physical, chemical and biological processes. These modifications frequently modify the environment, especially the soil, so that it is vital that information on dynamic processes of the soil (for example, on nutrient dynamics), be integrated with information on all other factors controlling the functioning of these complex systems.

Biological, physical and chemical processes influence natural resource management. For example, applied nutrients, the soil and its organic matter, and their interactions with climate affect crop yield through their influence on the balance between concurrent mineralization and immobilization, and nutrient availability. Thus inputs of organic matter impact the supply of essential nutrients (N, P and S), and the timing of their release in mineral form, both on unfertilized soils and on soils to which fertilizer is applied. We must understand these processes and their controls sufficiently to provide practices to improve the management of natural resources whilst maintaining or increasing the productivity of acid infertile soils of tropical America.

Several subdisciplines of soil science have already made great progress using quantitative methods. For example, quantitatively-defined class limits in soil taxonomy has increased our ability to organize our knowledge of the soil resource, and quantitatively-defined critical levels of nutrients are very useful tools for making economically-sound fertilizer recommendations to farmers, particularly in high input cropping systems. However, there is a need for better measurement techniques in input-efficient systems of soil management to provide, for example, more accurate and timely use of fertilizers, especially nitrogen. Nitrogen left in the soil after plant growth, irrespective of whether it was applied as manure, commercial fertilizer, or came from the use of legume crops, may leach to ground water. This potential for contamination demands much more sensitive and integrated approaches to the management of nitrogen and other nutrients in different cropping systems.

We must be able to measure total and available nitrogen and phophorus in soils, as well as establish the criteria for methods to predict the ability of soils to release these nutrients over time under different environmental conditions. At the same time, we must design cropping systems in which plant requirements and uptake are in synchrony with nutrient releases from the soil. For this purpose, adequate soil nitrogen and phosphorus tests must be developed and should be based on careful analysis of the relationship between the most profitable rates of nitrogen and phosphorus application and those that are environmentally safe.

Soil Organic Matter

Studies on soil, especially on soil organic matter (SOM) have tended to follow two approaches in the past. One approach has concentrated on elucidating the chemical structure of SOM, the other on biological activity of soil fractions i.e. what is SOM versus what does it do. It is now widely recognized that these two approaches should be integrated to provide an insight into the role of SOM dynamics in alleviating nutrient and stress problems in soil. It is also recognized that our knowledge of biological processes involved in the transformations of SOM, including inputs from plant debris (plant-soil interactions) is limited and yet these biogeochemical activities are the main means of providing plants with nutrients, especially in the absence of high fertilizer inputs.

Given this change of scenario from high input to efficient sustainable systems using lower, strategic inputs, it is now recognized that our knowledge of SOM dynamics is meager and requires further study and additionally requires the development of appropriate methodologies for this "dynamic approach". The "dynamic approach" probably at its simplest level means measuring changes in total OM content of soils over time and under different treatments or land use. We know that such changes involve relatively long periods of time but there are potential early-warning methodologies available, which although requiring refinement could be useful for predictive purposes thereby limiting the requirement for long term studies.

Nutrient Cycling

To be sustainable, agroecosystems should closely resemble natural ecosystems in certain respects. For example, increased species richness (polycultures, hedgerows) may decrease risks of production failure by providing alternate crops and by promoting natural predators of pests. However, high species diversity can be very difficult to manage in practice. Thus, species richness for its own sake may be counter-productive. Nutrient cycles in undisturbed ecosystems tend to be more closed and less "leaky" than in agro-ecosystems. However, an important characteristic of agroecosystems is that they export large amounts of nutrients in crop biomass, and therefore, require large inputs, regardless of the amount of recycling that may occur within the system. By design, these systems have large nutrient through-flows that will necessarily alter their biological and physico-chemical characteristics relative to natural ecosystems. The greatest challenge is to minimize nutrient losses through these systems and maximize efficiency of internal nutrient recycling.

Therefore, rather than less intensive management, sustainable agroecosystems will require more intensive and better-informed management of all ecosystem components. The primary goal of management should be to optimize internal natural processes, using exogenous inputs within the constraints of sustainability. Understanding of the factors affecting gains and losses of nutrients by natural processes is of paramount importance in developing management practices for efficient use of nutrients by plants, and efficient cycling within the system.

Soil biology

Natural ecosystems have evolved in a manner that conserves nutrients. As an example, nitrogen is rarely lost in unfertilized ungrazed grassland in large quantities by any process. Immobilization and mineralization processes are in synchrony with plant uptake, which results in minimal nutrient losses. Agroecosystems that mimic natural systems in terms of lack of soil disturbance and return of crop residues to the soil help maintain the synchrony of nutrient cycling processes and minimize nutrient and organic matter losses.

In general, soil degradation from poor management has occurred even though short-term, high levels of crop production provided excellent opportunities to improve soil properties and their long-term productivity. In a system in dynamic equilibrium with interchanges governed by chemical, physical and biological interactions, soil biological activity is often depicted as a wheel rotating in the soil in response to energy (carbon) inputs and having a central role in nutrient transformations. Attention should, therefore, focus on the necessity of understanding the processes involved in nutrient transformation in soil with emphasis on soil biological activity.

The soil, the soil rhizosphere (the soil immediately around a plant root) and the rhizoplane (the root surface, including the mucigel and adhering root debris) are marvelously complex and scientifically interesting ecosystems. The number of microorganisms found in these environments is impressive. Some of these microorganisms have both positive and negative influences on plant growth and development. The positive influences include: (i) decomposition of plant residues, manures, and organic wastes, (ii) increase in the availability of plant nutrients, (iii) biological nitrogen fixation, (iv) plant growth promotion, (v) control of soil nematodes and insects, (vi) biological control of weeds, (vii) bio-degradation of synthetic pesticides or industrial contaminants, and (viii) enhanced drought tolerance of plants. The negative or detrimental influences include: (i) nutrient immobilization, (ii) plant diseases, and (iii) the microbial production of phytotoxic substances.

The activities of soil biota are extremely important in nutrient cycling and maintenance of soil conditions in agroecosystems, thereby contributing to agricultural sustainability. There is a diverse array of organisms comprising the soil biota and the habitats and microhabitats in which they reside. For the purposes of agroecosystem management, the shoot/litter/root/microbial/fauna/soil system should be considered as a series of interacting components, all of which play roles in nutrient immobilization or mineralization at various times.

In sustainable agroecosystems, the soil biota play an important role in regulating nutrient cycling processes and maintaining soil structure. Soil biota influence sustainability in several key areas which include: (i) internal cycling of nutrients, and (ii) altering soil structure by affecting soil aggregates and porosity and the formation and distribution of soil organic matter. Careful thought and management are required to achieve an effective synchrony of biotic and chemical interactions (principally in terms of nitrogen and phosphorus cycling). Newly-developed methodologies are becoming available for investigation of the problems identified above.

Examples of these newer methodologies include isotope labelling of whole soil e.g. ^{15}N and ^{13}P, microbial biomass measurements, natural abundance of ^{13}C and ^{15}N isotopes, soil physical fractionation techniques.

CIAT's scientific research group for production systems and soils management will be focusing on this "dynamic approach" to SOM and nutrient management rather than the outdated traditional soil chemist's or physicist's approach.

The rationale for this thrust is that it is particularly important for tropical soils with their high leaching potential, high levels of acidity and toxic metals (Al + Mn) and low levels of available P and N because they are less likely to be remedied by expensive inputs of fertilizer.

There is thus the need to study the SOM fractions and their dynamics and their interactions with nutrient cycling using the techniques mentioned above in order to assess their impact on ecosystem function.

CIAT has the largest collection germplasm tolerant to acid infertile soils, toxic levels of aluminum in its Genetic Resources Unit and includes rice, beans, cassava and tropical forage grasses and legumes. This germplasm will play a major role in the development of sustainable production systems on the predominantly acid soils of Latin America.

For CIAT's targeted agroecosystems the achievement of productive and sustainable agricultural production systems involves primarily developing alternatives to slash and burn agriculture in the forest margins, arresting erosion on hillsides and maintaining soil organic matter in savannas.

Such an approach cannot be done without due attention to the socioeconomic/political environment and without farmer participation. Improved soil, water and nutrient management technologies will not be attractive to farmers if they require long-term investments without the security of land tenure. Similarly few non-tenured farmers will invest in trees or permanent erosion barriers if they do not bring immediate returns. In addition, as pointed out in the CGIAR Task Force document, the policy environment must be examined for fertilizer use as this is the only long-term option for replenishing nutrients removed from the agroecosystem in agricultural products.

The new approach to soils management will be knowledge-based and management intensive. This implies that farmers must have this knowledge and a policy environment which encourages this approach. The achievement of this goal will require the participation of farmers and a better understanding of how farmers make decisions on resource allocation and choice of farming system components within the farm. Thus the PSSM-SRG will also emphasize research on socioeconomic aspects of Latin American farmers.

Constitution of the PSSM-SRG

CIAT's Production System & Soils Management Research Group has the mix of disciplines needed to undertake the task of achieving increased production systems without degrading the natural resource base and the group supplies the necessary cross-discipline expertise to ensure that technological developments are linked with social, economic and policy issues.

Competence areas

The PSSM-SRG consists of some 22 scientists whose disciplines include soil chemistry, soil physics, soil microbiology, plant nutrition and physiology, agronomy & production systems, animal nutrition, agricultural economics and sociology. The group's activities range from laboratory to field research, from basic biology to sociology and spans the spectrum of small holders to ranchers.
This group of scientists interacts with others with expertise in biotechnology, genetic resources, land use management and resource economics to ensure a holistic approach that uses advanced methodologies from different disciplines. The group is part of the MAS (management of acid soils) consortium which involves some 15 institutions from NARS and universities in developing countries, universities in developed countries and other international centers (ICRAF, CIMMYT, ORSTOM, IFDC, CATIE).

Competence disciplines & activities

Soil chemistry

- Improvement of soil analysis to reflect plant available nutrient pools especially for acid tropical soils
- Analysis of nutrient cycling and use efficiency in prototype production systems
- Application of crop and cropping system models that represent crop growth, phenology and nutrient cycling

Soil physics

- Analysis of land use systems and soil physical conditions in relation to erosion risk and compaction
- Application of models that simulate soil physical trends under contrasting land uses

Soil microbiology

- Biological nitrogen fixation and transfer in pasture and agropastoral systems
- Integration of biological inputs of N with fertilizers in cropping systems
- Improved symbiosis with soil microorganisms

Plant nutrition/physiology/weed ecology

- Matching plant requirements to soil constraints
- Physiological traits and selection protocols to increase yield and overcome abiotic constraints
- Effect of weed competition on land degradation

Agronomy & production systems

- Analysis and validation of alternative cropping systems compatible with natural resource protection; application of mechanistic models of soil and plant processes

- Dynamics of key soil processes in agropastoral systems

Animal nutrition

- Analysis & quantification of forage/animal interactions

- Identification of nutritional/antinutritional factors in forages grown in soils of low fertility

- Grazing patterns in agropastoral systems

- Nutrient cycling via the animal

Agricultural economics

- Assessment of the economic benefits and impact of alternative agricultural technologies at the farm level

- Evaluation of the impact of external factors, such as prices and other policies, on on-farm land use strategies

- Modelling of socioeconomic processes

- Social technologies; alleviation of socioeconomic constraints through economic analysis of institutions

Sociology

- Development of participatory research methods to evaluate alternative technologies at farm and community scales

- Analysis of farming systems in the decision making process at farm and community scale

- Analysis of on-farm testing of alternative production systems

Members of Production Systems & Soil Management SRG

Competence	Staff member
Soils Science	J.I. Sanz
"	D. Friesen
"	R. Thomas - Leader
"	A. Gijsman
"	B. Knapp
"	M. Ayarza
Ecophysiology	M. Fisher
Agronomy	K. Mueller-Saeman
"	R. Howeler
"	M. Thung
"	R. Moreno
"	G. Rippstein
"	R. Kirby
"	C. Wortmann
Plant Nutrition	D. Beck
"	I.M. Rao
Animal Nutrition	C. Lascano
Economics	G. Henry
"	D. Pachico

CIAT Project Profile

Phosphorus Acquisition and Recycling in Low P-Supplying Tropical Soils

Purpose: To identify plant traits and mechanisms responsible for efficient acquisition, utilization, and recycling of P and to match requirements of upland rice, beans, cassava, maize, and tropical forages to the low P-supplying constraints of soils

Rationale: Phosphorus (P) is the major nutrient limiting crop and forage production in low-fertility soils (oxisols, ultisols, and andisols) of Latin America. The P-supply capacity of these soils is low even in those soils with a high total P content because of chemical reactions that fix phosphate-P into forms that are unavailable to most plants. A major option for resource-poor farmers using these soils is the adaptation of plants to the soil constraints rather than attempts to modify the soil via high inputs of fertilizer. Crop and forage genotypes that can use scarce nutrients more efficiently would improve and stabilize production for resource-poor farmers. One advantage of phosphorus fertilizer is that it tends to remain in the soil-plant system and is not subject to large losses via leaching associated with the use of N fertilizers, for example. Therefore, basal or corrective P fertilizer applications could be viewed as a capital investment with beneficial residual effects occurring over time.

However, in general, socioeconomic constraints impede the application of large quantities of P to low P-supplying soils of Latin America. There is a need then to devise a strategy to manage native and applied P resources more efficiently for low P-supplying soils in the region. The key research components to develop such a strategy are: 1) characterization of soil P environments and P sources, 2) identification of plant traits and mechanisms to develop screening procedures to evaluate genotypic differences in P uptake and use efficiency, 3) development of P efficient crop genotypes using conventional and advanced genetic approaches, and 4) development of integrated crop-pasture systems that can benefit from combined organic and inorganic P inputs.

The proposed research would be done in collaboration with national programs, universities, and institutes in developed countries; CIAT would conduct strategic research and facilitate the exchange of germplasm and information across state/country borders.

Expected Benefits: The project will allow closer matching of crops with the environment, an increased efficiency of phophorus fertilizer use, and the identification of traits conferring adaptation to the major constraining nutrient in tropical soils.

Expected Outputs:
- Characterized soil P environments and available P sources
- Defined plant traits and mechanisms and improved screening procedures for morphological/physiological molecular traits
- Nutrient efficient genotypes developed
- Integrated production systems efficient in P utilization and recycling

Activities:
- Develop methods to characterize available P sources.

- Produce thematic soil maps.
- Conduct diagnostic surveys of constraints to farmer adoption of alternative P supply
  strategies.
- Elucidate plant attributes for P uptake/utilization.
- Determine critical levels of tolerance to soil constraints.
- Evaluate germplasm for P use.
- Evaluate P balance and cycling in prototype systems.
- Develop a P decision support model.
- Conduct ex ante analysis of practices that prevent P fertility maintenance.

Research Partners: CIMMYT, ICRAF, IFDC, EMBRAPA-CPAC, EMBRAPA-CNPAF, EMBRAPA-CNPAB, CORPOICA, Cornell University, University of Hohenheim, CSIRO, University of Hawaii

Potential Donors: IDB, UNDP, DLO, NORAID

Time frame: 5 years

Funding: $6.2 million

CIAT Project Officer: Idupulapati Rao

CIAT Project Profile

Sequestration of Carbon and Gaseous Fluxes
in Tropical Production Systems

Purpose: To understand the processes of uptake and loss of greenhouse gases and their controls so as to devise systems of sustainable agriculture for the tropical lowlands that contribute to lessening of global warming

Rationale: Concentrations of greenhouse gases in the atmosphere (carbon dioxide, CO_2, methane, CH_4, and nitrous oxide, N_2O) are increasing at rates that will cause substantial climate change within 50-100 years. Of the one-quarter of the total that agriculture contributes, one-third comes from the tropics, mainly by deforestation and converting the savannas to agriculture.

Changes in patterns of land use in the lowland tropics to continuous cropping, to crop-pasture rotations, or to permanent pastures have important implications for greenhouse gas emissions. There are few data on the amounts of soil carbon lost to the atmosphere during deforestation or the amounts of carbon that can be fixed in tropical soils during reclamation of degraded lands or in mixed agropastoral systems. We need to quantify the changes in gains and losses of greenhouse gases as land use in the tropical lowlands changes.

Concern has been expressed that more than 50% of the area sown to improved pastures is degrading due to mismanagement. However there is a need to identify more precisely, using satellite information linked to GIS, the exact areas and extent of degradation occuring in the savannas. This project will examine these issues for tropical lowland production systems.

Expected Benefits: The project will produce information of benefit to the farmer and to the global community at large in terms of reductions in greenhouse gases.

Expected Outputs:
- Quantified carbon dioxide/methane pools and fluxes
- Quantified nitrous oxide pools and fluxes
- Manangement practices to promote C storage and reduced methane emission
- Improved fertilizer N efficiency and management of green manure to reduce nitrogenous gas volatilization

Activities:
- Establish long-term exeriments on-farm and on-station in Colombia and Brazil.
- Estimate above- and below-ground biomass production.
- Estimate litter and root decomposition.
- Measure and model soil organic matter dynamics.
- Develop C, N, and methane flux models.
- Estimate regional effects and compile GIS database.
- Estimate burning and degradation of pastures.

Research Partners: CABO-DLO (The Netherlands); CENA and EMBRAPA (Brazil); CIET-IVIC (Venezuela); Cornell, Ohio State, Colorado State Universities (USA); ICRAF; University of Bayreuth (Germany)

Proposed Donors: GEF, UNEP, EPA, UNESCO

Funding: $6 million

Time frame: 5 years

CIAT Project Officer: Myles Fisher

CIAT Project Profile

Integrated Nutrient Management
for Tropical Lowland Agroecosystems

Purpose: To integrate the use of inorganic and organic inputs with germplasm adapted to the soil constraints of tropical lowland agroecosystems

Rationale: Intensification of agricultural production on the acid soil forest margins and savannas of Latin America is constrained by the lack of diversity in acid soil tolerant germplasm and low soil fertility. The use of high levels of inputs and machinery, especially in monocrops, is thought to be unsustainable, since it results in deterioration of soil biophysical properties, soil and nutrient loss, and a potential escalation of pest and disease problems. To manage these marginal soils better, a new paradigm is needed that relies more on biological processes by 1) adapting germplasm to adverse soil conditions, 2) maximizing nutrient cycling to minimize external inputs, and 3) increasing the efficiency of input use.

To match germplasm requirements to soil constraints, soil environments need to be further characterized, involving the production of thematic soil maps. Critical levels of tolerance to soil constraints need to be established for the range of adapted germplasm available in addition to the further improvement of germplasm for soil constraint tolerance.

Improved legume-based pastures are an important component of this new paradigm, as they can be used to recuperate degraded soils by accumulating organic matter and providing a source of N input via biological nitrogen fixation. But they require investments in inputs for establishment that are often beyond the means of graziers. Establishment of pastures in association with a crop such as rice defrays the costs of inputs for pasture alone and has proven to be a viable alternative in frontier areas of the savannas. However, as farmers see the profits to be made from rice, this development could deteriorate into rice or other monocropping with detrimental effects on the soil resource base and environment. Alternative systems incorporating components that attenuate or reverse the deleterious effects are required, and biophysical measures of system performance need to be developed.

This project includes an investigation of "best-bet" options using grain legumes, green manures, intercrops, and leys as system stabilizing components. The data obtained will be used to develop integrated models that simulate the effects of system components and management on system sustainability. Indicators of land quality will be developed by on-station and on-farm studies. The latter will involve cross-sectional analyses of existing farming subsystems in an attempt to mimic in space what happens in time. A diagnostic analysis of farmer's perceptions and problems is also included.

The project will be of a long-term nature involving crop rotation cycles of 5 years on-station and will focus on the strategic aspects of ley farming in the savannas and forest margins. The development of technological options will occur in parallel with the identification of farmers needs and perspectives of ley farming systems.

Expected Benefits: Prototype systems combining crop and livestock components will improve nutrient cycling, pest and disease control and soil quality, in a productive and sustainable manner.

Expected Outputs:
- Characterized soil environments and critical levels of soil constraints determined in adapted germplasm
- Analysis of inputs and performance of contrasting cropping systems
- Models of soil-plant dynamics
- Integrated use of inorganic/organic inputs
- Guidelines for on-farm decision making

Activities:
- Produce thematic soil maps characterized by biophysical constraints.
- Quantify inorganic/organic inputs.
- Determine nutrients released from residues/fertilizers.
- Determine crop yields/animal production.
- Analyze carry over effects of crop rotations.
- Monitor pest and diseases.
- Develop predictive models of organic input decomposition.
- Develop practices to efficiently use organic/inorganic inputs.
- Model fluxes of nutrients through inorganic/organic pools.
- Analyze farmers' resource allocation patterns.
- Conduct system economic analysis.
- Develop chronograms for integration of organic/inorganic inputs.

Research Partners: CORPOICA, CIMMYT, EMBRAPA-CPAC, EMBRAPA-CPNAF, EMBRAPA-CNPAB, Cornell University, Ohio State University, IFDC

Proposed Donors: UNDP, World Bank, BID

Funding: $?

Time frame: 5 years

CIAT Project Officer: Richard Thomas

CIAT Project Profile

Integrated Inorganic/Organic Farming Methods for Smallholders

Purpose: To integrate the use of inorganic and organic inputs on smallholder farms and to understand how farmers decide on the allocation of materials, time, labor, and financial resources

Rationale: Intensified land-use in marginal areas, such as the hillsides and forest margins, is resulting in large-scale environmental degradation and loss of soil and biodiversity. Resource-poor farmers are forced to exhaust the nutrients in the soil and apply inappropriate crop and soil management technologies, many revolving around shifting cultivation. Remedies like those associated with the Green Revolution are inappropriate for this sector of the farming community. A new soil paradigm that relies more on biological processes by adapting germplasm to adverse soil conditions, maximizing nutrient cycling to minimize external inputs, and increasing their efficiency of use has been suggested as one means of rectifying unsustainable farming systems for smallholders. One of the key aspects of this approach is the integration of on-farm resources, such as manures and crop residues (organic inputs), with off-farm resources, such as fertilizers (inorganic inputs) and pesticides.

Research is needed both on the strategic aspects of the integration of on- and off-farm resources and on the decision making processes of farmers with respect to their allocation of materials, time, labour, and financial resources to these inputs.

Benefits: Stabilization of the shifting cultivator will drastically reduce further tropical deforestation and will have a large impact in frontier areas.

Expected Outputs:
- Inventory of inorganic/organic inputs of smallholders
- Integrated use of inorganic/organic inputs
- Guidelines for on-farm decision making with respect to inputs

Activities:
- Quantify amounts and nutrient contents of crop residues/manures/tree clippings
- available on-farm.
- Quantify nutrients released by litter and roots.
- Quantify amounts, types, and placement of fertilizers.
- Develop predictors of organic input decomposition.
- Model fluxes of nutrients through inorganic/organic pools.
- Quantify role of soil fauna in nutrient cycling.
- Analyze farmers' decision making on resource allocations.
- Identify reasons that farmers continue unsustainable practices.
- Develop calendars for integration of inorganic/organic inputs.

Research Partners: Bayreuth University and University of Hohenheim (Germany); CENICAFE (Colombia); CIRAD/ORSTOM; EMBRAPA-CPATU (Brazil); IBSRAM; ICRAF; North Carolina State University, Ohio State University, University of Florida (USA); University of Madrid
CIAT Project Officer: R. Thomas

Proposed Donors: GTZ, SDC, UNDP, Rockefeller Foundation

Funding: $700,000

Time frame: 5 years

CIAT Project Officer: Richard Thomas

LAND MANAGEMENT SRG

EXECUTIVE SUMMARY

The Land Use Program as it appears in the Annual Report 1993 has since been transformed into the Land Management Scientific Resources Group, as part of the definition of the new Action Plan for CIAT. With the latest incorporation of a SS in 1994, a total of 4 SS are now budgeted in the Group.

The basic research themes of the Group focus around the understanding and anticipation of land use changes, the determinants and impacts of land management, and their implications for technology development and diffusion. The major goals are to influence policy-making and technology generation (insofar as helping to identify the required technological "profile" for sustainable agriculture). This requires the causal analysis of trends in land use, the study of the spatial distribution of agricultural land use patterns in relation to ecological factors, understanding the role of cross-scale (micro/macro) interactions in land use dynamics, and the identification and development of policy-relevant indicators of sustainable land use.

The activities of the Group center on three target agroecosystems: savannas, hillsides and forest margins. Some of the new project ideas involve the whole ecoregion.

The major clients of the Group are policy-makers at the national and regional levels, and the NARD's and other CIAT's Programs that concentrate on technological generation and diffusion.

The current strategy involves the consolidation of the existing capacity; the gradual move from service activities to cooperative activities, and at the same time, the generation of own projects; the gradual broadening of the scope so as to include ecological and socio-economic approaches; and the seeking of external financial support for the launching of new research themes, whenever possible.

This report presents the past and current research activities grouped into broad categories corresponding to each major agroecosystem, to commodity-focused research, and to central or general land management research and activities.

Future research activities committed and proposed are described. Some of them have a high chance of being funded by external donors. Future research involves agroecosystem themes, continental projects, biodiversity-related projects, commodity-related activities, and theoretical research.

INTRODUCTION

Overall Goal and Objectives
The overall goal of the Land Management SRG is to improve the management of land resources in tropical America in a sustainable way.

Historical Background
The forerunner to the Land Management Scientific Resources Group was the Agroecological Studies Unit, providing services for the CIAT Commodity Programs.

The objectives of the Unit were:
1. To assist management in setting research priorities.
2. To assist scientists in defining the geographic extents of researchable problems.
3. To evaluate the potential areas of impact of new technologies resulting from research.
4. To identify new areas of research.

In 1991, CIAT produced its Strategic Plan announcing the launching of a major research effort on resource management, additional to the existing efforts on germplasm development. This included the creation of four Programs within Resource Management namely: Land Use, Forest Margins, Hillsides, and Savannas. The Land Use Program incorporated the former Agroecological Studies Unit, and it was formally created in 1992. The objectives of the Land Use Program, were:

1. Understand the dynamics of land use.
2. Appraise policy alternatives for improved land use.
3. Assess the impact on land use of new technologies and policies.
4. Strengthen national capacity to improve land resource management.

In the CIAT Medium-Term Plan (1993-1998), six SS positions (including the Leader) were defined for the Program (3 for 1992, 4 for 1993, 5 for 1994, and 6 for 1995 and thereafter). The GIS Specialist was recruited in 1992, joining the existing specialist on Agricultural Land Use. The Leader of the Program took office early 1993, completing a total of 3 SS.

Due to the CIAT's (and CGIARs) economic crisis of 1993, the recruiting of the planned SS was frozen. The goals of the Program were cast into the following basic research themes:

1. Understanding and anticipating trends of land use in tropical America.
2. Analyzing the spatial distribution of land use patterns in relation to ecological factors in tropical America.
3. Understanding the role of cross-scale (micro/macro) interactions in land use dynamics.
4. Identifying and developing policy-relevant indicators of sustainable land-use.
5. Providing GIS services to other Programs.

As an outcome of the new Action Framework approved by the Board of Trustees in November 1993, five Scientific Resources Groups were created in February 1994. The Land Use Program was converted into the Land Management Scientific Resources Group. Also in early 1994, an Agricultural Anthropologist was incorporated into the Group.

which total now 4 SS budgeted in the Group. The recruitment of a Tropical Ecologist was launched in late 1993, but the Selection Committee has not yet been designated.

Contribution to CIAT's Strategic Plan
During the preparation of CIAT's Strategic Plan, a GIS approach was used to determine CIAT's priority agroecosystems.

The evaluation involved: (i) Environmental description of Latin America and the Caribbean (done by generating a classification of the continent based on environmental variables, overlaying socio-economic variables, and ranking the environmental classes according to derived indexes, such as rural poverty, environmental degradation risk, relative productivity and potential contribution to growth); (ii) Selection of likely candidates for environmental classes (through a systematic assessment of the classes, including also the priority of the class in terms of CIAT's commodity responsibilities); (iii) Characterization of actual land use within each class (through subdivision into subzones, their characterization in terms of generic production systems, and regrouping into land use clusters; and (iv) Selection of agroecosystems as possible foci for research (through an evaluation process taking into account economic potential, resources potential, resource problems, equity, technological considerations, and institutional considerations).

This process led finally to the selection of three priority agroecologies for CIAT's resource management research: (1) the cleared margins of rain forests, (2) well-watered hillsides, and(3) tropical savannas. On this basis, the decision to create one Program for each agroecology was taken by CIAT.

Having determined the agroecosystems of interest, further multidimensional geographic analyses were used to prioritize potential study areas. One of the first of these was to identify a study site in the Hillsides agroecosystem of Central America.
Variables belonging to the physical environment, the use of the land, and the socio-economic aspects, were used. The information was digitized and processed through a Geographical Information System (GIS), using a grid of spatial cells.
Multivariable analysis revealed rural impoverishment, demographic concentration, urbanization and urban impoverishment, and migration as the major factors explaining a large portion of the variance in the original 21 variables. Forty two relatively homogeneous groups of cells were defined through cluster analysis.

On the basis of correlation between descriptive variables at the regional scale, a number of dynamic processes such as concentration of resources and small farms, urbanization or demographic concentration, migration, conversion of forests to pastures, isolation and colonization, and the intensification and expansion of plantations, all in their spatial context, were inferred.

The study was presented to a Workshop held in CATIE in August 1991. This led to the identification of La Ceiba (in Honduras) as the chosen site for interinstitutional research. This is one of the selected sites for the Hillsides Program research. The methodology developed for this study was subsequently modified and used to identify study areas in the other agroecosystems as described below.

Major Clients and Regional Impacts

Land use, and particularly agricultural land use, is a very important activity in Latin America. The most rapidly changing agricultural frontiers lie in tropical America. The sustainability of food production is intimately tied to the forms of land use. However, land use in Latin America is also considered to be the source of the most important problems of environmental degradation, from soil erosion to biodiversity loss, with local, regional and global impacts. The Group's research will provide support for policy-making regarding the sustainable use of land, as well as guidelines for the development of technology that increases productivity of the same time that it concerns the environment.

The major clients of the Group are thus, policy-makers at the national and regional levels, and the NARD's and other CIAT's Programs that concentrate on technological generation and diffusion.

Historical Assessment of Research Activities

General Strategy

The general strategy adopted in the last two years involve:

1. To consolidate the existing capacity (which currently lies mostly in GIS and the geographical aspects of land use).

2. To gradually move from service activities to cooperative activities with other Programs and SRG's, and the NARD's, and at the same time, to generate a number of own projects.

3. To gradually broaden the scope so as to include the necessary ecological and socio-economic approaches.

4. To seek external financial support for the launching of new research themes, whenever possible.

For reason of clarity, the research presented here is grouped into the three major priority agroecosystems, a commodity-focused category, and a central or general category. This research includes finished, ongoing and committed activities.

Forest Margins

Research Prioritization and Site Selection for Forest Margins Areas, Brazil

A large scale characterization of parts of the Brazilian Amazon including Acre, Rondonia, Maranhon and Para, was carried out. Following the initial analysis the individual areas of forest margins were processed with secondary data on agricultural and pastoral production data. Satellite images for Para (Paragominas) and Acre/Rondonia were digitized and overlaid with digitized soil, geology and vegetation maps. The results were presented in a report which is being used in consultation with CIAT's partners in Brazil to define the final study area. As a consequence of the studies, Acre/Rondonia was selected as the site for the alternatives for Slash and Burn (ASB) Project and the IDB Project described below. This study has finished.

Diagnosis of Agricultural Land Use in Southwest Brazilian Amazon

This is an IDB-sponsored project that started in 1994 in a site selected on the basis of the prioritization study. This research aims to characterize and analyze processes of deforestation in Acre and Rondonia in order to then be able to identify, test, and adapt alternatives to slash-and-burn agriculture that would effectively reduce rates of forest conversion.

Activities include: (a) collection and synthesis of secondary data, (b) interviews of colonist-farmers and cattle ranchers, (c) GIS analysis of land use patterns over time, (d) field sampling and analysis of changing plant communities relative to different land uses and intensities of land uses, and (e) analysis and synthesis of results.

In August/September 1994, a field trip was made to conduct—in collaboration with IFPRI, ICRAF, EMBRAPA-Acre, EMBRAPA-Rondonia and PESACRE (NGO)—about 80 farmer interviews as a major part of characterization activities of the project.

It was apparent that deforestation is a function of policies supporting colonization, road building, direct or indirect incentives supporting creation of pasture land and cattle ranching, and the lack of disincentives for timber extraction. For areas with poor soils (most of the two sites), it may be impossible to slow deforestation by increasing productivity of rice, beans, cassava, and/or pastures, or by improving fallows or developing perennial crop based agroforestry systems.

For the very limited areas with better soils (alfisols and ultisols), EMBRAPA, CIAT, and ICRAF may be able to work with farmers on the development of farmer-adoptable permanent cropping alternatives.

Digitalization of cadastral data for sites in Acre and Rondonia is underway, including areas around those sites. Data for rivers, topography and vegetation is also available.

A project on the link between livestock and deforestation, including micro-macro linkages, is pending on getting a PostDoctoral Fellow.

Savannas

Site Selection Cerrados Region, Brazil

A classification and site selection of the Cerrados region of Brazil to determine appropriate study areas for joint research with EMBRAPA and local agencies was completed in 1992. Data from the climate database and the land system study were used to provide images of climate, soils and terrain for the region. These were complimented by data from the Brazilian agricultural censuses from 1970, 1975 and 1980. The census data were combined to produce a set of images showing average land use patterns and the trend in land use during the ten years. Some 38 images were combined using Factor analysis to produce 12 factor images, a statistical subsample was extracted from these and a two stage cluster analysis was used to produce 11 representative classes of cerrados demarcated by biophysical and land use patterns. These were used to characterize 12 potential study areas in respect of the areas of savanna represented in the region. The study was used in a workshop in Brasilia to select candidates for the final study area. The digital elevation model calculated for the study has been requested by the National Geophysical Data Centre, NGCD Boulder Colorado, as the most advanced dataset for the region.

Study Area Characterization. Altillanura Colombia

The study area of Altillanura between Puerto Lopez and Puerto Gaitan in the Department of Meta in eastern Colombia has been selected for in depth study by the savannas program of CIAT. The Land Management SRG has undertaken to develop a detailed GIS coverage of the region. Soil maps at a scale of 1:100,000 have been digitized and a simple user interface has been developed. Work is proceeding to produce a digital elevation model of the area with sufficient precision to be useful for running erosion models.

Negotiations were initiated with the Colombian Ministry of Agriculture and now with DANE, the national agency for census and statistics, to collaborate in an ongoing monitoring of the actual land use of the region. The Land Management SRG will use data to prepare a sampling framework for the monitoring of the area using remote sensing and extensive sampled ground truthing.

Correct elevation models now exist for a representative sample of map sheets from the region. These can now be overlaid with the access, rivers, soils and land use data. Satellite images of land use will shortly be available for combining with the digital images. A complete DEM (Digital Elevation Model) is expected in the near future.

Strategies for Sustainable Agricultural Land Use in the Lowland Savannas of South America. Planning Study

The Planning Study for the project "Strategies for Sustainable Agricultural Land Use in the Lowland Savannas of South America" was completed in September 1994, with the formulation and submission of a 5-years project (to be described later). The study was supported by the Dutch Ministry for Development Cooperation (DGIS), the same institution to which it was submitted.

The project was designed through a participatory process, and it was approved in draft form at a Workshop convened and hosted by CIAT. The project purpose is to identify and assess strategic and policy options for the sustainable use of the lowland savannas of South America.

The Workshop was the culmination of a process which involved visits from CIAT scientists to agricultural, environmental, business and NGOs institutions of Bolivia, Brazil, Colombia and Venezuela, and the preparation of position papers by each of the participant countries. The Workshop took place in July 1994, with the participation of high level representatives from national agricultural research centers, agricultural ministries, universities, the private sector, and NGOs, in addition to the scientists from Wageningen and CIAT. The final project proposal was written at CIAT immediately after the Workshop, with consultations with a number of participants of the Workshop.

Written expressions of interest from the institutions participating in the Workshop have already been received. This indicates the high scientific and political priority given by the countries of the region to the project.

The structure of SSALLSSA reflects a tripartite collaboration: at least one research team in each of four countries, a project team at CIAT and a project team in the Netherlands. This collaboration ensures the integration of local knowledge and advanced research methodologies, and the transfer of the comprehensive methodology to national teams.

Hillsides

Resource degradation evaluation and regional characterization of catchment areas in the hillsides of Central America and the Andes

An assessment of the state of degradation in the hillsides of tropical america was required in the CIAT Hillsides Program. To provide a broader overview of the problems in Central America and the Andean region, the definition of hillsides was extended to lands between 800 and 2000m., except highlands in Brazil, Chile, Argentina and the Guyana shield, and arid areas with less than 3 growing season months. Rainy months and soil depth were calculated. The levels and causes of degradation were estimated from the 'World Map on the Status of Human-Induced Soil Degradation' UNEP/ISRIC 1990.

Of about 92,000,000 hectares mapped as hillsides in this study, water erosion was by far the most important effect. Very small areas of wind erosion or chemical deterioration were noted. Moderate water erosion was found to occur in 14,000,000 hectares. Strong water erosion accounted for 11,600,000 hectares. Altogether some 26 percent of the total area was subject to serious erosion. The main causes were equally deforestation, overgrazing and agricultural activity.

Work is now in progress on overlying the limits of the hillsides catchments by the FAO Soil map of the world and the GLASOD map of soil degradation, for Colombia and parts of Ecuador and Panama.

Land use development in the hillsides of the Andes. The Case of Northern Cauca in Colombia with reference to a comparison area in Bolivia

This is a project funded by BMZ with CIAT in collaboration with the University of Kassel and CIP. The hillsides of the Andes are a complex patchwork of environment, agricultural history and communities of different racial origins. In many areas environmental damage is obvious in the form of visible erosion. This leads to decreasing productivity and problems of water quality and silting downstream. The less obvious forms of degradation include loss of biodiversity from forest felling and erosion of the genetic base of traditional farming systems.

The aim of this project is to improve the productivity of Andean hillside agriculture and ameliorate the environmental effects of inappropriate practices. The expected outputs include: An accurate spatial database detailing: topography, drainage, soils, climate, land use, access and infrastructure, to be accessed with a GIS to overlay cropping systems, social structures and marketing etc.; a clear picture of the linkage of social, economic and physical factors within the areas; and a study of potential or actual environmental hazards within or outside the area due to the agricultural management.

Study Area Characterization, Northern Cauca, Colombia. Andean Hillsides Simulation Modelling

This study complements work being done by the Hillsides program in the Rio Ovejas watershed. Initial work is proceeding to produce a detailed digital elevation model of the area from 1:25,000 maps. This will be completed early in 1995 and the data will be used to calculate slopes.

An agricultural and socio-economic census has been undertaken for the Rio Cabuyal within the Ovejas watershed and this will be mapped along with other data such as soils, rivers, climate, roads and slope. Land use and land use change are being extracted from air photographs for 1950, 1970 and 1990 for the Rio Cabuyal. These data are also being used to help characterize land use over a 100 by 50 km area covered by SPOT satellite imagery and land use and land use change over a 185 KM by 185 Km area covered by Landsat TM and MSS imagery dating back to the 1970s'. Three dimensional digital orthophomaps are being prepared with land use, rivers and roads draped over them. This use of visualization greated helps in understanding the use of the landscape by enabling one to see three dimensional images of it as it is.

These data will be used with other more comprehensive data as inputs to AEGIS + farm simulation modelling and the TOPOG watershed modelling programs to explore the possible impacts of different cropping systems on erosion and water yield.

This work is being undertaken in cooperation with several NGOs, the CVC (Regional Planning Authority) and the Universities of Georgia and Leicester.

Commodity-focused Research

Latin America rice distribution

This study was initiated in the Agroecological Studies Unit. The distribution of the rice crop was needed for development of a rational environmental classification of the crop in Latin America and to guide priority setting for research in the crop. The distribution was mapped in two stages. A first approximation was constructed using available secondary information, mainly from agricultural census data. Data on production figures and hectares planted were plotted automatically on coverages of municipio boundaries, where available, and by hand otherwise. The 1:1,000,000 topographic maps were used in a manual distribution of points corresponding to 1000 hectares of crop sown. The distribution resulting was digitized.

The maps produced were plotted and sent out to collaborators throughout Latin America. The maps were returned to CIAT and recompiled into the 'second approximation'. The resulting distribution was overlaid with the environmental classification based on the CIAT databases and a breakdown of the rice growing environments of the continent was compiled.

Asian cassava distribution

This study is necessary for the priority setting of the cassava Biotechnology Network in Asia, and to complete the studies already made for Africa and Latin America. A mapping of cassava in Asia has been produced.

Recent census data have been provided to the LM SRG in tabular form. The administrative units maps of all countries in Asia have been digitized and have been provided in draft form to the cassava program to assist in a questionnaire census of cassava processing. The administrative boundary maps were superimposed on the Digital Chart of the World (DCW) and the tabular data were used to distribute the areas planted to cassava in each of the administrative units. The distribution map will be used to compile an inventory of cassava growing environments. A subset of the FAO soils map and the NOAA digital elevation model must be made for the area and the climate data interpolated using algorithms developed in the unit.

Central Activities

General GIS Laboratory and Network Installation

The GIS Specialist was recruited in the second half of 1992 to build up the GIS area. Equipment and software was installed by the end of 1993. The present facility is based upon the latest server and workstation technology with excellent networking facilities. During 1993 staff were trained in basic GIS techniques including high quality data entry using conventional digitizing tablets and modern map scanning techniques, data base and the programming of the GIS software ARC INFO using its macro language.

Data restrictions in Latin America imply the need to produce own elevation and slope data for detailed simulation modelling experiments. This has required the Group to move into the area of soft- copy photogrammetry with allows the construction of accurate and detailed three dimensional images of small study areas. The use of Stereo satellite images which allow larger areas to be mapped in three dimensions at reduced resolutions and cost, is also being explored. This work will proceed with cooperation from the University of Georgia.

Many of the areas of work are covered by clouds throughout the year which makes them impossible to sample using air photos or normal (optical) satellites. To secure data in those areas, capability in radar imagery and differential interferometry is being built, which will permit detailed mapping, elevation extraction and calculation of slopes from ERS1 (Earth Resources Satellite) imagery. This work will be done in cooperation with the University of Stuggart and Milan Polytechnic.

The GIS Laboratory is moving into the remote sensing/image analysis of satellite images through cooperation and technical transfer from the Universities of Leicester and Edinburgh.

Air photos are being analyzed in detail to characterize land use and land use change for detailed site specific work for the Tropical Lowlands, Hillsides and Bean programs. Initial work is proceeding through cooperation with the CVC, the Regional Planning Authority for the Cauca region and the University of Georgia.

Normal air photos cannot be used to map mountainous regions accurately due to distortions to the imagery. In such areas the capability to map such regions using digital orthophotography with position fixing on the ground being done by GPS (Global Positioning Satellite) is important. To improve this capability CIAT will purchase two precise GPS receivers in late 1994.

In 1995 it is expected to move further into complex GIS analysis integrating crop growth, hydrological and erosion models (TOPOG, AEGIS + and WEPP) with CIAT's GIS databases.

Data Base Operations

Digital database creation continued throughout 1994 to meet the growing needs of the commodity programs and the ecoregional programs. The process of converting CIAT's existing GIS datasets from older computer mapping systems to the newer GIS system and subjecting them to rigid quality control procedures is going on.

Stochastic Rainfall Models

Over the last 16 years CIAT has produced what is perhaps the best climate database for the tropics. It is widely used by CIAT and distributed to other CGIAR centres and to major institutions throughout the world. Data from some 18,000 stations are now held in the files.

In order to utilize these data for risk analysis a robust system of stochastic simulation of daily rainfall is necessary. Markov rainfall models were chosen. The first publication from this research describes the testing of the third order Markov model with resampling of parameters. It shows that for tropical situations the third order model outperforms other more simple applications and that the resampling of parameters accurately simulates the year to year variance which other models fail to account for. This model has recently been employed in Burkina Faso by IFDC in a project associated with the Famine Early Warning System of FAO (FEWS).

Work has proceeded with the generalization of the model with an aim to provide interpolated mapping of the model parameters to interface with GIS linked models of cropping risk. It was conclusively proved that the order of the model required is closely associated with climate system. This resolves a controversy of many years standing between researchers in temperate countries and the tropics. It is postulated that the frontal weather systems of the temperate regions decouple the longer lag periods of the model necessary for tropical simulation. Additional data received will allow the development of an interpolation routine which can be generalized for the broadscale use of the model.

General

Land Quality Indicators

A participative process of definition of a CIAT-wide framework and research strategy on indicators of sustainable agriculture was launched. A document on Measurements and Indicators of Sustainability was produced by an interdisciplinary and interinstitutional team involving CIAT (LM), CIMMYT and GASE (an environmental NGO).

An international workshop on Land Quality Indicators (LQI) for the Lowland Savannas and Hillsides of Tropical America was implemented jointly with the World Bank, in June 1994. LQI were discussed and proposed for the two agroecosystems. The need for defining agroecosystem-specific indicators was highlighted. The World Bank will publish a document integrating earlier proposals and the outputs of the Workshop. As a follow-up to the Workshop, proposals for activities supported by the Bank have been prepared, and are being discussed with the Bank.

World Trade in Plant Nutrients

A large proportion of the exports of the developing countries are agricultural or forestry products. These products carry with them the basic plant nutrients N P K. This study looks at the balance of trade in terms of these nutrients. Years 1967 and 1985 were taken as base years. The 1960s give a view of the newly post colonialist world pre green revolution and 1985 points to the last years of the cold war.

World trade figures for all agricultural and forestry products were taken from the FAO publications and data tapes. Tonnages of product were converted into elemental equivalents of N P K and mapped. Fertilizer trade figures were obtained from IFDC and are mapped for comparison. Preliminary observations show that the obvious sink for these elements is the developed world. Europe is particularly noticeable in this. India clearly shows the benefit of the Green Revolution: in 1967 it was a net importer of plant nutrients in products, by 1985 it had become a strong exporter. Many African nations are strong exporters and the outward flow is not balanced by fertilizer imports.

After further analysis of the maps a publication will be forthcoming. It will be interesting to compare the pattern established as the post cold war world develops. It is proposed to follow up the study with a third reference year, possibly as data for 1995 or 1996 become available.

Latin America protected areas

In order to discount legally protected areas, native reserves, national parks etc. when embarking on the natural resource strategic planning exercise, it was necessary to compile a digital coverage of these areas for Latin America. This project has now matured into a maintenance and update stage and will be carried on as a basic resource for the Land Management SRG. Recent developments have included the publication of the CIAT working document 'Legally protected areas of Latin America'. An environmental classification of the protected areas is included.

To produce this the CIAT climate database to make continent wide coverages of the CIAT agroecosystem classification, the Koppen climate classification and the Holdridge Life Zone map were used. They were overlaid on the protected area coverage and an inventory of protected areas was produced showing the area protected for each environmental class. The inventory highlighted the fact that the tropical amazonian rainforest is by no means the environment at greatest risk of disappearing. The smaller areas of montane rainforest, dry tropical forests, highlands and agriculturally productive lands have diminishingly small areas undisturbed. Very little of these areas is legally protected. These fast disappearing areas are urgently in need of conservation and must be taken into account in all of CIAT's planning.

The recent digitization in CIAT of the vegetation map of South America will allow the production of a breakdown of protected areas by vegetation type. This will illuminate much of the present debate on conservation and biodiversity fueled by the Rio Conference.

GIS applications in biodiversity

CIAT is in an excellent position to apply advanced techniques of GIS and environmental classification to the problems of characterization and maintenance of genetic diversity. The coexistence of expertise in GIS and in germplasm research is a quite unique comparative advantage of CIAT.

a. ***Phaseolus vulgaris* core collection.** The Germplasm Research Unit in CIAT holds over 27,000 accessions of *P. vulgaris* complete with characterization and provenance data. However, many users find the costs involved in accessing the full collection of this valuable resource to be prohibitive.

   One way to solve this is to make a stratified sampling based on the environment from which the accessions came. Using the CIAT climate database and the digital version of the FAO 1:5,000,000 soils map an environmental classification was developed based on the specific factors relevant to genetic diversity in the cultivated species. Using this scheme the accessions in the germplasm collection were classified and a structured sampling was used to select individuals for the Core Collection.

b. **Mapping of the environments of wild relatives of crop plants.** The LM SRG has developed a powerful technique of climate comparison based on the 12 point Fourier transform. The technique has been used in the past to guide the teams searching for predators of cassava mealybug and green mites to send as biological control agents to Africa.

   Working with a Visiting Researcher of the University of Cambridge, the Group has developed a method of using these transformed climate data to produce a probability density mapping of climates similar to the collection sites of wild relatives of *P. vulgaris* held in the germplasm collection. This work has identified new important areas for germplasm collection. The first maps were produced in July 1994, and indications are that the technique will yield significant dividends. Location data for wild cassava species are at present being processed in collaboration with the World Conservation Monitoring Centre (WCMC) in Cambridge and further environmental similarity research will shed light on the diversity of genetic material in this species.

   Further work on mapping wild species in *Arachis* and other crop plants will be the mainstay of future efforts for *in situ* conservation.

Participation in the 2020 Vision for Food, Agriculture and the Environment

The Group is participating on the CIAT's contribution to the project. The 2020 Vision initiative by IFPRI seeks to identify solutions for meeting future world needs while reducing poverty and protecting the environment. The initiative will convene an international conference in June of 1995. The Group is actively participating with simple simulation modelling, scenario analysis, and prospective analysis, for the lowlands of Latin America.

FUTURE RESEARCH STRATEGY

In tune with the current CIAT-wide strategy of projectization, the LM SRG is following a strategy of aggressively looking for external funding of new research initiatives that are considered relevant by the Group. As an element of this strategy, region-wide proposals are being added to the agroecosystem -specific projects.

The Group will emphasize both site specific and ecoregional research. According to its goal on sustainable land use, the investigation of the ecological and economic determinants and impacts of land use will be added to the geographical and anthropological dimensions already incorporated. The Group will seek to complete its minimum core competence by the incorporation of the Tropical Ecologist and Resource Economist (already approved by the Board of Trustees).

The Group will continue to expand its contacts and cooperation with additional research institutions, not only agricultural, but also including the broader issues that impinge on sustainability and impoverishment. New institutional contacts have already been established with:

- The Inter-American Group on Sustainable Development of Agriculture and the Natural Resources.
- The International Geosphere-Biosphere Programme (IGBP) and the Human Dimensions of Global Environmental Change Programme (HDP), in relation to their joint core project on land-use/cover change (LUCC), and IGBP/DIS on soils database.
- The Earth Council, Costa Rica.
- The New World Dialogue on Environment and Development.
- The United Nations University, Tokyo.
- The 2050 Sustainability Project (World Resources Institute/Brooklyns Institution/ Santa Fe Institute), USA.
- The International Institute for Applied Systems Analysis, Austria.
- The Beijer Institute (The International Institute of Ecological Economics of the Royal Swedish Academy of Sciences).
- The INDERENA (The Colombian National Institute for the Renewable Natural Resources and the Environment).
- The Ministerio de Agricultura, Colombia.
- The Ministerio de Medio Ambiente, Colombia.
- The Instituto Geográfico Agustin Codazzi, Colombia.
- The Colegio Verde (NGO), Colombia.
- The University of Kassel, Germany.
- The Hohenheim University, Stuggart, Germany.
- The National Geophysical Data Centre, Boulder, Colorado.
- The World Conservation Monitoring Centre, Cambridge, U.K.
- The University of Washington, Seattle.
- The University of Georgia, GIS Laboratory, Athens, Ga.
- The University of Guelph, Canada.

New Project Initiatives

During 1994/95, the Group will continue with the ongoing projects already described. Besides, the Group has generated a number of New Project Initiatives, some of which have been proposed to external donors. Only the new major new initiatives will be mentioned here.

System Characterization with Hillsides (C. America)

The Land Management (SRG) characterize and analyze land use dynamics in C. American hillsides, especially within Honduras and Nicaragua. Work will commence in late 1995. One important activity will be to examine how characteristic the hillsides program test sites are. This will be done by extending pioneering classification work for Central America, already described, to classify similar regions in C. America at small scale. New work will work at a larger scale, permitting more detailed analysis. To accomplish this, additional data on land use and population will be obtained from sampling the hillside areas using air photographs and satellite imagery to permit extrapolation to large regional areas. Better altitude and slope data may be obtainable in Honduras from work being done by the University of Mainz under a BMZ project. On ground surveys will be done.

Nutrient acquisition and utilization in the savannas of South America

This project has been proposed by the Tropical Lowlands Program. It calls for the production of thematic soil maps characterized by biophysical constraints to extrapolate the experimental findings and to judge the potential benefits of specific lines of research. It will involve the identification of methods to correlate typical soils characteristics with specific soil mapping units.

Depending on the scale, a considerable input of digitization could be involved. Present climate interpolations may be adequate but if not, further work in obtaining more detailed climate data and interpolating to a newly developed Digital Terrain Model (DTM) will have to be done.

Many other areas of CIAT research will benefit from the base data.

Carbon sequestration and gaseous fluxes in tropical lowland ecosystems

This project proposal put forward by the Tropical Lowland Tropics Program will involve considerable collaboration from the Land Management Group. Detailed GIS support for the study areas in Carimagua - Colombia, Planaltina - Brazil and Acre/Rondonia in Brazil are envisaged.

If extrapolation to like regions is needed some of the existing datasets may be used. It is likely that the medium scale climate interpolation will be required and costs can only be determined when the areas in question are known. The timeframe of the project is 1995 and could well extend to 1996 depending on the availability of funds.

Outputs would be primary GIS coverages of the areas in question regarding soils, climate, actual and potential land use. The specific output for the carbon sequestration project would be estimates of actual carbon sequestration under sown pastures and forecasts of the potential effect if extrapolated to other areas.

This interprogram project would have relevance to projects in Beans, Cassava, Upland rice and Tropical Forages as well as the Tropical Lowlands Program. It will have major impact also with the intercentre project Slash & Burn with ICRAF.

In situ conservation for Arachis germplasm

The Tropical Forages Program wishes to initiate a project on the *in situ* conservation of wild relatives of the species *Arachis pintoi* now being actively researched as a major pasture legume for the neotropics. The potential for this and related species could well include major areas in Africa and the Asian tropics. The germplasm is endemic in southern Brazil, Paraguay and parts of lowland Bolivia.

A detailed Digital Elevation Model of the areas in question is imperative for the interpolation of precise climate characteristics. The coordination of this exercise with the soils map coverages of the area will allow a careful classification of the niches at present inhabited. A land use coverage is then needed to identify which of these niches are under threat. Ideally this should be a dynamic monitoring exercise to guide the process of protection of areas where the germplasm is present.

Resource degradation and land use in Latin America. A new updatable digital map as an aid to planning for sustainable agricultural development

Local and regional land use maps have been produced for some areas of the continent but the last complete coverage was made at a very small scale (1:5,000,000) and dates from the 1960s. A mapping of land degradation has been made more recently (GLASOD) but at an even coarser scale (1:10,000,000 nominal). The compilation was the task of a limited number of 'experts' and the result has been questioned by many who have first hand knowledge of individual areas.

Agricultural land use statistics are compiled by administrative units and figures are aggregated for reporting. In Latin America the minimum disaggregation is often the municipio, canton or parish. Remote sensing can give a good basis for the subdivision of land use into the major classes of agricultural activity, but this is very expensive and so, at the continental level, is necessarily static.

The method for subdividing the land surface into rational homologous units described at the beginning of this document would be very costly for the whole continent. Local knowledge of the state of the agricultural system and of land degradation abounds but at present there exists no framework for coordinating this into a continental synopsis. At present the only integrated mapping of land type for the continent is the FAO Soils Map of the World at 1:5,000,000. This map as a basis for compiling the abounding local knowledge into an updatable GIS database that will give an overview of the state of agriculture in the continent not previously available.

The procedure would consist of the following steps: (1) Compile a mailing list of informed experts throughout the region. (2) Definition of a common set of reporting criteria with a short manual. (3) Subdivide the latest version of the soils map of the area into pieces that can be easily handled by a key informant using his/her local knowledge. (4) Mail out the map sections with data requests on land use and land degradation. Present land use type in broad term (i.e., forest/annual crops/pasture etc.) could be coupled with a simple estimate of productivity (a subjective scaling). (5) Development of a database schema to hold the incoming information. (6) Development of data conflict elimination procedures. (7) Compilation of a continental level GIS coverage of the received information.

The information on land use and land degradation will be overlaid by the maps of ntural ecozones, to detect ecological conflicts or opportunities. Socio-economic data will assist in the analysis of poverty and its environmental associations.

An integrated spatial database for the Andean regions of Colombia, Ecuador, Peru and Bolivia

The Andean region in these four countries is generally considered to be under considerable population pressure which drives a process of degradation of the hillsides environment. This, indeed, is the case in many areas but the underlying mechanisms are different from case to case. The Andes are the centre of origin of a number of highly important crops. Conservation of the landraces and wild relatives of these crops is of critical importance to world agriculture. Overgrazing and inappropriate cultivation techniques are widespread.

The expected outputs include: (1) A comprehensive GIS database of the region at a precision of 1 km or better. (2) A set of thematic maps showing the main agro-ecological characteristics of the area. (3) CD-ROM for wide application. The possibility of incorporating interfaces to present crop models should be explored. (4) A better understanding of this very diverse region. The database will assist national governments and NGOs to identify homologous areas throughout the region. For *in situ* conservation of germplasm this is essential.

Identification of sown pastures (predominantly Brachiaria) in the savannas, and estimates of their state of degradation

It is estimated that over 30 million hectares, or about 20-25% of the cultivable area of the Cerrados of Brazil have at one time or another been sown to *Brachiaria* pastures. These pastures degrade at varying rates depending on grazing practices. Renovating them directly to improved pastures is costly and hence rarely considered. Tropical Ley farming systems can make the regeneration of these resources profitable and environmentally attractive. Increased productivity in areas not too remote from markets will help to set base prices for the commodities and reduce pressure on the marginal frontier lands.

Identification and monitoring of the rate of degradation and the spatial extent of the problem will allow National programs to target research and extension in agro-pastoral programs.

Expected outputs would include: (1) A methodology for diagnosing *Brachiaria* pastures and their various states of degradation. (2) A quantitative method of characterizing degradation on the ground sufficiently rapid for use in ground truthing remotely sensed images. (3) A time series of degradation in geographic context. When coupled with the spatial database of a study area this will yield important insights in spatial terms not available from point studies on the ground.

Characterization of farmers' systems and participatory research

The Bean Program coordinates the PROFRIZA network with Colombia, Ecuador, Peru, Venezuela, and Bolivia as members. SS from Land Management will assist in interviews for characterization of farmers' systems and in participatory research in five to six sites in three or four countries.

An intensive diagnostic and characterization survey of farmers' practices and adoption or non-adoption of project-introduced resource-conserving technologies in both countries will be conducted in order to assist research to be conducted by the Hillsides Program in Honduras and Nicaragua.

Assessing indicators of land quality for sustainable agricultural development in the latin american hillsides and savannas

Indicators are needed which are robust, easy and inexpensive to use and are "user friendly". For the assessment and calibration of indicators, however, an intensive testbed of data will be required for each testing region.

Through the Land Management Scientific Resources Group and the Tropical Lowland and Hillsides Programs, CIAT can conduct an integrated identification, testing and calibration of useful Land Quality Indicators. The indicators could include: nutrient balance, land management practices, proportion of land use types, population characteristics, agrodiversity, and others.

The study would analyze several potential indicators of land quality to determine: cost and scale of measurement; applicability across land use types; effectiveness in evaluating changes in land productivity potential; and ease of use and interpretation by project managers.

Integrating macro perspectives and local management for sustainable land use

In order to increase the compatibility between land-based growth under open market economies and sustainable development, national policies and development projects need to determine ways to reach acceptable trade-offs between private and social interests. A systemic approximation is needed to understand and take into account the causal interlinkages between: (1) the processes by which resource users make management decisions, particularly regarding choice of crops and technology alternatives; (2) the processes by which resource users impact the sustainability of the natural resource base; (3) the processes by which ecological changes affect the decisions by resource users; (4) the processes by which resource use policies are formulated, how such policies affect land users' decisions, and the institutional channels by which they are brought to bear on farmers and their practices at the local level; (5) the processes by which specific technological options are selected and developed.

The expected outputs of this 3 to 5-years project are: (1) Institutional mechanisms to facilitate participatory, decentralized approaches to resource-use planning. (2) A systemic framework including alternative scenarios for resource use within and across ecosystems based on dialogues between users and policy makers. (3) Interactive information systems at the local and at broader ecosystem levels to help assess impacts of different technological, management, policy, and economic scenarios.

The Department of Santa Cruz in Bolivia would be an appropriate research location for several reasons, including its economic, institutional and ecological characteristics.

Strategies for sustainable Agricultural Land Use in the Lowland Savannas of South America (SSALLSSA)

This five-years project is the product of the Planning Study described before, and it has been submitted to the DGIS og the Netherlands. The purpose of the project is to assess strategic policy options that foster sustainable agricultural land use in the lowland savannas.

A major challenge for research in the tropical agroecosystems of Latin America is to develop technologies and management options that increase agricultural production while conserving the natural resources, including the invaluable Amazon rainforests. In the Cerrados of Brazil and the Llanos of Venezuela the savannas are being utilized for intensive annual cropping systems applying high inputs. Although these intensive systems have been profitable in the short-term, indications are that the cultivation of annual crops as currently practiced leads to soil degradation; and increased weed, disease and insect populations, affecting cultural practices and reducing crop yield.

Although the soils of the savannas are generally considered to have good but fragile structure, they are highly acidic and very infertile. As a result, even if high levels of inputs are utilized, the medium- to long-term productivity of intensive annual cropping systems is expected to decline as soil physical properties deteriorate. New technologies that maintain soil structure are thus required to foster a sustainable intensification of land use in the savannas, as well as appropriate policy options.

The outputs expected from the project include: (1) Trained teams on R&D for Sustainable Agriculture in each participating country, involving scientists from institutions in the agro-technical, environmental and socioeconomic fields; (2) Interactive georeferenced information systems to support decision-making at different levels, assessing the impact of agricultural technologies and policy options under different economic scenarios; (3) Policy guidelines to promote the development of sustainable land use patterns and the generation of economically viable, ecologically sound and socially acceptable agricultural technologies; (4) Public awareness on the economic and ecological impact of alternative forms of land use and their social consequences; and (5) Set of criteria to assess proposals for development cooperation on land management projects.

Agroecosystem Health

A paper on agroecosystem health as a guiding concept for agricultural research has been prepared and will be published shortly by IDRC. Preliminary discussions have been completed regarding cooperation with the University of Guelph in relation to the Agroecosystem Health Project (supported by the Canadian Eco-Research Program of the Tri-Council Secretariat). The principal goal of this project is to develop a framework for evaluating and improving the health of agroecosystems. The project has focused on temperate agroecosystems and there is now a strong interest to include tropical agroecosystems. A visit by the Project Director to CIAT is planned for late 1994.

The 2050 Project. "Transition to Sustainability in the Next Century"

The P2050 is an innovative project led by the World Resources Institute, the Brookings Institution, and the Santa Fe Institute. The purpose of the P2050 is to define conditions under which global society could be sustainable in 2050, and using that vision as a starting point, determine policy strategies and actions for the next decade that will be needed to achieve those conditions. Conversations about potential collaboration have taken place with the Deputy Director of the P2050. Possibilities for collaboration include participation in the research, as well as organizing a Latin American Conference around the project.

Multigoal Identification Workshops

Two intensive workshops are planned for 1994/early 1995 focused upon the hillsides and savannas, respectively. Those workshops are aimed at generating a collective vision of the multiple goals of different social actors, the perception of the problems, dilucidating their causal structure, and identifying the possible actions to be taken and their impact.

They combine systems analysis approaches with Group dynamics and Delph techniques. The output is a clear and shared vision of the problems in the form of a conceptual model (and sometimes of a simulation model). This is very useful to put the problems, the technological solutions, and the policy issues into an integral perspective, to furthher guide research, and to perform preliminary policy assessments.

Interprogram Collaboration. The very intense collaboration with different Programs of CIAT (both in Natural Resources Management and Germplasm) is evident from the activities described above.

Relation of CIAT Projects to CGIAR System-wide Programs. Projects in the forest margins areas of Acre/Rondonia are closely connected with the global Alternatives to Slash and Burn Project. The studies on the savannas are relevant to the CG response to Agenda 21 with respect to sustainable agriculture. The proposed project on the resource degradation and land use in Latin America updatable database for Latin America ties directly with the CIAT ecoregional proposal to the CG. Some of the new proposals connect with the biodiversity conservation theme.

Institutional Relations

INSTITUTIONAL RELATIONS AND DEVELOPMENT SUPPORT

INTRODUCTION

Institutional relations and development is a Center-wide function that, on the one hand, links CIAT to its donors and partners, to science and technology, and to the Center's broader institutional environment and, on the other hand, contributes to strengthening agricultural research and development systems.

While all CIAT managers and scientists participate in the institutional relations and development function, there are areas at CIAT, such as communications, documentation, and training, which give specialized support to it.

INSTITUTIONAL RELATIONS AND DEVELOPMENT SUPPORT (IRDS) brings together the various specialized linkage support capacities and activities in a single organizational structure, which attunes them to CIAT's overall strategies. Consequently, IRDS permanently co-evolves with the whole of CIAT.

Since CIAT's last EPMR, profound changes have reshaped CIAT's institutional environment and the Center itself, leading to drastic adjustments in IRDS. A brief review of those changes and their consequences will, therefore, be presented first to help better understand the responses of IRDS.

Second, the changes in IRDS will be examined in a broad overview.

Third, challenges for the future will be outlined, also in broad strokes.

Finally, somewhat more detailed accounts of each IRDS Unit will be presented.

A QUINQUENNIUM OF PROFOUND CHANGES

New and more numerous needs of clients

The agricultural technology needs of CIAT's clients, and related research and institutional development needs have moved from simple production-enhancing aims to simultaneously targeting increases in agricultural output, greater competitiveness in open markets, the arrest of resource and environmental degradation, and equity concerns. Therefore, more problems need solving and more alternative solutions to any given problem are required. A direct consequence is that human resources need to be trained to address the new needs, and new information and documentation services have to be established to satisfy emerging information demands.

At the same time, CIAT's traditional commodity research partners, the scientists of national agricultural research institutes, have strengthened and matured in their technical capacity (often through training provided by CIAT), thus offering an opportunity for devolving some of CIAT's training activities to them.

Changing institutional players and responsibilities

More institutional players deal with the changing R&D agenda. The institutional scenario has evolved from being dominated by the national agricultural research institutes to accommodate an increasing number of other actors such as universities, farmers associations, agribusiness, and NGOs.

Distribution of responsibilities among institutional players is changing as well, mainly because of drastic reduction of the public sector in favor of the private sector and NGOs, but also because of readjustments within the public sector.

This process is fairly haphazard, not yet settled, and not without inefficiencies. For instance, some responsibilities have changed hands, occasionally only to be returned to where they were, others are being duplicated, and some go unattended.

The consequences for CIAT of the increased institutional complexity are twofold. The number of inter-institutional interactions is growing. And collaborative work suffers from discontinuities in partnerships, from the need to repeat actions because of forced changes in partnerships, and from occasional inaction of partners due to their institutional uncertainties.

Within the region, new institutional players have also emerged, and old ones have gained new prominence. They include the three horizontal cooperation programs supported by IICA in South America, namely PROCISUR, PROCIANDINO and PROCITROPICOS, which, *inter alia*, are recognized fora for articulating subregional research and training priorities and for coordinating some IARCs-NARS interactions.

New interests, demands and priorities of donors

Donors' interests have broadened from increasing staple food production to encompass sustainability and equity concerns. This has influenced CIAT's decision to shift its research strategy from a commodity to a resource management research focus.

With regard to the research process, donors have moved from demanding effectiveness and excellence to also demanding output orientation, efficiency, and transparency in the use of research resources. CIAT's response has been twofold. First, the Center increased its public awareness effort to inform donors on the use of their resources and resulting impact. Second, the Center made fundamental changes in research organization moving from programs, which had open-ended activities, to mandate-based projects, which have pre-determined outputs to be obtained within specified time limits and using tightly budgeted resources.

The project-based research approach has been coupled to a decentralized funding strategy in which scientists are empowered to seek research grants. A large front of linkages to donors has thus been opened.

With respect to the type of research to be performed by CIAT, donors emphasize strategic research, as opposed to activities closer to the development end of the research and development spectrum.

Many donors stress the need for a demand-led rather than a supply-driven research agenda, which implies the participation of various stakeholders in the planning and implementation of the research agenda.

Almost all donor countries reduced official development aid because the growth of their economies has slowed down. And they reduced support to international agricultural research at the expense of other development objectives. This triggered a financial crisis in the CGIAR system, which led to a system-wide budgetary cut of about 30%. CIAT's adjustments to the crisis included a downsizing of IRDS by about half.

Potential discrepancies between donor and client interests

Although there is a basic coincidence between CIAT's donors and clients on the need to achieve sustainable and equitable growth of agricultural output, the weight given to growth, equity, and sustainability may vary between them. Countries often give great weight to economic growth, while donors tend to weigh equity and sustainability more heavily.

As stated above, donors emphasize CIAT's contribution to strategic research, yet scientifically lesser developed client countries demand more development-like services.

CIAT's projects need to reconcile such divergent interests, lest the Center lose the support of the parties concerned. More negotiations with them have become necessary for gaining project approval. And the parties and their constituencies must be better informed to avoid and dispel misunderstandings and to maintain their support.

Privatization of science and technology

Science and technology are ceasing to be public goods and becoming private property. Intellectual property rights (IPR), a major instrument in this process, have been promoted forcefully by some leading industrial countries to appropriate products and production processes and recently resources such as germplasm as well.

This is a contentious issue for lesser developed countries. They often feel that they are losing access to science and technology, and there is a widespread perception that industrialized countries are misappropriating germplasm from developing ones.

To CIAT this is both an opportunity and a challenge. The opportunity is to act as a science and technology bridge between countries of different levels of scientific development. The challenge is to be seen by both parties as being beneficial to their interests.

Much careful informing and negotiating is required to succeed in this endeavor. Failure would lead to losing support from the concerned parties and, therefore, endangering CIAT's institutional sustainability.

New communication technologies

An unprecedented revolution in communications technology is in full swing. The capacity to store, transform, retrieve, and distribute information has recently increased by many orders of magnitude, and the cost of information management has simultaneously decreased by several orders of magnitude per unit of information. This offers a magnificent opportunity to successfully face some of CIAT's new challenges.

A more complex CGIAR

At the time of the previous EPMR, the CGIAR encompassed 13 centers, which were essentially autonomous. Now the CGIAR has 17 centers, and the system is becoming an integrated matrix of programs by centers. Some of the centers, CIAT among them, are being assigned a convening role among sister centers to coordinate or lead inter-center activities in the program by centers matrix. This implies new communication needs.

A more complex and less autonomous CIAT

As set forth in the Funding Request for 1995, CIAT has become a more complex and integrated Center.

Instead of four self-contained commodity programs, six research support units, and a training and communications support program, the Center is now a highly interlinked matrix of six programs (with a much expanded scope) by five Scientific Resource Groups (which include but do not take the place of the research support units), with more than 80 projects (plus a set of complementary projects), and an institutional relations and development support area.

Each of the former programs operated strong networks with NARS. These linkages have remained, and new ones have arisen in biotechnology-based commodity research networks (cassava, beans), and in resource-related inter-institutional R&D consortia (such as the Central American Hillsides Consortium, the Consortium for Managing Acid Soils, and the Savannas Consortium).
Projects, networks and consortia involve more varied and numerous partners (from developed and developing countries); and
success depends increasingly on each and every partner, rather than on a lead institution (mainly CIAT), as was the case before.

Management and information intensive linkage to the institutional environment

CIAT's increased internal complexity and the highly decentralized and augmented links to donors, partners and clients have generated a mesh of interfaces which, to be successfully managed, are transaction-intensive and require profuse information input. Specialized support services to address this emerging situation are taking shape.

EVOLUTIONARY OVERVIEW OF IRDS

From Training and Communications Support Program to Institutional Relations and Development Support

What at the time of the last EPMR was the Training and Communications Support Program (TCSP) became the Institutional Development and Support Program (IDSP) in early 1992. Shortly afterwards CIAT's BOT decided to eliminate the word Program from IRDS (reserving the label Program for research Programs), and to transform the position of Program Leader to one of Associate Director, Institutional Relations.

The transition from TCSP to IRDS changed the emphasis from a set of activities or means (training and communications) to the ends for which the means were deployed (institutional development). Also, the IRDS incorporated a newly created project development capacity and accommodated CIAT's Seed Unit, which shifted its focus from seed technology to the development of alternative seed systems (a type of institutional development).

The transition from IDSP to IRDS recognized the emerging need to give specialized support to institutional relations, and the need to legitimize the leadership of IRDS at a directorate level. Dropping the name Program without replacing it by another reference to a structural underpinning, e.g., Division, has been somewhat unfortunate in that it makes it difficult to refer to the organizational embodiment of IRDS.

Evolution of IRDS components

Training

At the time of the last EPMR, CIAT offered post-graduate non-degree related training in

* Intensive introductory commodity-specific research and production courses;
* Individualized on-the-job training by disciplines or fields of interest;
* Specialized courses (e.g. on IPM, bean breeding); and
* In-country courses on bean on-farm research and artisanal seed production; cassava production and processing, and IPM; cost-reducing rice production technologies; and forage seed supply mechanisms.

Degree-related training was offered in research projects leading to M.Sc. and Ph.D. thesis.

Undergraduate Colombian students of agricultural and related sciences were given the opportunity to work under the supervision of CIAT scientists on research projects for their graduation thesis.

Training strategies, processes, and outputs were relatively stable over the years 1987-1991. A detailed account of that period can be found in "Training for Tropical Agricultural Research and Development 1987-1991" prepared for the in-depth internal review of IRDS held in December 1992.

In 1992-93, drastic changes were made to shift from somewhat introductory to more specialized training, and to respond to the substantial reduction in funding.

Commodity-specific introductory research and production courses were eliminated, leaving only individualized post-graduate training, both degree and non-degree related. In-country courses were also eliminated. And training support staff and the number of CIAT-funded trainees were slashed radically.

In-country courses, and to some extent the introductory research and production courses, were "devolved" to the countries by developing national and subregional training capacities. The strategy was to establish institutionalized training bodies; to train the trainers of these bodies; to support them in producing state-of-the-art training materials; and to assist them in preparing and submitting projects to agencies which would fund the training bodies for three to five years. An external evaluation praised this innovative and successful approach.

Commodity-related advanced research training, either individualized (non-degree and degree-related) or in groups, will continue being offered in response to NARS' needs. In the short run most of it will, however, have to be funded by the beneficiaries or sponsors interested in their being trained.

A CIAT-led interinstitutional training program on sustainable agriculture is in an advanced planning stage, and funds from IDB are expected to be available for 1995. This should mark the beginning of a longer term effort to develop national and regional capacities in resource management research.

Training of Colombian undergraduates has been and will be maintained.

Information-documentation

The need to satisfy additional information demands of CIAT and NARS scientists in resource management research, the challenge to do so with diminishing resources, and the availability of new information management and communication technologies led to substantial changes in the Information-Documentation Unit.

CIAT's well known and widely appreciated specialized information services on beans, cassava, and tropical pastures, which were costly due to labor-intensive abstracting, had to be given up. They were replaced with less costly technology-intensive means, without negatively affecting the information supply to CIAT scientists. However, some of the weaker NARS have probably suffered from the lack of this service.

The new information-documentation needs for resource management research have been met with new services, despite shrinking financial resources, thanks to creative management and newly available technologies.

Communications

To improve effectiveness and efficiency, publications and graphic arts plus public information were integrated into a single Communications and Public Awareness Unit.

The output and distribution of press releases were increased drastically, and new printed, electronic, and visual media were developed to better inform donors.

As in the Information-Documentation Unit, creative management and advanced technology met the challenge of maintaining the previous output of scientific publications despite shrinking financial resources and growing local production costs.

Project Development

The Project Development Office was established in response to donors increasingly wanting to invest in projects with well defined outputs, precisely budgeted inputs, and a pre-established duration.

The Office aims at maximizing the probability of success in CIAT's submission of project proposals to donors.

Technically sound projects must be submitted to the right donor, at the right time, in the right format. For this, the Office has established a donors data base; a standard state-of-the-art project format, which flexibly adjusts to donor-specific preferences; and a desk-top publishing capacity which allows for attractive yet unpretentious presentation.

Institutional relations

The former position of TCSP (and IDSP) leader is now that of Associate Director, Institutional Relations, **ADIR**, in response to the increasing complexity of CIAT and its environment, and the resulting need to manage numerous new institutional interfaces.

In addition to "line" responsibilities (training, conferences, visitors, information-documentation, communications, and project development), the ADIR attends new functions and others which have grown so much that they need special attention.

The ADIR, in close collaboration with directors, leaders and other staff, monitors NARDS[1] to

* Identify R&D needs and opportunities;

* Assess CIAT's image;

* Survey the quality of CIAT-NARDS relations; and

* Ascertain trends in the institutional and policy environment;

with a view to identifying needs and opportunities for cooperation (technical advice, germplasm exchange, training, information-documentation, etc.), project development,

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[1]It is convenient to recall CIAT's use of the following acronyms:

NARI(s): National agricultural research institute(s); typically of the public sector; often referred to by others as NARS.

NARS: National agricultural research system(s). Include all relevant research institutions, be they public, private, non-for profit, non-governmental, etc.

NARDS: National agricultural research and development systems. Includes development organization over the same spectrum as NARS.

public awareness, corporate image improvement, conflict avoidance and resolution, and for CIAT's institutional adaptation and promotion in general.

The ADIR maintains a high level CIAT presence among stakeholders by regularly visiting or participating in

* leading NARDS offices;

* country representation of donors and international development agencies;

* headquarters and local representations of regional development agencies;

* cooperative programs such as the PROCIS, PRIAG; and

* fora such as the PCCMCA.

This is part of monitoring CIAT's institutional environment, contributes to maintaining a high profile among stakeholders, and, very specially, should help obtain and maintain the support of NARDS decision makers, in their institutions, in their countries, and internationally (particularly vis-à-vis donors).

The ADIR, in collaboration with directors and leaders, intervenes directly in the establishment of new interinstitutional arrangements such as agreements, consortia, and certain projects.

Recently, the ADIR, was instrumental in establishing CIAT's interim IPR policy. The experience obtained in the process would indicate an additional function for the ADIR, that is, help maintain a balance in the delicate situation where the interests of developing countries (CIAT's clients and partners) may be at odds with those of developed countries (CIAT's donors and also a source of advanced research inputs).

To the extent that these functions existed in the past, the Director General, the Deputy Directors General, and Program Leaders had no difficulty in dealing with them.

However, due to a substantial quantitative increase in functions, and a parallel increase in the workload of the Director General and the Research Directors (both originated by the increased complexity of CIAT and its environment), these functions have been increasingly entrusted to the ADIR.

As some of the responsibilities entrusted to the ADIR exceed the original terms of reference for the position, it may be timely to revise them.

10

CHALLENGES AHEAD

A first challenge for IRDS is simply to continue successfully discharging its manifold responsibilities. To keep up what is already in place, counteracting the forces which permanently tend to degrade complex man-made systems.

A major challenge is to keep abreast of the changing needs and opportunities in client countries, adequately interpreting them, and effectively channeling the information to places in CIAT where it could serve as an input and catalytic trigger for new endeavors. This will require the full implementation of the fledgling IRDS information system, and that every CIAT senior staff be a sensor who systematically captures and feeds information into this system.

Another serious challenge is to raise public awareness in developing countries. So far, CIAT's public awareness activities have essentially targeted the donor community and their constituency; no public awareness media have been specifically designed for client countries. However, CIAT's success will increasingly depend on adequate support from decision makers and their constituencies in client countries. This, will require communication as carefully designed as that already targeted at donors and their constituencies.

Finally, and closer to CIAT's end objectives, there is the crucial challenge of serving the information and human resources development needs for sustainable agricultural development.

Sustainable land use will be information-intensive rather than intensive in the use of physical inputs. There will be a need for large numbers of trained professionals in the field, and massive amounts of information will have to be made available to these professionals and their clients in user-friendly formats.

CIAT's experience in the training of trainers and the emerging technologies for data transfer and information management should be mobilized to meet these needs.

This is not to say that CIAT should try to single-handedly tackle such an enormous task. Rather, CIAT should catalyze, and if need be give leadership to, collaborative efforts to boldly seize this opportunity. The wealth of information already available and growing in the CG-IARCs and other institutions ought to reach the end users without further delay. Technically it is becoming feasible; financially it should be attainable. May we have the managerial vision and courage to make it happen.

UNIT REPORTS

TRAINING

OVERALL GOAL

National and subregional institutions with the capacity to develop sustainable agriculture and land use.

OBJECTIVES (redefined as of 1994)

1. Skilled NARS scientists working in focused and high priority research projects.

2. Subregional capacity for training technology intermediaries in commodity production and in participatory relations with farmers.

HISTORICAL ASSESSMENT

Training of researchers

In December 1992, IRDS was submitted to an in-depth review which covered the quinquennium 1987-1991. A set of ten documents prepared for that occasion is available. One of the ten documents, titled TRAINING FOR TROPICAL AGRICULTURAL RESEARCH AND DEVELOPMENT 1987-1991, gives a comprehensive account of CIAT's strengthening agricultural research and development systems in developing countries through training. It reports on the strategies, the processes, the output and the evaluation. The report covers 1067 persons trained at CIAT and 2515 persons trained in in-country courses in Latin America.

The evolution of training after 1991 has been outlined above, under Evolutionary Overview of CIAT.

Some data on this evolution follow.

The yearly average of NARS trainees at CIAT fell from 213 for the period 1987-1991 to 72 in 1992, 58 in 1993, and an estimated 120 in 1994. That is an initial reduction to one third, than to almost one fourth of pre-crisis levels, followed in 1994 by a recovery to slightly over half of the pre-crisis levels.

The training performed in 1992-1993 was very strongly demand led. Practically all trainees were funded by their own institutions or other sponsors (although CIAT still covered the research costs involved). In this regard it is interesting to note that the reduction of the number of trainees relative to pre-crisis levels was greater in commodity-specific training, where it dropped to about 20% of the 1987-1991 levels, than in not commodity-specific training (mainly biotechnology and genetic resources) where it dropped by one third in

1992 and more than half in 1993. This would indicate a greater interest of NARS in biotechnological research training than in commodity research training.

Training conducive to higher degree thesis remained essentially unchanged in absolute numbers. About nine trainees from NARS started higher degree research every year in the period 1987-91. Since then, the corresponding figures were 13 for 1992, six for 1993 and eight for 1994. Given the reduction in total numbers of trainees, the proportion of higher degree students has, of course, increased. From about 4% per year in 1987-91 it raised to 18% in 1992, and declined thereafter to 10% in 1993 and 7% in 1994.

Training of higher degree research students from industrialized countries remained unchanged. An average of five per year initiated their programs in the period 1987-91. Since then, the corresponding figures were five in 1992, seven in 1993, and five in 1994.

Training of trainers

To devolve in-country training on commodity production to the NARDS, CIAT developed the following strategy which, for short, will be referred to as training of trainers.

The strategy has four interrelated objectives: 1) to build and consolidate interinstitutional training mechanisms at national or subregional level; 2) to train the instructors for these mechanisms; 3) to develop instructional materials; and 4) to prepare training projects to be funded and implemented once the training teams are in place.

To date the strategy has been applied to establishing teams of trainers for training in

* Commodity production (beans, cassava, and rice);
* Agricultural research management; and
* Management of technology transfer.

The achievements are summarized in Table 1.

Commodity production.

The training of trainers for bean, cassava, and rice production was implemented in an IDB-funded project. A "Final Project Review" in English prepared by a team of consultants, and the Final Project Report in Spanish are available.

TABLE 1. TRAINING OF TRAINERS: SUMMARY OF ACHIEVEMENTS

Commodity / Topic	Trainers No.	Learning Units No.	Participating Countries
RICE	20	7	Colombia
	14	5	Ecuador
	21	4	Dominican Republic
	16	5	Venezuela
BEAN	21	7	Costa Rica Cuba El Salvador Guatemala Haiti Honduras Mexico Nicaragua Panama Dominican Republic
CASSAVA	20	6	Argentina Brazil Paraguay
PLANNING, MONITORING AND EVALUATION OF AGRICULTURAL RESEARCH	18	4	Argentina Bolivia Brazil Colombia Costa Rica Chile Ecuador Holland Mexico Uruguay Venezuela
TECHNOLOGY TRANSFER MANAGEMENT	24	4	Colombia (Ministry of Agriculture)
TOTAL	154	42	Countries: 20

Agricultural research management.

The strategy has also been applied to the training of eighteen Latin American research management experts belonging to eleven countries, under a contract with the International Service for National Agricultural Research, ISNAR. CIAT's training for trainers coordinator and training materials staff collaborated during sixteen months to the training of trainers and to the preparation of 1) four instructional modules on Planning, Monitoring and Evaluation of Agricultural Research, 2) four fasciculi on the same topics, and 3) a manual to train trainers in agricultural research management.

The general objective of the project was to improve planning, monitoring and evaluation (PM&E) of agricultural research in Latin America and the Caribbean. This objective was achieved through a participatory strategy by which the regional research directors and specialists participated in planning the project, undertook thirteen case studies, designed training materials and other training support documents and applied their experience and skills in providing training in three subregional courses and one final diffusion workshop.

The evaluation of this project stated that " the materials and reports show a careful use of instructional design principles. It is noteworthy the effort to apply the systems approach for the instructional planning of the training materials, the workshops and the courses. This process has well been integrated with the participatory methods akin to adults....The training activities have been designed so as to have adults learn not only information but to take position in relation to the PM&E process being presented. This type of training focus on the trainee's experience which makes learning more sustainable and compromising".

Management of technology transfer.

In cooperation with the Ministry of Agriculture of Colombia, CIAT's training for trainers project and the training materials section participated in the training of a nationwide team of trainers who are actually training a group of nearly 300 "multipliers" in management of technology transfer for the National Extension System based on UMATAs, that is municipal units of technical advice for farmers.

The first phase has been completed with the training of the national team and the production of four training modules four fasciculi to distribute among the UMATAs technical staff and a general orientation module to satisfy the needs to conduct training in 1) characterizing a production system in a participatory manner, 2) conducting participatory planning, 3) designing agricultural technology development projects with community involvement and 4) conducting follow up and evaluation of agricultural development projects.

A second phase in which the section will be involved relates to generating training follow up strategies and instruments in order to consolidate the extension management process in the 1000 UMATAs of Colombia.

FUTURE STRATEGY

The two main training objectives will be pursued along the following avenues.

Training of researchers

For objective one "Skilled NARS scientists working in focused and high priority research projects" CIAT will

* Continue offering
    * ** individualized training in research (both not degree-related and degree related) on germplasm development;
    * ** advanced group training in research on germplasm development; and
* Begin offering group and individualized training related to resource management research.

Training in germplasm development will be largely done by CIAT on its own. New funding resources for this are being explored. An example of such new funding is the oncoming international course on Biotechnology for the Conservation and Utilization of Agrobiodiversity, which will be funded by ICETEX from Colombia, the Organization of American States, and CIAT.

Training for resource management research will be largely interinstitutional. Steps towards a consortium between CIAT, CATIE, and IICA, with IDB funding are well advanced.

Training is obviously the means to increase the skills and capacities of NARS scientists as stated in objective one. The complementary part of the objective, i.e., that these scientists work on focused and high priority projects, refers to two things. That most training activities also aim at helping trainees better focus their research on substantive issues, that is, at prioritizing research; and that usually trainees design or improve their research projects as an integral part of their training.

Training of trainers

For objective two "Subregional capacity for training technology intermediaries in commodity production and in participatory relations with farmers", CIAT will continue establishing and strengthening national and subregional training capacities.

Essentially the focus is on "devolving" training responsibilities to NARDS, whenever conditions are right to do so. Devolution is not exclusively of CIAT responsibilities. CIAT's capacity of training trainers also is made available for the devolution of responsibilities by other Center's, as was the case with ISNAR as described above.

Although the aim of training of trainers is primarily devolution, assignments other than for devolution are also accepted, provided that they are close within CIAT's interests (e.g. Management of Technology Transfer for the Colombian Ministry of Agriculture). In such cases fees exceed cost recovery and proceeds are applied to bridge funding gaps between devolution projects.

INFORMATION AND DOCUMENTATION UNIT

1. INTRODUCTION

a. Overall Goal and Objectives

Overall Goal

To provide CIAT, and its partners, with the most efficient and effective information and documentation services required to fulfill research objectives.

Objectives

To identify the scientific information needs of CIAT scientists and their research partners.

To acquire, organize, and disseminate scientific information utilizing the most efficient and effective technologies available.

To strengthen access to and exchange of information through participation in information networks with other agricultural research institutions and information providers at the national, regional and international levels.

To promote training for end-users and information intermediaries in managing and accessing scientific information.

Outputs

Improved access to and use of information (through the design, implementation and use of information systems, services and networks to satisfy the needs of users.)

Improved collaboration with external institutions (to stimulate greater sharing of information, exchange of experience, and cooperation on joint projects.)

Strengthened capacity for effective information management.

Information innovations (to facilitate use of and access to agricultural and natural resource information.)

b. History of Overall Program Activities

The major program activities of the Information and Documentation Unit from 1989 to the present include automation of operations and services, information networking at the local, regional, and international levels, and promotion to stimulate wider awareness and use of bibliographic resources.

c. Major Clients

The major clients for the Information and Documentation Unit products and services are CIAT scientists, staff of national agricultural research and development institutions, and regional and international information and documentation networks. Half of the Unit's products and services are delivered outside of CIAT and most of them go to researchers in developing countries, primarily in Latin America. The Unit also serves universities, agri-professionals, agroindustry, farmers, administrators, and libraries.

2. HISTORICAL ASSESSMENT

a. Achievements

Automation of Operations and Services

In the period 1989-1994, the Information and Documentation Unit has made a major investment in emerging technologies in order to promote wider awareness and greater

use of its bibliographic resources, as well as to streamline operations. An automation plan was developed in late 1989 which has resulted in gradual evolution towards an electronic library and implementation of the following innovations:

- o automation of the card catalogs
- o full automation of the indexing/abstracting/cataloging processes including downloading from CD-ROM databases, scanning of author abstracts, generation of value-added products from databases, and use of translation software for machine translation of abstracts
- o external bibliographic databases on CD-ROM
- o end-user workstations for direct access to internal/external databases
- o online searching of external databases

- o electronic mail and access to CGNET, Bitnet, Internet and other telecommunications networks for ordering/receiving publications, searching databases, participating in discussion groups, downloading electronic files
- o installation of specialized software for electronic transmission of scanned documents via Internet
- o adoption of desktop publishing techniques for improved quality of information products
- o full-text publishing of CIAT publications on compact disc
- o publishing of CIAT bibliographic databases, including SINFOC commodity databases, on compact disc
- o network access to CIAT internal bibliographic databases, external CD-ROM databases, and research support applications (e.g., Current Contents) on an information server in the CIAT-wide local area network
- o development of software applications in Micro CDS/ISIS to facilitate searching of CIAT bibliographic databases

Networking

The Information and Documentation Unit participates in networks to share information resources with other libraries and documentation centers, information providers, or other institutions involved with research in agriculture and natural resource management. Networking, in particular, electronic networking, results in fast access to a much broader range of services, products, and information, usually for a minimal transaction cost. Network activity over the period includes the following:

International Level

- o Input center for the FAO-sponsored AGRIS bibliographic database. Contribute 600 database records per year.
- o Member of AGLINET, FAO-sponsored document delivery network.
- o Publication gift and exchange agreements with 500 libraries and documentation centers in developing countries.
- o Union Catalog Database of Journals of the International Agricultural Research Centers. Contributed 3,500 database records. Database distributed to NARS on diskette.
- o CIARL - Compact International Agricultural Research Library on CD-ROM of the CGIAR centers. Participated in the production of the full-text publication on CD.
- o Cooperation with CIRAD in the production of CD SESAME. Contributed 2,500 bibliographic records.
- o Agricultural Databases of Latin America and the Caribbean CD-ROM. Contributed 60,000 bibliographic records comprising the complete databases of the CIAT Library to this IICA-sponsored regional project.
- o World List of Agricultural Serials (WLAS). Collaborating with the National Agricultural Library (U.S.) to include CGIAR center journals on CD-ROM.

- o Distribute CGIAR developed software applications in Micro CDS/ISIS to NARS libraries in Latin America.
- o Electronic networking with information personnel in CGIAR and other institutions through listservers and discussion groups.
- o Electronic networking with partners on special projects including electronic mail and transfer of data files.

National Level

- o BACOL - Bibliografía Agrícola Colombiana CD-ROM Project. Contributed 8,000 bibliographic records for Colombian agricultural literature to a national CD-ROM project.
- o Directory of Directories on Natural Resource Management Database. Coordinating development of a cooperative database on directory-type information sources for natural resource management.
- o Distribution of Pages of Contents, 6 series, for over 900 core journals in CIAT's collection to researchers in NARS in Latin America.

Promotion

Several measures have been taken to increase public awareness and use of publications, databases, and other resource materials in the CIAT Library.

Publications

- o Alert services including production of Pages of Contents (contents of more than 800 core scientific journals at CIAT in 6 subject specialized series); bibliographic bulletins listing new accessions to the collection and databases including specialized references to cassava, forages, beans, and tropical acid soils.
- o Information sheets on databases for searching at CIAT and other resources available.
- o Quick bibliographies on focussed topics developed in conjunction with program scientists to meet research partner information needs.

Exhibits

- o Exhibition booths at scientific meetings in the region to promote use of publications and databases.
- o Internal rotating exhibits of books, journals, software, and audiovisuals on topics of current research interest.

Training and Orientation

- o Demonstrations of new databases and electronic reference tools for CIAT staff.
- o Training courses in information access and management for researchers and information personnel.
- o Workshop in basics of database searching in CD-ROM for CIAT staff.
- o Orientation of visitors including tours, database demonstrations, and distribution of materials, including software applications.

b. Impacts

The Unit's public service statistics for bibliographic searches, photocopies of documents, and distribution of bibliographies and technical or promotional publications increased exponentially in the period. There was a 1000% increase in database searches between 1987 and 1992, up from 272 per year to 3,002, primarily as a result of the availability of CD-ROM databases, plus greater publicity and training. Productivity in cataloging and indexing increased by 35% as a result of automation in processing.

Automation of the collections and adherence to international bibliographic standards has made it easy and feasible to share CIAT's databases with partners and clients in a variety of forms, including publications, print-outs, diskettes, CD-ROM, or as electronic file transfers. It has also made it far more efficient and effective to access resources located outside of CIAT and to participate in the global information market.

c. Constraints

The greatest challenge that the Information and Documentation Unit has faced in the last five years and will continue to face in the future is increased demand for services and declining human and financial resources. The Unit absorbed a 50% reduction in personnel (15 full-time positions) between 1992 and 1993. The operating budget has had a real decline (in constant dollars) of 4% per year since 1989. Scientific journals have an average annual inflation of 18%. This inflation has reduced the purchasing power of the Unit. It has resulted in cancellation of important scientific journals that support basic research and made it near impossible to subscribe to new journals and databases to support new CIAT research programs in natural resource management disciplines. The Unit must rely more and more on secondary alert services such as Current Contents to identify articles of interest which can then be ordered directly from the author or obtained from document suppliers for a fee. This may be a cost effective alternative for CIAT scientists, but the impact on research partners in the region is erosion of traditional services, i.e., reduced access to important journal literature. In addition, as more and more of the Unit's budget is consumed by acquisitions, there are fewer resources left to improve other existing services or develop new ones.

d. Components Terminated Since 1989

The major program that was terminated in 1992 was production of the abstract journals on cassava, beans, and tropical forages–journals that had been in publication for nearly twenty years.

e. New Components

Bibliographic service for CIAT commodities–beans, cassava, and tropical forages–will continue through more cost effective channels such as database searches on demand, a new series of bibliographic bulletins by commodity (citations only, not abstracts), and specialized bibliographies. Other new components to the program are referenced above in the Achievements section and below in 4.b New Major Project Initiatives.

3. FUTURE STRATEGY

a. Project Outputs and Activities for 1994/95

Output 1 - Users alerted and trained in use of information services

- a. Demonstrations
- b. Media products
- c. User training

Output 2 - Users updated on scientific information

- a. Pages of Contents
- b. SDI services
- c. Journals circulated
- d. Alert bulletins

Output 3 - Users' information search needs met

- a. Reference service
- b. In-house database search service
- c. Online search service
- d. Bibliographies

Output 4 - Users obtain access to identified information

- a. In-library use of information products
- b. Loan
- c. Photocopying

Output 5 - Updated and Accessible Information Bank

- a. Selection
- b. Acquisition
- c. Processing

d. Databases (computer applications support)
e. Maintenance (database and collection maintenance)

Output 6 - Access to and sharing with external information sources
a. Networking
b. NARS librarian training
c. Input of CIAT publications into external databases
d. Exchange of publications
e. Distribution of electronic applications

b. New Major Project Initiatives

Special Project

The Information and Documentation Unit has submitted a special project for donor funding that would recover gray literature essential to research in natural resource management. The project is complementary to existing projects in CIAT's natural resource management programs for the hillsides and tropical lowlands. It is a cooperative project with ten national institutions and one regional organization, and it involves networking, database building, and dissemination.

Internet Access

CIAT has recently obtained full interactive access to the Internet telecommunications network. The Unit must increase access to information services available through the Internet and should take the lead in alerting CIAT staff and partners to products and services available. The Unit should also provide leadership in ensuring that CIAT information and databases appropriate for external distribution are available on the Internet. The Internet will be exploited as an alternative to provide information support to CIAT research programs, especially those information-intensive areas that are not being adequately served by existing in-house services. This will require a management commitment to funding of hardware and software tools and telecommunications services.

c. Inter-Program Project Initiatives

The Information and Documentation Unit established a liaison program with CIAT programs and scientific resource groups. A professional subject specialist has been assigned to each of the research program areas and SRGs in order to maintain close contact with research projects and information needs and to ensure that Unit services and products are based on demand. The liaison is also responsible for development of special bibliographies or other services in conjunction with program research staff.

The Unit has proposed that information and documentation be a line item in all special project budgets in order to subsidize the portion of cost for databases, journals, books, photocopies, searches, software and other resource materials necessary to support special projects.

d. Relation of CIAT Projects to CG System-Wide Programs

CGIAR Restructuring of Information Management

The Information and Documentation Unit will be closely involved in the current restructuring of inter-center information activities. It is expected that the Unit will participate in proposed system-wide, cost-effective measures such as joint purchasing of journal subscriptions and related services and joint database development, among other possible activities, to promote greater sharing of resources and less duplication of effort and to contribute to a more unified image of the CGIAR.

Ecoregional Research

The Unit also expects to collaborate closely with CIAT programs and information counterparts in other international centers in implementing information support to ecoregional research initiatives. The Unit has already participated in the planning phase for the East African Highlands Ecoregional initiative and has contributed proposals to the MAS - Managing Acid Soils initiative as well as to the Central American Hillsides initiative.

COMMUNICATION AND PUBLIC AWARENESS UNIT

1. Introduction

Goals: To effectively communicate CIAT research results, accomplishments, and challenges, through print, electronic media, and personal contact, with various target audiences. Most CIAT communication falls into one of two categories:

Scientific communication: Directed primarily to increase communication among scientists in developing countries of the tropics, but also including researchers in the developed nations, as well as educators and extension specialists.

Public awareness: Communication to promote a positive image of CIAT in the donor countries, primarily to encourage donor funding, and in partner countries to maintain a favorable working environment. PA activities of the CU focus mainly on the mass media: written and visual communication, and press relations.

2. Historical assessment

What is now the CIAT Communications Unit previously operated as three separate units: Scientific Publication, Distribution, and Translation; Public Information; and Graphic Arts. Those groups were merged in January 1992 as the Communication and Public Awareness Unit, under the management of a unit head.

Scientific publication. A Publications Advisory Committee, comprised of both scientific and information staff, was established in 1992. Its purpose is to set publication policy and to screen publication proposals, thus minimizing the publication of non-essential materials.

The budget for publishing books ($21,000 in 1992) was terminated, and a Publications Revolving Fund (PRF) established. Income from sales is credited to, and publishing and promotion expenses are debited from, that budget. A pricing policy was established whereby CIAT recovers manufacture and distribution expenses from book sales in developing countries. That price is multiplied by 2.5 times for sales in developed countries. Thus, the developed-country sales subsidize distribution in developing countries. Book publishing is self-sustaining, and the PRF is healthy. There is no lack of funds for publishing future books.

Despite a 25% staff reduction, CIAT has at least maintained its prior level of scientific publication. This was done partly by computerization. We have also started bringing in journalism students, who do their 6-month internships working on Spanish publications, and may bring English-language interns in the future. We are identifying persons, including CIAT spouses and
local expatriates, who have communication *talents* and teaching them the *tools* and *skills* essential for writing and editing.

Public Awareness. In 1992-93, CIAT increased its public awareness activities exponentially. We developed a press list of about 800 media contacts worldwide. We initiated a program by which we write and disseminate about 30 press releases yearly, in both English and Spanish. This has resulted in positive articles about CIAT in the *Washington Post*, the London *Financial Times*, the *Frankfurter Allgemeine Zeitung*, *Asahi Shinbun*, and the *Sydney Morning Herald*.

We continued to publish *CIAT International*. In 1993 we initiated *CIAT On-Line*, a series of two-page bulletins targeted to our donors. We have published *Shareholders in Development* brochures summarizing CIAT's relationships with Australia, Canada, Germany, Japan, and USA.

CIAT started systematic video production in 1993 with the release of *A Fragile Paradise: The Environmental Challenge of Tropical America*. The English edition was broadcast on at least 50 TV channels and the Spanish edition, on 30 or more. We produced *The New*

CIAT, an 8-minute program for orienting donors, in 1993. Two documentaries, intended for TV, are now underway: *Wild Savanna: South America's Frontier of Hope* and *The Search for Carolina Gold: A genetic odyssey in rice.*

3. Future strategies

Compact disc technology opens the door to vastly cheaper, and easier, access to scientific data. We are archiving publications in electronic form so they can be compiled as specialized electronic reference sets. We will increase joint publication with outside publishers in both developed and developing countries. New communication channels will be established for reaching scientists and administrators in developing countries more efficiently. We are expanding our computerized translation program to include Spanish-to-English. We will move both scientific and public awareness materials onto the Internet. We hope to reach decision makers more efficiently by targeting public awareness materials directly into prestigious international media and other channels. We will move into video news releases.

PROJECT DEVELOPMENT OFFICE (PDO)

1. Introduction

Overall Goal

To secure financial resources for CIAT projects.

Objectives

To assist CIAT Program/SRG staff in the design of projects relevant to the needs of NARS partners and donors and in the preparation and submission of proposals delivered timely to appropriate donors.

Outputs

The major outputs of the PDO are:

- project designs utilizing the work breakdown structure approach which links activities to outputs and outputs to purpose
- training materials in project design for CIAT staff
- CIAT administrative manual for the identification, approval and administration of projects

- up-to-date donor data base identifying relevant donor contacts and programs

- high quality desktop publishing proposals that have both technical and communications effectiveness

This office did not exist at the time of the last EPMR in 1989. Since the creation of the PDO in March 1992, the objectives for it have remained the same. However, as a result of the recently Board approved Action Plan for CIAT, increased emphasis will be given to the participation of NARS in both the project identification/design phase and in the proposal phase.

Major Clients and Regional Impacts

There are three major client groups for the services of the PDO:

- CIAT program/SRG/administrative and management staff

- donor staff

- project staff with NARS and regional partners

The impact of the PDO includes:

- improved efficiency and effectiveness of all CIAT research activities (including those funded both by core and by complementary) through adoption of a project institutional culture

- improved accountability with donors as a result of investment of funds being linked to the production of specific outputs within a specified time frame

- improved efficiency of a regional agricultural research system in Latin America through the transfer of project design skills to NARS and regional partners in consortium projects

- a diversified project funding base that increasingly taps in partnership with NARS the bilateral and multilateral country or regional specific assistance

2. Historical Assessment

Achievements

In 1993, CIAT submitted 10 detailed proposals for special projects of which 7 were funded. This is a very high success record.

In 1994, all CIAT program/SRG leaders and unit heads participated in a PDO workshop on project design using the logical framework and work breakdown structure approach which is used by most donor agencies. The PDO played a key coordinating role in the development of the CIAT Action Plan and definition of the project profiles.

Also in 1994, the PDO prepared an administrative manual for internal CIAT project identification and approval procedures and design and proposal guidelines. This is being revised in a modular approach which can be distributed (without the CIAT cost information) to NARS and regional partners.

Impact

In 1994, CIAT has converted all its research activities (both core and complementary funded) to a project basis. In previous years, core funded research which accounted for approximately $25 M of a total $30 M budget was not done in the form of projects but rather was implemented as on-going activities without specified completion dates and outputs.

Constraints

The major constraints to converting CIAT to a project basis that increasingly is supported through donor project funding are that many CIAT staff have not had experience in proposal preparation and their NARS partners have not had experience in the particular project design approach we have adopted.

All CIAT leaders and unit heads as well as many senior scientists have now taken the project design workshop. Additional workshops still need to be offered to the remaining senior scientists as well as to those research associates who assist in project design and proposal preparation.

The priority for offering the project design workshops has been assigned first to CIAT staff. The workshop has been given to only one NARS partner (the National Agricultural University at Palmira). Additional workshops for NARS will need to be offered if CIAT intends to actively pursue bilateral and multilateral donor funding where agencies expect the national partner to take the lead role in submitting project proposals.

In order to identify relevant donor funding opportunities, considerable more time must be spent in personal visits to donor program staff. Traditionally, CIAT has concentrated on donor contacts responsible for multilateral core contributions. Diversifying CIAT's funding base to include more bilateral project funding is currently constrained by our lack of knowledge of donor programming priorities. Moreover, whereas in the past CIAT could touch base with just one or two donor contacts (responsible for the CG core contribution), the process is much more complex when seeking bilateral funding since many geographic desk officers must now be consulted.

Components Terminated Since 1992

None

New Components Since 1992

The major new component is the involvement of the PDO in 1994 in visits to donors in order to document country priorities, programming themes, approval processes, proposal guidelines, and relevant donor contacts.

3. Future Strategy

The future strategy for the PDO will be adjusted as a result of the Directors' Committee decisions on the following resource mobilization policy issues:

- Balance Between Latin American Ecoregional and Africa/Asia Project Fund Raising Initiatives

The relative effort for project fund raising for CIAT eco-regional initiatives for Latin America versus global responsibilities for commodity research in Africa and Asia must be decided.

- Focused versus shotgun approach

A strategy to increase bilateral project funding will likely necessitate a targeted approach to national partners in Nicaragua, Bolivia and Ecuador as these appear to be the most important countries for European donors. As part of this strategy, CIAT will need to develop much closer ties with donor field representatives in these countries.

- CIAT Priority Setting For Projects

Out of the 100 potential projects identified in the Action Plan, CIAT management will need to priorize which ones to pursue first, based on discussions with NARS on needs and discussions with donors on their priorities.

Some priority setting will also be needed as to the time spent on pursuing the large project funding opportunities (eg. with GEF, EU, and bilateral donors) versus the time spent exploring new foundation opportunities which are likely to fund much smaller projects.

The strategy to match CIAT projects to NARS and donors priorities is essential. Certain biodiversity training proposals have the opportunity to be submitted to GEF, the EU, JICA and the IPGRI system wide initiative. CIAT will need to avoid duplication and have an overview of the various donor opportunities before targeting one for a specific proposal.

- Targeted partners for GEF projects

CIAT will likely assign priority to work with national partners in developing proposals for GEF funding from the UNDP rather than the World Bank for a variety of reasons, including the flexibility to not be locked into specific sites identified for investment loan projects.

- True Participation By NARS Partners In Project Identification and Proposal Preparation

In the past, CIAT has traditionally taken the lead role in identifying and designing the project and then preparing the proposal which would then be submitted to the NAR for endorsement. The new strategy for bilateral funding will require NARS to be equal partners in this process. This will be much more time consuming but nevertheless is essential.

- New NGO Partners

In preparing a strategy for seeking GEF project funding and European Union environmental funding, CIAT may wish to proactively approach certain key ngos such as the World Wildlife Fund who are already well respected by many donors.

- Closer Liaison With Planning Ministries

In the past, CIAT has had very little liaison with planning ministries. CIAT will need to strengthen these relationships (e.g. with DNP in Colombia) if we wish to pursue European Union project funding since endorsements from the planning ministry are normally a requirement.

- Administrative Implications

Work will be needed in the harmonization of data bases between the PDO donor data base, the Communications Unit data base, and the CIAT staff trip report data base to ensure that information on relevant contacts is incorporated into each.

To EPR

CIAT External Program Review (EPR)

Response Summary To Specific 1989 Recommendations & Suggestions

<u>**RECOMMENDATION #1.**</u> (3.1.3.1. Beans//Germplasm, p. 13)

" that a greater effort should be made with the GRU to increase germplasm screening activities and to speed up the processing of backlogged materials."

CIAT' S INITIAL RESPONSE: CIAT agrees with the need for more rapid processing and screening of the germplasm collection in beans. CIAT has successfully negotiated with ICA for the construction, near Bogota, of a long-awaited facility which will provide greatly increased quarantine capacity in Colombia. While CIAT has had contracts with other organizations in third-country quarantine projects, these have proved insufficient in relation to the backlog of those 9,000 viable materials which remain unprocessed at this time. This increased quarantine capacity in Colombia, combined with the continuing activities in third-country quarantine, should reduce the backlog to a normal level within the next three years. Screening of germplasm is a continuing activity and most of the 25,000 presently processed materials have been screened for a range of disease and insect resistances and specific plant and environmental characters. As new material is processed through quarantine it undergoes the same screening process.

1994 ASSESSMENT: In 1989 there was about 25,800 accessions in the Phaseolus collection and about 9,000 accessions held in backlog. A revision of the passport data (as result of forming the core collection) revealed that much of the backlog represented duplicates of materials already in the bank or breeding lines. After review, the backlog was reduced to about 5,000 accessions. Following this experience it was clear that passport data of potential new introductions should be reviewed carefully.

In the period 1990-1994, the GRU received 1,545 new accessions which were selectively introduced. ICA' s quarantine greenhouse close to Bogota which was built for screening CIAT introductions only began operations in 1992 and at a rate far below expectations (about 400 per year). Between the Bogota facility and greenhouses in CIAT, a total of 2,225 accessions of Phaseolus were processed.

At present we estimate that about 3,000 accessions of *P. vulgaris*, 400 of P. *coccineus/polyantus*, and 700 of *P. lunatus* remain to be processed, includingstudy of passport data. Another 400 accessions of non-cultivated species are also in backlog, but conditions for seed production of many of these are poorly understood. Total accessions pending analysis: 4,500.

As to screening of germplasm, more than 20,000 accessions have been evaluated for several important diseases. See also related Recommendation 5.

RECOMMENDATION #2. (3.1.3.7. Beans//Developing Countries, p.18)

" that CIAT (should) take steps to assemble information on the occurrence and distribution of major constraints to bean production in Africa."

CIAT' S INITIAL RESPONSE: CIAT agrees that the information on major constraints in Africa should be assembled in one analysis. At the moment information is available from all three regional programs with respect to the major constraints in each country. A bean map has been prepared for Africa and this is being revised and updated with new information being gathered by the economist who was recently appointed to the African program. This information, combined with what is already available, and together with an updated map, will be analyzed in the near future and presented in one report which will outline the degree to which biological, environmental and socioeconomic constraints are affecting bean production in Africa.

1994 ASSESSMENT: The bean Program completed an extensive survey of constraints for production regions in Africa. The survey includes definition of production environments based on edaphic and climatic data and extensive information on cropping practices. Emphasis is on sub-Saharan Africa, other regions are also treated. Of 22 biotic constraints, angular leaf spot, anthracnose and bean stem maggot were estimated to cause the greatest yield losses. Of seven abiotic constraints, low soil N, low soil P and water deficit were the most important. Estimates of importance were stratified by major regions to provide researchers with a more strategic view of constraints. The information is being made freely available to NARS and other institutions through the publication "African bean production environments: their definition, characteristics and constraints" (Wortmann and Allen, 1994). The survey will serve as primary resource for priority setting for regional projects in Africa in the coming years, although it is gratifying to note that the assessment of the major priorities coincides with the consensus developed with African researchers over the past ten years.

RECOMMENDATION #3. (3.3.8. Rice//Recommendations, p. 36)

" that the Rice Program (should) pursue more actively the use of population improvement methodologies like recurrent selection."

CIAT' S INITIAL RESPONSE : CIAT agrees, as evidenced by the fact that the Rice Program recently recruited a breeder with such an expertise. The Program has also developed male sterile lines for recurrent selection in the uplands and is transferring this character to the irrigated lines.

1994 ASSESSMENT: CIAT's rice program began population improvement in 1989 targeting rice blast (*Pyricularia grisea Sacc.*). The broad genetic base used to develop the original population allowed selection of improved materials for upland and irrigated conditions. In 1993 the second cycle of selection was completed. The parents produced after the first cycle have shown significant superiority (resistance to the disease) in relation to the original population. This study is still under way, with more emphasis being placed on other important agronomic traits.

For upland acid soil savannas, populations developed jointly by CNPAF/ EMBRAPA and CIRAD-CA, in Brazil, were introduced to CIAT 1992. After two years of evaluation and selection, improvement has been achieved for earliness, plant height (shorter plants), and blast resistance. A new population was created, using the introduced populations as a source of male-sterility. This work is just beginning for this ecoregion and the initial results are very promising.

During the 1993 Upland Rice Breeding Workshop (Montpellier, France), with the participation of CIAT, IRRI, WARDA, and NARDs, CIAT jointly with CIRAD-CA were recognized as leaders in this area and were designated responsible to put together all available information on population improvement on rice and to collect samples of all populations developed worldwide.

RECOMMENDATION #4 (3.3.8. Rice//Recommendations, p. 36)

" that since the yield trials have frequently shown rather poor statistical precision, the Rice Program (should) make a serious effort to explore the reasons."

CIAT' S INITIAL RESPONSE: CIAT agrees, noting that the area in question is an ecosystem in which neither it nor other IARCs have previous rice experience, and with a unique set of environmental constraints. Having identified many of these constraints, the Program has responded by increasing the size of its experimental plots, the number of replications and the sampling methodology.

1994 ASSESSMENT: The upland rice breeding section began evaluation of its advanced lines outside the breeding site where the materials were developed in 1988. The idea was to assess the reaction of the improved lines under farmers conditions. The first observations made showed that the soil heterogeneity was much higher than the experimental area and the coefficient of variation (CV) of the trials were very high. The first alternative was to increase the plot size, instead of the number of replication, based on the fact that farmers in the savanna region are used to managing large units of land, therefore the results would have more impact. From 1990 onward bigger plot sizes were used and the observed CV in the yield and agronomic trials were around 15 to 20%, considered acceptable to detect the differences between treatments. After that first year there was not any other effort to analyze this aspect in more detail.

RELATED SUGGESTIONS (3.3.6. Rice Program/Future Activities)

CIAT's Information Unit (IDS) has developed a computerized data-base, CATAL, into which bibliographic references on rice research and development relevant for Latin America are incorporated with the Rice Program' s support. Presently (June 1992) it holds approximately 4,500 references to documents available at the Information Unit. Of these, about 1,500 correspond to documents that have either been produced in Latin America or refer to the region. Further to CATAL, the Information Unit has incorporated the world' s major agricultural bibliographic data-bases on CD-ROM (AGRIS, CABI, AGRICOLA, SESAME, KIT, etc.) with an astonishing wealth of information (millions of references) including, of course, information on rice.

Services for Latin American rice researchers based on this system are bibliographic searches, photocopies of documents, and Specialized Dissemination of Information (SDI).

The Information and Documentation Unit collaborated with the Latin America Network Coordinator of CIAT' s Rice Program to strengthen the bibliographic coverage of the rice literature, especially in Latin America. During the period 1989 to the present the Unit indexed 3,000 documents on rice, selected by the Rice program, for the CATAL database. A copy of the database was given to the Rice Program for reference and distribution to regional clients and IRRI. The Unit also developed a quick bibliography on Rice in Central America and the Caribbean for distribution to partners and clients in that region. Other Information and Documentation services available to Latin American rice researchers are bibliographic database searches (internal and commercial databases), photocopies of documents, and specialized dissemination ofinformation alert services.

<u>**RECOMMENDATION #5.**</u> (3.5.1.7. GRU//Recommendations, p.47)

" that the GRU should intensify the effort to have experts decide on a manageable core collection consisting of a limited number of accessions that contain an appropriate amount of genetic variability."

CIAT'S INITIAL RESPONSE: CIAT agrees on the need to create core collections. At the moment, however, consensus within the scientific community as to what precisely constitutes such a grouping is lacking. It is agreed that core collections would allow the assembly of a key, representative set of materials which could be used for characterization studies, including work at the molecular level, and for provision of germplasm which is generally representative of the wide range of germplasm availability in the various collections at CIAT. CIAT will closely monitor the current debate on this subject to assist in formulation its own policies towards core collections. In the meantime there is need to reduce the collections to more manageable numbers by identifying duplicates. The GRU will continue to work along these lines using various genetic markers.

1994 ASSESSMENT: A core collection of *Phaseolus vulgaris* has been compiled based upon a model combining historical, morphological and agroecological data. Passport data of accessions were utilized to pinpoint collection sites and to relate accessions to the agroecological characterization of the region origin. Special emphasis was placed on characteristics of soil, photoperiod, rainfall and growth cycle (a surrogate for temperature). Such a model is unique in the formation of core collections and could have important applications for other cultivated species or for wild species, to develop applications of GIS in germplasm conservation. About 1200 accessions of cultivated common beans were identified from the primary centers. A sample of 300 accessions from the secondary centers was made based on seed characteristics and morphology. Elite lines and genetic stocks were also included. The wild core collection consists of 100 accessions selected to cover the whole range of distribution of wild *P. vulgaris*.

The bean core collection is being characterized at the morpho-physiological and molecular levels. The collection is being increased for seed distribution to Latin

America and Africa NARs. The collection has already been planted at different sites in Colombia and in Ecuador under different environmental conditions for agronomic characterization. The integration of GIS, agronomicand molecular data has been initiated.

The world collection of *Manihot esculenta*, maintained at CIAT, consists of over 5000 accessions representing the diversity of nearly all cassava producing countries of the world. Experience with the seven agroecological zones established to orient cassava research, and parameters of geographic origin, morphological diversity and isozyme patterns, were used to define a core collection of cultivated cassava. The cassava core collection has already been evaluated for several root quality characteristics such as starch and cyanide content, for physiological traits including photosynthetic capacity and drought tolerance, and tolerance to poor soils, pests and diseases in the major agroecological zones of cassava production.

The bean and cassava core are being used to:

Characterize the spacial distribution of genetic diversity in cultivated and wild Phaseolus and Manihot species, with special emphasis on possible genetic exchange among species, gene pools and/or wild and cultivated forms.

Relate inter- and intraspecific variability to agroecological parameters, thus defining those parameters or combinations of parameters which have most contributed to diversification.

Determine the relationship between, a) genetic groups identified through analysis of molecular markers; b) the distribution of economic traits in the germplasm; c) and the agroecological parameters of the sites of origin.

<u>**RECOMMENDATION #6.**</u> (3.5.1.7. GRU//Recommendations, p. 47)

"that considering the increased activities necessary for the tropical pastures and cassava collections and its great genetic variability, CIAT (should) seek resources for adequate staffing for the GRU."

CIAT' S INITIAL RESPONSE: CIAT agrees that increased resources for the GRU will be necessary as the Unit increasingly takes over responsibilities for the tropical pastures and the cassava collections. The arrival of the new Unit Head in late 1989 will facilitate reassessment of the Unit' s requirements, which will be addressed within the limits of funding available to CIAT.

1994 ASSESSMENT: The history of GRU staffing since 1989 is as follows:

GRU Staffing[1] (1989-1994)			
Sections	Year		
	1989	1991[3]	1994
1. Beans Core	18	18	13
2. Tropical Forages Core	7	19	15
3. Cassava Core	—[2]	6	7
4. Seed Health Core	5	5	3
5. Electrophoresis Core	—	2	2
6. Coordination	4	4	3.5
Total Core	34	54	41.5
Glembloux Project on Beans	9	—	—
GRAND TOTAL	43	54	41.5

1. Includes the Unit Head, junior staff, and support staff.
2. In 1989 the in vitro collection was part of BRU.
3. GRU in depth review.

The key years of this table 1989, 1991 & 1994 correspond to the third EPR, a GRU in depth review and the current fourth EPMR.

The expansion in GRU staff from 1989 to 1991 reflected the following:

(a) Transfer of germplasm support staff (10) from the Tropical Pastures Program to the GRU IN 1990.

(b) Transfer of cassava germplasm staff from the BRU to the GRU following the 1989 EPR. Though delayed, a curator of the cassava collection has been appointed in 1994.

In 1994 in a joint effort between CIAT and IPGRI, a senior scientist on genetic diversity was appointed in order to provide input and coordinate the development of a Latin American consortium on plant genetic resources and agrobiodiversity. This consortium will involve other IARCs as part of the system wide program on Genetic Resources coordinated by IPGRI, relevant NARS and NGO's.

The decline in total GRU staff since 1991 reflects the continuing financial cuts experienced by CIAT. The Head of the GRU who resigned in late 1992 has not yet been replaced because of budget cuts. The Program Committee of the Board of Trustees in 1994 also urges that this anomaly be addressed. Recruitment of this position will be initiated in the first quarter of 1995.

CIAT recognizes that the increasing external influence of the Biodiversity-Convention and the now formalized Inter-Governmental Committee for the

Conservation of Biodiversity, along with the FAO Trust Agreement, which will be signed in the near future, will place extra demands on the GRU. These demands will not only result from increasing accountability requirements but also from increased demands of countries in LAC for technical training & support so that they may fulfill their obligations as members of IGCCB.

RECOMMENDATION #7. (3.5.1.7. GRU//Recommendations, p.48)

"that CIAT considers duplication of the collection and the maintenance of a collection of sexual cassava seeds, as insurance against the possible loss of the living cassava collection maintained in tissue culture."

CIAT'S INITIAL RESPONSE: CIAT agrees on the need to duplicate the cassava collection. This will have to be done comprehensively using various methodologies. The cost of duplicating international collections by meristem conservation in other institutions tends to slow the use of this methodology for duplication. A collaborative project proposal has been presented to IBPGR for a feasibility study on the use of sexual seed as a conservation media. It seems appropriate for CIAT to develop basic research on the concepts underlying the use of sexual seed conservation in cassava as one complementary means for conserving the collection. The other possibility is the use of cryopreservation, which is already under study at CIAT in collaboration with IBPGR. If a breakthrough can be achieved in this area it may be possible that the whole collection (either as meristems or sexual seeds) can be duplicated and stored in liquid nitrogen at far lower costs than any of the other methodologies..

1994 ASSESSMENT: Two candidate institutes, FCRI in Thailand, and EMBRAPA, Brazil have been identified as recipients of safety duplicates of the living cassava collection. Negotiations are beginning with FCRI, but the issue of financial support has prevented a commitment from EMBRAPA. Transfer of the collection to FCRI is expected to begin in 1995, for maintenance in tissue culture. Although the 1989 EPR recommended the possibility of duplicating the cassava collection in the form of sexual seeds, true seed does not appear to be a viable mechanism of safe duplication, as a large proportion of the collection does not produce seed under the conditions of its field maintenance, and would therefore not contribute to a pool of alleles being maintained. Also, the scientists involved in gene-pool development need the maintenance of genetic combinations that have evolved for centuries under particular agro-climatic conditions, and not just a collection of alleles. Cryopreservation still seems to be a more promising option for long term, low cost conservation of cassava genotypes. A project is being prepared for funds to continue research in cryopreservation of cassava at CIAT in collaboration with ORSTOM, France, which has complementary experience to ours.

RECOMMENDATION #8. (3.5.2. BRU//Assessment, p.49)

" that even greater efforts (should) be made to find special funds and other resources to allow the Biotechnology Research Unit to expand."

CIAT'S INITIAL RESPONSE: CIAT agrees with the need for the BRU to expand its activities and every effort has been made to develop collaborative research projects in developed and developing countries which can provide an expanded overall effort on the CIAT commodities in which the BRU would play a crucial part. The development of the advanced research networks should be seen as a particularly effective means by which collaborators in advanced laboratories can increase and better coordinate their research efforts on CIAT commodities. CIAT is also seeking special funds for advanced research at headquarters on work for which we have a comparative advantage. Many such special projects at CIAT will be in conjunction with collaborative research projects taking place in other institutions.

1994 ASSESSMENT: Seeking special project funding to carry out on priority topics is a continuous effort of the BRU. As a result the amount of complementary funds for the BRU in the last two years has equaled the funds allocated from CIAT core.

A priority competence area for expansion of the BRU's capabilities in Population Molecular Genetics. The need for this expertise to allow the BRU better accomplish its role within CIAT and in relation to our partners in the NARS has been stated in the Report of the BRU in depth review of 1992 (G.J. Persley) and recommended by the last CIAT BOT meeting (July, 1994).

<u>RECOMMENDATION #9.</u> (3.5.2. BRU//Assessment, p.49)

" that an internal biosafety committee be established very quickly."

CIAT'S INITIAL RESPONSE: CIAT agrees that a biosafety committee should be established. A survey will be made of similar committees in other institutions in order to establish the guidelines by which the CIAT committee should operate. In establishing this committee CIAT will take into account any biosafety guidelines which may be established by the Colombian Government.

1994 ASSESSMENT: A CIAT Institutional Biosafety Committee was established in 1990-91; and the CIAT Biosafety Guidelines were approved by the BOT in 1991.

In the last two years the BRU has generated transgenic organisms (*Stylosanthes*, rice, cassava) for testing in the greenhouse and eventual experimentation under field conditions. CIAT is seen as a model by our national partners for developing appropriate experimental conditions for testing transgenic organisms. It is therefore necessary to implement a biosafety greenhouse in CIAT as an essential step towards the management of field releases under national/regional biosafety guidelines.

<u>RECOMMENDATION #10.</u> (3.5.4. AESU, p.51)

" that CIAT management (should) give greater attention to clarifying the role and future responsibilities of the Agroecological Studies Unit."

CIAT'S INITIAL RESPONSE: In its strategic plan CIAT has proposed the undertaking of a study to determine what role the Center should have in an ecosystem-focused approach, and whether or not a new program should be created to deal with sustainability issues. Any alteration of the Unit's current role will await the outcome of such a study.

1994 ASSESSMENT: The Agroecological Studies Unit worked almost exclusively on definition of the target areas for the CIAT initiative in NaturalResource Management research until the formation of the Natural Resource division. At this time the resources of the unit were incorporated in the newly formed Land Use Program. A new agenda of research was developed covering aspects of land use in resource management research. The support services previously provided to the commodity programs by the AESU were continued under the mandate of the new program.

RECOMMENDATION #11. (3.6.2. Station Operations, p. 58)

" increased attention (should be paid) to the needs of program experiments in decisions on commercial cropping by Station Operations."

CIAT'S INITIAL RESPONSE: CIAT agrees that a proper balance is require between commercial operations and the need to attend program experiments. The DDG in charge will be evaluating the needs of the programs in order to ensure that experimental use continues to receive preferential treatment.

1994 ASSESSMENT: The Field Operations Unit gives priority to all the services requested by the programs or to the research from the point of view of the land preparation, planting, cultural labors, irrigation, etc. No services are given to the commercial production if the same have to be provided to research.

RECOMMENDATION #12. (3.7.1. Assessment of Mandate Area, p.61)

" integrated strategies across CGIAR Centers in dealing with national programs, particularly in non-mandate specific activities such as management training, on-farm research and networking, and in areas of overlapping mandate such as the maize/bean intercropping so important in Latin America, the Caribbean and Africa."

CIAT'S INITIAL RESPONSE: CIAT agrees, and has already initiated such efforts, as shown by the agronomy trials training course held in Ethiopia in conjunction with CIMMYT, the joint training courses on grain legume research held in Africa in conjunction with IITA, and the forthcoming Central America regional training program in on-farm research (also with CIMMYT).

1994 ASSESSMENT: The Bean Program continued with earlier initiatives and establishing new activities in 1989/90 including: joint courses and workshops with CIMMYT in Costa Rica, Ethiopia, Malawi and Swaziland; with ICRISAT in Mozambique and Ethiopia; with IITA in Mozambique; and with CATIE inCosta Rica.

In Africa, inter-center collaboration in training continued to increase, including in 1992 the Crop Management Research Training Course (CIMMYT-CIAT), MSTAT-C (CIAT, CIMMYT, CIP), Economics Course (CIAT, CIMMYT), Training of Trainers

Course (several centers), and Consumer Acceptability Course (CIAT, ICRISAT). Inter-network collaborative activities expanded in 1992. A working group meeting on soil fertility research for the E. Africa highlands where maize-bean systems predominate was organized by CIAT, and CIMMYT with ICRAF participating. In Latin America, joint activities have included an inter-center training course for national program economists (CIAT, CIMMYT, CIP); a CIAT-CIMMYT newsletter for maize-bean systems in Central America; and a joint CIAT-CIMMYT effort in seed production in Peru.

One of the essential pillars of CIAT' s resource management research strategy is to work inter-institutionally, in a participatory and mutually complementary way to address high priority problems of actual or potential lack of sustainability in the lowlands and mid altitude hillsides of tropical America. This provides a natural framework to come together with sister Centers both to complement each other in the case of overlapping mandates and in the case of non-mandate specific activities. CIAT profoundly believes in such a synergistic approach.

RECOMMENDATION #13. (3.7.1. Assessment of Mandate Area, p. 61)

" being selective in responding to the broad range of demands that have come out of NARDS consultations."

CIAT'S INITIAL RESPONSE: CIAT agrees that it cannot respond equally to all requests or suggestions that result from our constant interaction with NARDS. We believe that we should be involved in only those in which we have a comparative advantage. It is encouraging to note that, in contrast to the consultations related to the development of the first plan "CIAT in the 1980s," when many suggestions were made that various commodities be added to our portfolio, 19 of the 20 NARDS' leaders who responded on this subject in our recent questionnaire agreed with the statement: "CIAT's current commodity mix is the right one." However, the "demands" are usually not in relation to additional commodities but rather for types of technical assistance, training, development activities and location-specific research that might best be done by others. We agree that we need to strike a balance between being responsive and saying "no" when appropriate.

1994 ASSESSMENT : The training-the-trainers approach has been incorporated as a transitional objective in CIAT's Strategic Plan (p.61) and in its Operational Plan (pp. 82, 87). Teams of trainers already deployed include a Central American Regional Bean Team, that has become part of the Regional Bean Network, and Rice Training Teams in the Dominican Republic and in Ecuador. Each of these teams is equipped with training materials developed by its members under the guidance of CIAT experts. They already have delivered courses to extensionists, and they have developed project proposals for their national authorities or for international funding. The Central American Bean Team, through PROFRIJOL, is seeking funding for a five years project to train 1,000 extensionists.

Teams presently being developed include Rice Trainers for Colombia and Venezuela, Cassava Trainers for the South American subtropics, and Tropical Forages Trainers for the Colombian, Llanos.

The technical and operational capacity of plant breeding programs within the NARS varies considerably in both Latin America and Africa. While some NARS have well trained professional staff, they lack operational funds to maintain active breeding programs; consequently, their activities are restricted to specific regions and constraints. In other areas, the exodus of professionals from research positions within national programs to higher paying jobs in the private sector, or to administrative positions within the government, causes considerable disruption in breeding activities, and in extreme cases, loss of genetic records or stocks. Only a few NARS in Africa and Latin America have sufficient technical and operational capacities to provide continuous support needed to maintain dynamic and successful breeding programs. Nevertheless, considering the limitations most NARS face, some breeding activities can be devolved to national programs breeders.

RECOMMENDATION #14: (4.2.5.7. CIAT and NARS//Recommendations, p. 84)

" that commending CIAT's effective development of the steering committee model and network activities in Africa and Latin America, the Center (should) continue its support for these efforts."

CIAT'S INITIAL RESPONSE: CIAT agrees that steering committees are an effective means for regional integration and participation and will continue such efforts. An important consideration is the financial resources required toguarantee the future existence of network activities and steering committees as CIAT involvement in a particular regional network is scaled down.

1994 ASSESSMENT: The Steering Committee remains the crucial management entity that oversees both research and training activities undertaken within regional networks. In some regions, the coordination of the network is being assumed by national scientists, with increasing emphasis on the identification of scientists as regional leaders in specific disciplines. As this process of greater regional assumption of responsibility continues, means by which the network itself develops a capacity to receive and manage its own funds are keenly sought, and national governments are increasingly encouraged to allocate funds to regional activities in recognition that it is more cost effective to do so. CIAT's role in the network continues to lie in scientific support as networks assume autonomy.

CIAT fully supports the steering committee approach which is an operational expression of CIAT's firm belief in a participatory approach to research and development as well as to institutional development.

RECOMMENDATION #15. (4.2.5.7. CIAT and NARS//Recommendations, p. 84)

"that in view of CIAT's success in working out a model for collaboration with EMBRAPA in Brazil, in cooperation with IITA, in relation to the Cassava Program for the semi-arid parts of Africa... the Center (should) continue to work toward similar outreach plans with other highly developed national systems."

CIAT'S INITIAL RESPONSE: CIAT agrees that the model being proposed for Brazil/CIAT/Africa cooperation is an example of the type of cooperation that can be effective without the inherent dangers of other bilateral arrangements. At the moment negotiations are in progress and it is expected that extra-core funding will be obtained. The possibilities for other such arrangements will be limited by the rate at which national programs develop sufficient strength to assume international responsibilities.

1994 ASSESSMENT: In 1990 a 5-year project (financed by IFAD, Rome, Italy) was initiated in cooperation with EMBRAPA and IITA for the development of cassava germplasm for semiarid and subtropical ecosystems. As a result, a group of elite clones is being tested on-farm in Brazil and segregating progenies from them have been introduced and are being evaluated in homologous ecosystems by IITA,, Nigeria..

The cassava Program is currently preparing a proposal for extending and expanding these activities in Africa, northeastern Brazil and the northern Coast of Colombia.

Realization of the potential productivity of improved cassava varieties under stressful environments (i.e. poor soils and marginal climatic conditions) demands an integrated crop/soil/pest management approach. In recognition of the vital role of the national agricultural research systems in carrying out these activities and in developing and testing improved production components, the Cassava Program has been active in seeking funds to support the national programs in South America and Asia. During 1992/1993 two projects were initiated and financed by non-core resources. These two projects are: a) an integrated soil/crop management project in Southeast Asia funded by the Sasakawa Foundation of Japan; b) an integrated pest management project in northeastern Brazil (EMBRAPA) and Africa (IITA) funded by UNDP. These projects are now fully implemented.

RECOMMENDATION #16 (4.2.5.7. CIAT and NARS//Recommendations, p.84)

" that CIAT headquarters (should) reinforce the efforts of its staff in Africa for inter-Center collaboration in training and research."

CIAT'S INITIAL RESPONSE: CIAT agrees on the importance of inter-Center cooperation, a primary feature of our regional programs, particularly in Africa. CIAT and CIMMYT have also developed joint activities more recently in Latin America. It is felt that this type of inter-Center cooperation is an effective means for reaching national programs so that training efforts avoid duplication and are fully integrated with one another. CIAT will continue to seek collaborative linkages with other international centers and regional organizations.

1994 ASSESSMENT: In Africa, CIAT has pioneered links also with IITA and ICRISAT, as each is an executing agency for the improvement of a grain legume crop in southern Africa. Joint activities center on training courses

The Bean Program has actively sought collaboration with non-bean regional networks and other IARCs in Africa, since many NARS bean researchers are also involved in cross commodity activities. Technical support to certain regional bean sub-projects is now being provided by agronomists of other Centers (CIMMYT and ICRAF) where they have specialized expertise and where they are well-placed logistically. CIAT is an active member of a task force, led byICRAF, charged with developing a regional initiative on natural resource management for the Eastern African Highlands. Within the initiative, CIAT is responsible for pest management research in intensified systems.

CIAT is in discussion with a center consortium led by IITA to establish physical infrastructure at Namalonge, Uganda , for coordinated research activities in the Eastern African Highlands.

<u>**RECOMMENDATION #17.**</u> (4.2.5.7. CIAT and NARS//Recommendations, p. 84)

"that .CIAT (should) pool its knowledge and experience with others, including ISNAR, for the training of research managers."

CIAT'S INITIAL RESPONSE: CIAT is still exploring ways of making its research management experience available to NARDS. Any specific training activity on this subject will be coordinated with ISNAR, as agreed at last year's IARC workshop "Human Resources Development through Training."

1994 ASSESSMENT: CIAT recently contributed its unique experience in the development of teams of trainers to jointly implement a training program in research management with ISNAR.

<u>**RECOMMENDATION #18:**</u> (4.5.3.Collaboration with other IARCs//Assessment, p.87)

"CIAT (should) contact with other Centers for an integrated approach on sustainability."

CIAT'S INITIAL RESPONSE: This is the approach envisioned by CIAT, particularly if the Center expands sustainability activities to the ecosystem level. The strategic plan refers specifically to the need for an interinstitutional approach to the American tropical forest ecosystem. In addition, the joint CIAT/IFPRI project "Natural Resource Management and Agricultural Development in the Humid Tropics" began a year ago and the first workshop will take place in Peru in November 1989.

1994 ASSESSMENT: A number of inter-Center activities have materialized over the last 3 years:

(a) A Central America Consortium for research in the hillsides areas was created in 1992. It involves CIMMYT, IFPRI, CATIE, IICA and CIAT.Full operationalization of the consortium research activities has been constrained by funding but a number of joint CIMMYT-CIAT research projects have been implemented.

(b) CIAT became part of the Alternatives to Slash and Burn project coordinated by ICRAF and involving IITA, IFPRI, CIFOR, World Resources Institute, IFDC, IRRI, TSBF and numerous NARDs.

(c) CIMMYT and CIAT have jointly designed and implemented research projects around maize- based agropastoral systems for the savannas of Colombia.

RECOMMENDATION #19. (5.3..3.1. Training Strategy, p. 91)

"that CIAT (should) systematize its on-going inventory of national program training needs and its schedule for filling them. This will require consultation not just with leaders in commodity research programs but with national research leaders."

CIAT'S INITIAL RESPONSE: CIAT agrees, and a specific objective to this end (was) included in the (first version of the) strategic plan.

1994 ASSESSMENT: In the training-the-trainers project, needs were assessed with national leaders. All training requests are submitted by national leaders (even though the candidates may be identified by CIAT staff).

CIAT outposted and headquarters staff in their collaboration with NARS contribute systematically to assessing training needs and in detecting training candidates with "high impact potential", that is, who are likely to substantially improve their own performance and their team' s output in response to their training.

Plans to develop an inventory of human resources in the NARS, to help select candidates, were dropped for being too demanding on resources. However, a fully functional CIAT alumni database is in place. This allows visualizing human resources development completed by country, program and institutions. And it leads to querying training requests which may seem unwarranted.

The training associates' role has changed drastically over the past 5 years and their number has been reduced from nine to three in 1992 & now one in 1994. In the past, training associates were commodity-specific subject matterspecialists, who also were responsible for the logistics of training courses at HQ and in-country. Now they are facilitators in learning programs for NARS scientists (group events and individualized programs). For this the associate has acquired a command of adult education and conferencing techniques. However, some crop-specificity of their technical capacity has been maintained for the three commodities for which CIAT has global mandate, i.e. cassava, beans, and tropical forages.

RECOMMENDATION #20 (5.4.4. Assessment//Information Services, p. 96)

"that CIAT (should) explore ways to get wider awareness and greater use of its SINFOC commodity collections and other bibliographic resources."

CIAT'S INITIAL RESPONSE: CIAT recognizes the need to improve NARDS' use of its information services. Improved mailing list software has recently been incorporated and activities to get better distribution lists from CIAT and NARDS' staff are in progress.

1994 ASSESSMENT: In the period 1989-1994, the Information and Documentation Unit has made a major investment in emerging technologies in order to promote wider awareness and greater use of its bibliographic resources, as well as to streamline operations. An automation plan was developed in late 1989 which has resulted in gradual evolution towards an electronic library and implementation of the following innovations:

- automation of the card catalogs
- full automation of the indexing/abstracting/cataloging processes including downloading from CD-ROM databases; scanning of author abstracts, generation of value-added products from databases, and use of translation software for machine translation of abstracts
- external bibliographic databases on CD-ROM
- end-user workstations for direct access to internal/external databases
- online searching of external databases
- electronic mail and access to CGNET, Bitnet, Internet and other telecommunications networks for ordering/receiving publications, searching databases, participation in discussion groups, downloading electronic files
- installation of specialized software for electronic transmission of scanned documents via Internet
- adoption of desktop publishing techniques for improved quality of information products
- full-text publishing of CIAT publications on compact disc
- publishing of CIAT bibliographic databases, including SINFOC commodity databases, on compact disc
- network access to CIAT internal bibliographic databases, external CD-ROM databases, and research support applications (e.g., Current Contents) on an information server in the CIAT-wide local area network
- development of software applications in Micro CDS/ISIS to facilitate searching of CIAT bibliographic databases.

The Unit's public service statistics for bibliographic searches, photocopies of documents, and distribution of bibliographies and technical or promotional publications increased exponentially in the period. Automation of the collections and adherence to international bibliographic standards has made it easy and feasible to share CIAT's databases with partners and clients in a variety of forms, including publications, print-outs, diskettes, CD-ROM, or as electronic file transfers. It has also made it far more efficient and effective to obtain access to resources located outside of CIAT.

RECOMMENDATION #21 (5.5.3. Assessment//Public Information, p.97)

" attention to the balance between demand for services from the publication program and resources available for it."

CIAT'S INITIAL RESPONSE: CIAT agrees. We consider the solution to be categorization and prioritization among publications rather than increasing resources.

1994 ASSESSMENT: Despite a 25% staff reduction, CIAT has at least maintained its prior level of scientific publication and increased public awareness communication by many times. This was done partly by computerization. We have also started bringing in journalism students, who do their 6-month internship working on Spanish publications, and may bring English-language interns in the future. We are identifying persons, including CIAT spouses and local expatriates, who have communication talents and teaching them the tools and skills essential for writing and editing. The Publications Advisory Committee now screen publication proposals to minimize the publication of non-essential materials.

<u>**RECOMMENDATION #22.**</u> (5.5.3. Assessment//Public Information, p. 97)

" careful analysis of policies for pricing publications and other CIAT materials to make sure they accomplish the desired distribution."

CIAT'S INITIAL RESPONSE: CIAT agrees. A recent example of careful pricing comes from one of CIAT's latest publications: traditional production would have lead to a cost of US$38.80 per unit. After careful analysis of the various cost components, a high-quality product was produced and made available for $16.00. However, it is recognized that money transfer is also an important barrier to a wider distribution in the Latin American market, where CIAT has a unique language role to play.

1994 ASSESSMENT: A Publications Advisory Committee was established in 1992. Its purpose is to screen publication proposals and set publication policy. The budget for publishing books ($21,000 in 1992) was terminated, and a Publications Revolving Fund (PRF) established. Income from sales is credited to, and publishing and promotion expenses are debited from, that budget. A pricing policy was established whereby CIAT recovers manufacture and distribution expenses from book sales in developing countries. That price is multiplied by 2.5 times for sales in developed countries. Thus, the developed-country sales subsidize distribution in developing countries. Book publishing is self-sustaining, and the PRF is healthy. There is no lack of funds for publishing future books.

<u>**RECOMMENDATION #23.**</u> (6.3.1.Organizational Structure//Decision Making, p.108)

"that top management at CIAT (should) be redefined to incorporate the third level in the hierarchy (the Program Leaders) and that a Management Committee be established, to be chaired by the Director General and to meet regularly and frequently, with an advance agenda and formal minutes recorded."
(This recommendation is the same as recommendation 2 for the EMR)

CIAT'S INITIAL RESPONSE: The CIAT Board and Management considered this issue (as well as numbers 24 and 25) as important and interrelated and initiated a thorough discussion of them. There was broad agreement with the general objectives of these recommendations but misgivings about the practicality an desirability of some specific aspects. We considered that it would be premature to make final decisions on these until the incoming DG has had the opportunity to study these matters and make this recommendations to the Board. Early action on these matters is anticipated.

1994 ASSESSMENT: the definition of top management is considered to bedependent on the context of the general organizational set-up, and the preferences and management style of the Director General. Consequently, during the tenure of Gustavo Nores as Director General, and the introduction of Resource Management Research into CIAT's mandate (with the concurrent expansion in the number of Programs from four to eight), the organization underwent a series of basic changes. The last important change was introduced as part of the implementation of the "Action Plan", which is built around a matrix approach (five Scientific Resource Groups with their respective Leaders; and six Commodity and Ecoregional Programs, also their respective Leaders). The organization plan that accompanies this matrix approach includes three standing committees, the Directors Committee, the Operations Committee, and the Scientific Resources Committee. In this context, top management is being defined as the Director General, the DDG-Research, the DDG-F&A, the Associate Director-Resource Management Research, and the Associate Director—Institutional Relations.

RECOMMENDATION #24. (6.3.2. Organizational Structure//Organizational Strategy, p.109)

"that the incoming Director General, in consultation with the Board of Trustees, (should) evaluate the current organizational structure in the light of the criteria listed by the Panels."

(This recommendation is the same as recommendation 3 for the EMR)

1994 ASSESSMENT: It is recognized that any organizational structures must adapt to developments within the organization as it adjust to the challenges in a dynamic environment. While to the EPR/EMR the organizational structure in place at the time of the Review may, at first sight, have appeared to be less than perfect, that particular structure had served a most useful purpose within the context of the organizational objectives and personalities of the Center at that time. With the series of redefinitions of objectives and work plans since the last review, concomitant adjustments in the organizational structure have taken place. The DG will continue to evaluate organizational adjustments in light of future development and—in close coordination with the Board—adjust the organizational structure to the needs of the Center.

RECOMMENDATION #25. (6.3.3. Organizational Structure...//Coordination of Research Support, p. 110)

"that (CIAT should appoint) a Coordinator of Research Support to supervise the work of CIAT' s advanced biology units as well as the other research services in the interim."

(This recommendation is the same as recommendation 4 for the EMR)

1994 ASSESSMENT: CIAT is in agreement with this recommendation. A GAS-level position was included in the budget (currently vacant). As part of the implementation of the Action Plan, the area of research services is once again under review. This review includes aspects related to organization, cost-savings, coordination, and supervision.

With the implementation of the Action Plan, the specialized research units were assigned to the newly created Scientific Resource Groups. At the same time, all aspects of the research work undertaken by these units which are related to the overall research plan of the Programs have been programmed (and are budgeted) as part of the respective projects as managed by the different Programs. We are pleased to be able to report that today, there is a very high continuity between the work of the Programs and the specialized research units.

To EMR

CIAT External Management Review (EMR)

Response Summary to Specific 1989 Recommendations and Suggestions

Recommendation #1. (2.2.b. CIAT's Legal Status...//Governance, p. 11)

"...the line between the terms of reference of the Executive Committee and the Audit and Operations Review Committee (should) be drawn more sharply."

PROGRESS REPORT: At the time that this recommendation was made, the Board Chairman and the Chairman of the Audit and Operations Review Committee were of the view that the respective TOR—as read and interpreted by the respective committee members—did not lead to confusion as to the respective responsibilities and tasks. Nevertheless, this recommendation was tagged to be taken in consideration in the course of subsequent re-phrasings of the TOR for the two committees. The issue was last considered at the meeting of the Executive Committee in July 1994, where "it was agreed that agendas must be set [for the meetings of the two committees under consideration] and the meetings managed in such a way as to ensure correct coverage of the necessary issues while avoiding duplication of efforts. The Board Chairman and Vice-Chairman would work on a paper to provide guidelines on how this should be done, taking into account the views expressed at this meeting." (Excerpt from the draft minutes.)

Recommendation #2. (3.3.1. Organizational Structure...//Decision Making, p. 22)[1]

"... top management at CIAT (should) be redefined to incorporate the third level in the hierarchy (the Program Leaders) and a Management Committee (should) be established, to be chaired by the Director General and to meet regularly and frequently, with an advance agenda and formal recorded minutes."

PROGRESS REPORT: the definition of top management is considered to be dependent on the context of the general organizational set-up, and the preferences and management style of the Director General. Consequently, during the tenure of Gustavo Nores as Director General, and the introduction of Resource Management Research into CIAT's mandate (with the concurrent expansion in the number of Programs from four to eight), the organization underwent a series of basic changes. The last important change was introduced as part of the implementation of the "Action Plan", which is built around a matrix approach (five Scientific Resource Groups with their respective Leaders; and six Commodity and Ecoregional Programs, also with their respective Leaders). The organization plan that accompanies this matrix approach includes three standing committees (the Directors Committee, the Operations Committee, and the Scientific Resources Committee. In this context, top management is being defined as the Director General, the DDG-Research, the DDG-F&A, the Associate Director-Resource Management Research, and the Associate Director—Institutional Relations.

[1]EMR recommendations #2, 3 and 4 correspond exactly with EPR recommendations #23, 24 and 25.

#2a. Related Suggestion. (3.3.1. Organizational Structure...//Decision Making, p. 20)

"The Panels believe that the principle of participatory management could be strengthened to the benefit of CIAT ... if closer communication between the second and third layers of the organization could be achieved and if there were a clearer delegation of authority to the Program Leaders."

PROGRESS REPORT: CIAT believes in the principle of participatory management and, since the last EPMR, has consistently been looking at ways and means to improve the communication at all levels of the organization. With the implementation of the Action Plan, and the concomitant move away from a strictly hierarchical organization, communication between different organizational layers have greatly improved.

#2b. Related Suggestion. (3.3.1. Organizational Structure...//Decision Making, p. 22)

"...The Panels would like to see steps taken to ensure that the Program Leaders' authority is in accord with the responsibility expected of them. While they should be held accountable for the outcome of program work and for the management of program resources, they should also be delegated concomitant authority. For example, they should:"

- **direct recruitment and selection of staff--to be sure, with adequate consultation and the right of final approval to the DG and the respective DDG;**
- **they should be their scientists' first line of contact in decisions related to work plans, sabbatical leaves, performance evaluation, and other personnel matters;**
- **they should be involved more directly in resource planning;**
- **and they should design the special projects for their programs.**

The image of authority would be effectively strengthened, in the Panel's view, if the title of Program Leader were upgraded to Director."

PROGRESS REPORT: This recommendation pertained to the particular organizational structure current at the time of the EPR/EMR in 1989. With the intervening, important changes in organization, especially the change associated with the implementation of the Action Plan, the role of Program Leaders has changed significantly. Please refer to the summary of the Action Plan in the Program & Budget document for 1994/1995.

Recommendation #3. (3.3.2. Organizational Structure...//Organizational Structure, p. 23)

"... the incoming Director General, in consultation with the Board of Trustees, (should) evaluate the current structures in the light of the criteria listed in Chapter 3 of this report."

PROGRESS REPORT: (also see responses to Recommendations under #2, above.) It is recognized that any organizational structures must adapt to developments within the organization as it adjusts to the challenges in a dynamic environment. While to the EPR/EMR the organizational structure in place at the time of the Review may, at first sight, have appeared to be less than perfect, that particular structure had served a most useful purpose within the context of the organizational objectives and personalities of the Center at that time. With the series of redefinitions of objectives and work plans since the last review, concomitant adjustments in the organizational structure have taken place. The DG will continue to evaluate organizational adjustments in light of future development and—in close coordination with the Board—adjust the organizational structure to the needs of the Center.

Recommendation #4. (3.3.3. Organizational Structure...//Coordination of Research Support Units, p. 24)

"... a Coordinator of Research support (should be appointed) to supervise the work of CIAT's advanced biology units as well as all other research services in the interim."

PROGRESS REPORT: CIAT is in agreement with this recommendation. A GAS-level position was included in the budget (currently vacant). As part of the implementation of the Action Plan, the area of research services is once again is once again under review. This review includes aspects related to organization, cost-savings, coordination, and supervision.

#4a. Related Suggestion. (3.3.3. Organizational Structure...//Coordination of Research Support Units, p. 24)

"To promote coordination (of the support units) with the more immediate problem-solving work of the programs, the Panels suggest that informal committees involving Program leaders be established with respect to (the BRU, VRU and SU ...)"

PROGRESS REPORT: With the implementation of the Action Plan, the specialized research units were assigned to the newly created Scientific Resource Groups. At the same time, all aspects of the research work undertaken by these units which are related to the overall research plan of the Programs have been programmed (and are budgeted) as part of the respective projects as managed by the different Programs. We are pleased to be able to report that today, there is a very high continuity between the work of the Programs and the specialized research units.

Suggestion #1. (3.3.5. Organizational Structure...//Management of Outposted Staff, p. 26)

"Panel perceptions "that deserve management attention" include the many particular problems facing outposted staff (particularly as regards administrative procedures)."

PROGRESS REPORT: CIAT realizes that outposted staff and outposted projects require special attention in terms of administrative and financial support. CIAT had recognized this area as deserving special attention prior to the Review and made a point of drawing the attention of the Panels to this issue in the hope that concrete solution models could be discussed with them. In the intervening period, we energetically engaged in the development of provisions that would lead to effective administrative and financial support services to outposted activities. This entailed the (1) defining the loci of responsibilities at headquarters for the provision of administrative/financial support to outposted projects; (2) setting up appropriate infrastructures within the outposted projects for the local provision of administrative services; and (3) providing appropriate training for administrative support staff and setting up policies and procedures that govern the administrative functioning of outposted projects.

Suggestion #2. (3.3.5. Organizational Structure...//Management of Outposted Staff, p. 26)

"The Panels would also consider it valuable for (outposted) staff to spend more time at headquarters before being posted elsewhere than appears to be the case presently."

PROGRESS REPORT:CIAT has always tried to arrange for outposted staff spending up to one year at headquarters during the first year of appointment. This, however, has proved to be difficult in many cases. The time required at headquarters ultimately depends on the needs of each scientist and in practice has varied from 2 to 12 months. CIAT acknowledges the need for a systematic and planned recruitment process so as to allow for more significant time spent at headquarters. This has been achieved.

Suggestion #3. (3.3.6. Organizational Structure...//Increasing NARDS Participation in Operational Planning, p. 26)

Regarding increasing NARDS participation in operational planning, "the Panels suggest that management consider inviting a few selected leaders of the appropriate commodity research programs of the relevant NARDS to take part in the APR."

PROGRESS REPORT: CIAT's Annual Program Review (APR) essentially is designed to be an internal event. Until now it has been used to review the accomplishments of Programs and Units and to question the extent to which strategies and approaches are in need of adjustment. In other words, the APR is not as much designed to provide a forum for "operational planning" as is implied in the suggestion as it is for "operational review" which—to be effective—must be organized as much as possible as an internal event in order for it to be as open and subject to mutual constructive criticism as possible. Also, since the APRs focus on all research programs (plus selected research support units), outside participation by leaders of "appropriate commodity research programs" would require the participation of quite a large group of individuals which would change the nature of the event. Nevertheless, given the fact that APRs typically focus on one selected commodity program per year (rotating in-depth reviews), CIAT has followed the EMR suggestion by inviting a very small group of collaborators from corresponding national commodity programs to participate. Such participation does indeed provide an external dimension to the review, and is quite welcome by the CIAT programs. The Center intends to keep participation by "outsiders" at the level described here.

Recommendation #5. (4.2. Planning...//Program-and Project-Based Management, p. 34)

"... (to broaden) participation in the budgeting process ... the process (should) be revised to include consultation on all aspects of the budget, including staffing patterns and costs, with those who will have the responsibility for budget implementation, down to the level of each cost center."

PROGRESS REPORT: CIAT recognizes the basic importance of involving all those with budget execution responsibilities in the budget preparation process. Unfortunately, in the 1988/89 period, uncertainties in the availability of financial resources at previously available levels was very high, and all those responsible for the different cost centers were asked to try to introduce economies to the extent possible. This environment was not conducive to innovative reviews of the budget at various levels. At the same time, CIAT recognizes that in a few program areas the respective budgets did not sufficiently consult concerning budget matters with the heads of sections. A series of steps were taken by CIAT (including the implementation of procedures that directly involve all section heads in the definition of resource needs as well as in the budget execution control process) to further sensitize all principal staff to the importance of resource planning and resource execution processes, which demonstrably led to an increased personal involvement and interest in the budgeting and budget execution process amongst principal staff.

With the implementation of the Action Plan, with its emphasis on project planning and project execution, the budgeting process now is involving one further level: the project leader/project team. The project-based system was only introduced in mid-year 1994. The project-based budgeting and budget-execution process obviously need to undergo further fine-tuning.

#5a. Related Suggestion. (4.2. Planning...//Program- and Project-Based Management, p. 34)

"We further suggest that CIAT remain flexible in its approach to program- and project-based management, depending on the nature of the specific activity, but that it seek to ensure that all program activities are strategy driven, that all programs or projects are structured to permit an evaluation of progress and costs

against objective criteria, and that program, subprogram or project leaders are held accountable for their progress and the associated cost."

PROGRESS REPORT: CIAT appreciates the import of this suggestion. It expresses an entire philosophy concerning the organization and management of the research/technology development process. CIAT closely identifies with the philosophy as expressed. In subsequent reorganization efforts—especially that as represented by the implementation of the Action Plan, CIAT has sought to further adjust its research organization, operational procedures and evaluation processes to closer approach the ideal expressed in this suggestion.

Recommendation #6 (5.2. ...Human Resources//Locally Recruited Staff, p. 37)

"... management (should) pursue vigorously the assessment of needs in the area of staff training and career development, design a more systematic set of policies to respond to the identified needs, and commit adequate resources to assure their realization."

PROGRESS REPORT: In terms of support staff training, as a result of the EMR recommendation CIAT re-structured its Human Resources Department to allow it to engage in increased activities in the areas of training needs assessment and identification of training opportunities and/or the organization of training programs. At this stage, requirements in terms of financial resources (it is estimated that at least two percent of the payroll of support staff in additional resources would be needed to provide sustained and effective training opportunities for support staff at different levels) precludes CIAT moving much faster.

In the area of career development, CIAT strongly feels that it is not the responsibility of an IARC to provide for career development for its support staff beyond (a) its own needs, and (b) providing a maximum of encouragement to pursue career development opportunities at the personal level, and to build into its personnel policies features which allow CIAT to recognize and reward individual initiatives in the development of their careers through such actions as job advancement and delegation of responsibility.

#6a. Related Suggestion. (5.2. ...Human Resources//Locally Recruited Staff, p. 37)

"... a supercategory in the research area (for highly experienced research associates) analogous to the GAS should be considered as should opportunities for such staff to attend professional meetings, occasionally travel abroad, and participate more frequently in research decision-making."

PROGRESS REPORT: The idea of a supercategory in research areas was brought to the attention of the Panel by CIAT Management because the idea had been entertained at CIAT for several years. Finally, in 1993, CIAT took the step to create the category of "Associate Scientist". Presently, four such positions exist (all filled). The experience to-date has been highly positive.

Suggestion #4 (5.3. ...Human Resources//Internationally Recruited Staff, p. 38)

"In view of the fact that there are no (senior staff) grade levels, management might wish to consider designation as 'Senior' or 'Distinguished' Scientist an occasional member of the research staff who has made extraordinary contributions to CIAT's objectives but who should not, for a variety of reasons, be moved into a managerial role."

PROGRESS REPORT: CIAT agreed—and continues to agree—with this suggestion. If and when the need or opportunity for such a move arises, CIAT will not hesitate seriously to consider this suggestion.

Recommendation #7. (5.3.2. ...Human Resources//Training, p. 40)

"... all first-line supervisors (should) be trained in financial management as is relevant to their assignments, as well as in supervisory skills."

PROGRESS REPORT: CIAT has made budgetary and organizational provisions for the creation of an internal capacity to provide training in the effective administration of financial and other resources (including, especially, human resources). However, funding uncertainties continued to retard the implementation of these provisions. Nevertheless, CIAT is committed to the process of increasing its operational efficiency through the decentralization of the decision- making process, accompanied by an enhancement of administrative/management skills by decision makers—especially at the principal staff level.

At the level of Program Leaders and Directors, an effort was made to have all participate in the CGIAR Secretariat-organized management training courses; at the level of senior scientists and higher-level support staff; a variety of workshops and internal short-term training courses were organized; CIAT also has encouraged staff members at various levels to participate in specialized training courses as offered in Cali (and, occasionally, in other cities in Colombia, and even outside of our host country). In these instances, to varying degrees CIAT participated in the financing of such participation in courses organized outside of the institution.

#7a. Related Suggestions. (7.5. General Administration//Themes and Challenges..., p. 72)

"A partnership needs to be developed between the area of administrative services and CIAT's line management, in order to both recognize the managerial functions involved in the job of section or unit leader and provide training in those managerial functions."

PROGRESS REPORT: CIAT fully concurs with this suggestion—the challenge is how to make it a reality. Since the EPR/EMR in 1989, CIAT has progressively decentralized the administrative process so as to make leaders, heads, and senior scientists full partners in the decision-making process concerning the use and deployment of human, financial and other resources. This decentralization process has particularly been stressed as part of the implementation of the Action Plan.

Recommendation #8. (5.3.3. ...Human Resources//Career Development, p. 40)

"...CIAT (should) seek or help identify funding for and recruit well-qualified Masters and Ph.D. candidates to conduct their dissertation research under the supervision of CIAT Senior Staff scientists."

PROGRESS REPORT: CIAT realizes that a considerable amount of valuable research data is available that has not been sufficiently analyzed to make it useful for incorporation in the formal research literature. To the extent that M.Sc. and Ph.D. students can be enlisted for the task of availing themselves of such data and including them in their dissertations and publications related to their dissertations, CIAT will make every attempt to follow this suggestion. However, there obviously are limits to this approach as graduate student theses are typically designed to generate information based on student-generated data sets rather than on already existing data. In recent years, CIAT has increasingly paid attention to mechanisms that allow for a more exhaustive use, and translation into formal body of knowledge, of the vast amount of data generated in the research/technology development process.

Recommendation #9. (5.3.4. ...Human Resources//Performance Planning p. 42)

"... CIAT (should) design and implement a system of individual performance planning and evaluation."

PROGRESS REPORT: CIAT recognized the need for explicit and formal performance planning and evaluation. The first step towards the realization of this goal was a commitment to this concept by Management, including the re-definition of the evaluation process of principal staff (which involves setting up personal performance plans in relation to a unit performance plan and year-end evaluations undertaken in relation to the earlier-established personal performance plans). The recent change-over from a program-orientation to a project orientation should further be conductive to individual performance planning and evaluation.

Recommendation #10. (6.3.4. Financial Management//Internal Control Policies..., p.62)

"... CIAT (should) continue to place a high priority on the development of administrative systems and procedures which will be more appropriate to the needs and circumstances of its outposted staff."

PROGRESS REPORT: An analysis of the situation that led to this recommendation showed that the relative weakness of administrative/financial provisions in outposted projects was largely a result of the historical path by which staff was posted outside of CIAT and Colombia. Specifically, outposted projects evolved along strictly technical considerations, with administrative concerns relegated to a secondary importance. Hence, with outposted staff largely devoid of administrative/financial skills and in the absence of an administrative support structure, outposted projects were indeed in an underprivileged position. Based on this analysis, CIAT restructured the organization of outposted projects based on two precepts. Firstly, for each project, a plan was drawn up for the building up of a local provision of administrative and accounting services (based largely on the recruitment and CIAT-based training of locally available administrative support staff). Secondly, the area of finance and administration at CIAT headquarters assumed primary responsibility for extending its realm of influence and supervision to the administrative/financial operations of outposted projects. This proved to be a major undertaking whose full implementation was not completed until 1993. Since then, the resulting successes in terms of administrative efficiency and accountability have been remarkable.

Recommendation #11. (6.1.3. Financial Management//Liquidity and Cash Management, p. 54)

"...CIAT (should) pursue a policy of maintaining its working capital fund at a level equal to 30 days of expenditures and it (should) pursue, with the CGIAR and other centers, the development of innovative funding mechanisms so as to improve its long-term financial stability."

PROGRESS REPORT: Despite great financial uncertainties that set in only two years after the EPR/EMR, the Center managed significantly to improve its position with regard to working capital. By 1994, fund balances kept in liquid form had increased to a level equal to 90 days of expenditures. Concerning the "development of innovative funding mechanisms", CIAT pursued a series of avenues, including the creation of an endowment, debt-swap mechanisms, donations from private business and philanthropists, and income from patents and services. Several of these initiatives were undertaken with the participation of the CGIAR system. While these efforts did not result in actual new funding mechanisms, yet other mechanisms are being explored by CIAT, including the creation of a regional fund for agricultural research. Notwithstanding all these efforts, probably the most important mechanisms for funding—and those that continue to deserve most of our attention—are the protection of existing flows of donor contributions, and the adjustment of our program to take advantage of greatly increased availability of funds for sustainability/environment in the post-UNCED era.

Recommendation #12 (6.1.5. Financial Management//Debt Swap Proposal, p. 20)

"... the CGIAR Secretariat and the centers (should) jointly agree on a set of system-wide policies which would guide the centers' debt swap operations."

PROGRESS REPORT: This recommendation was specific to the debt swap plans and activities underway in 1989. Subsequently, very considerable additional effort was placed in this undertaking, unfortunately though without success. At this stage, debt swap opportunities have lost all appeal and no longer constitute a promising avenue for funding.

Suggestion #5. (6.3.5. Financial Management//Cash and Investment Management, p. 62)

"We are impressed with the proactive approach taken toward the management of financial resources ... at the same time, we urge caution ... CIAT ... must be prepared to fully protect the Center's financial management in the case of apparently adverse results ... These risks must be closely monitored by the A&ORC of the Board."

PROGRESS REPORT: CIAT is in full agreement with this suggestion. On the one hand, it is the responsibility of the Center to obtain reasonably attractive returns on the investment of surplus cash and to protect its inflow of monies from adverse shifts in the exchange rate market; on the other hand, all financial decisions must be made within the context of avoiding undue risks. To this end, CIAT has a Board-approved investment/money management policy whose application by Management is continuously monitored by the Board. Since the time of the EMR/EPR in 1989, CIAT's investment management activities have generated rather large returns and proved to be a major factor in alleviating the very severe financial constraints in the years 1992, 1993, and 1994.

7 September 1994

Major Bean Program Events at CIAT Headquarters (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	XVI Bean Production Course	6 Feb - 17 Mar	CIAT	22	Colombia, Peru, Nicaragua, Ecuador, Venez., Guat., Honduras, Paraguay
	Workshop on the Bean Program Strategic Plan	24-29 April	CIAT	35	USA, Africa, Colombia
	International Conference on Snap Beans in the Developing World	16-20 Oct	CIAT	54	19 countries
	OFR-Bean Production System Course	8 weeks	CIAT	14	Latin America
	Small Farmer Seed Production	14 weeks	CIAT	6	Latin America
	CIAT Intensive Review of Bean Program	Dec	CIAT		BOT, outside reviewers, BP
1990	Primer Curso para Especialistas en Mejoramiento de Fríjol	22 January- 9 March	CIAT	18	Colombia, Mexico, Ecuador, Guat., Peru, C. Rica, Chile, Hond., Nic., Rep. Dom.
	Workshop on the Advanced Phaseolus Beans Research Network (BARN)	11-14 Sept	CIAT	88	19 countries
	PPO Workshop	30 July-2 Aug	CIAT	36	Bean Program, NARS
1991	Curso Multidisciplinario Intensivo sobre Investigación de Fríjol	04 Feb - 15 March	CIAT	15	Mexico, Honduras, El Salvador, Nicaragua, C. Rica, Panama
	Course "The role of socio-economics in Commodity Research programs"	16 Sept - 11 Oct	CIAT		Latin America
	International Bean Trials Conference	21-25 Oct	CIAT	82	19 countries
1992	CIAT Intensive Review of Bean Program	Dec	CIAT		BOT, outside reviewers, BP
1993	Workshop on the Advanced Phaseolus Bean Research Network (BARN)	7-10 Sept	CIAT	97	16 countries

Major Events in PROFRIJOL (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	Small Farmer Seed Production Courses	14-16 Aug	Honduras	17	Phase II
		1-7 Oct	Panama	24	
	OFR Course	6-16 Mar	Peru	21	
		15-19 May	Nicaragua	17	Phase II
		10-19 July	Honduras	26	Phase II
		7-11 Aug	Nicaragua	27	Phase III
	PPO Workshop (Phase 1)	30 May-2 June	La Habana, Cuba	15	Panama, C. Rica, Honduras, Guatemala, El Salvador, Cuba, Dom. Republic
	PPO Workshop (Phase 2)	12-16 July	S. José, C. Rica	16	Panama, C. Rica, Honduras, Guatemala, El Salvador, Cuba, Dom. Republic
	Regional OFR Course (CIAT-CIMMYT)	25-29 Sep	C.Rica	22	Phase I from 7 countries
		20 Nov - 1 Dec		22	Phase II
1990	Producción no convencional de semilla	22-26 Enero	Caisan, Panama	22	Panama
	Taller de Formación de Capacitadores en Maíz y Fríjol para América Latina	19-23 Febrero	C. Rica	23	Central America
	Investigación en Fincas	23-28 April	Danli Honduras	11	Honduras
	Investigación en Fincas	7-11 May	Managua Nicaragua	18	Nicaragua
	Meeting on Socio-Economic Network	30 May-1 June	Costa Rica	10	Economists Central America
	PPO Workshop, Socio-economics network for research on basic grain in Central America	13-15 July	El Salvador		Central America
	Producción de fríjol para extensionistas	23 July - 3 August	Danli, Honduras	24	
	Investigación en fríjol	24-29 Sept	Zacatecas, Mexico	35	Mexico

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
	Reunión Anual PROFRIJOL y Asamblea	Marzo	Guatemala	22	Central America and Caribbean
1991	Foundation meeting of socio-economics network for research on basic grains in Central America	24-26 Jan	San José, Costa Rica	12	Central America and Caribbean
	Reunión Anual y Asamblea PROFRIJOL	14-16 March	Panama	26	Central America and Caribbean
	Formación de Capacitadores	8-13 April	Nicaragua	21	Central America and Caribbean
	Taller Nacional Producción Artesanal Semilla	10-12 Julio 26-31 August 18-21 Sept	Panama Estelí Honduras	26 26	
1993	Reunión Anual PROFRIJOL y Asamblea	25-28 Marzo	Guatemala		Central America and Caribbean
	Taller Internacional sobre Mustia Hilachosa del Fríjol	22-26 Nov	Panama	18	Central America and Caribbean
1994	Taller Internacional sobre el Picudo de la Vaina	19-21 Enero	Danlí, Honduras	14	Guatemala, El Salvador, Hond., Mexico

Major Events in PROFRIZA (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	Evaluation, Selection and Management of Rhizobium Symbiosis in Beans (PROFRIZA)	July	Lima		Professors and lab technicians
	Small Farmer Seed Production Courses	21-27 Enero	Ecuador	14	Fase II
		7-12 Mayo	Peru	15	Fase III
		14-19 Agosto	Ecuador	14	Fase III
		2-10 Oct	Ecuador	19	
		20-25 Nov	Paraguay	21	
1990	Promoción y Producción de semillas de nuevas variedades de fríjol con participación de agricultores	14-20 Enero	Cuenca, Ecuador	16	Fase II
	Promoción y Producción de semillas de nuevas variedades de fríjol con participación de agricultores	29 June-7 July	Chincha, Peru	14	Fase I
	PPO Workshop	2-6 Abril	Bolivia		Representantes de 18 organizaciones
	Taller Regional con Mejoradores y Fiopatólogos		Ecuador		Bolivia, Ecuador, Perú, Colombia, CIAT
	Primera Reunión de Leguminosas de Grano de la Zona Andina (RELEZA I)	7-9 Mayo	Quito Ecuador	85	Bolivia, Colombia, Ecuador, Perú, Venezuela, Chile, USA, CIAT, PROFRIZA, COTESU, CIID
	Promoción y Producción de Semillas		Ecuador	21	5 Agrónomos, 16 Agricultores
			Loja	20	13 Técnicos, 7 Agricultores
			Chincha	24	14 Técnicos, 10 Agricultores
1991	Segunda Reunión de Leguminosas de Grano de la Zona Andina (RELEZA II)	24-29 Junio	Colombia	100	Colombia, Ecuador, Peru, Bolivia
1992	Curso sobre Investigación Participativa	8 Jun - 10 Jul	Colombia	7	Ecuador, Peru, Bolivia, Colombia
	Tercera Reunión de Leguminosas de Grano de la Zona Andina (RELEZA III)	17-20 Junio	Bolivia		
1993	PPO Workshop	19-23 Abril	Quito		Andean countries

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
	Cuarta Reunión de Leguminosas de Grano de la Zona Andina (RELEZA IV)	22-25 Junio	Peru	66	Andean countries
1989	Research and Production Course in Brazil	9-21 April	Brazil	17	Brazil
1990	Adoption Studies in Brazil Workshop	27-29 May 18-22 Nov	Vicosa, Brazil		Economists

Major Bean Program Events in Pan-Africa (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	CIMMYT/CIAT Regional Workshop on Research Methods for Cereal/Legume Intercropping	23-27 January	Lilongwe, Malawi	67	Angola, Botswana, Burundi, Ethiopia, Kenya, Malawi, Mauritius, Mozambique, Rwanda, Tanzania, Zambia, Zimbabwe
	Workshop on Bean Improvement in Africa: Varietal Improvement	30 Jan - 2 Feb	Maseru, Lesotho	34	Burundi, Rwanda, Zaire, Ethiopia, Uganda, Angola, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia, Zimbabwe, Mauritius, Sudan
	Grain Legume Training Course	March (three weeks)	Maputo, Mozambique	27	Research Assistants
	Pan-Africa Working Group Meeting on Entomology	7-9 August	Nairobi, Kenya		Entomologists
1990	Virus Working Group Meeting (Pan-African Meeting)	17-21 January	Kampala, Uganda	15	Virologists, breeder/pathologists from Kenya, Tanzania, Uganda, Cameroun, Nigeria, The Netherlands, Colombia, UK, USA, West Germany
	Bean Aphid and BCMV Training Workshop	23-25 January	Lilongwe, Malawi	22	Malawi, Tanzania, Zambia
	Soil Fertility and Cropping Systems Research Working Group Meeting	12-14 Feb	Nairobi, Kenya	16	Burundi, Ethiopia, Kenya, Malawi, Tanzania, Rwanda, Uganda, Zaire, Zimbabwe
	First Graduate Training Course in Cropping Systems with Beans	14 May - 5 June	Arusha, Tanzania	22	Burundi, Ethiopia, Kenya, Malawi, Mozambique, Swaziland, Tanzania, Uganda, Zambia

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1991	Farmer Participatory Research Course	13-22 May	Arusha Tanzania	19	Kenya, Madagascar, Malawi, Mozambique, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe
1992	Bean Bruchid Research Travelling Workshop	16 Sept - 3 Oct	Various		Covered southern Uganda, northern Tanzania, northern Zimbabwe
	Pan-African Working Group Meeting on Drought Research in Beans	27-30 April	Ethiopia	13	Participants from five countries
	Pan-African Working Group Meeting on Fungal Diseases	30 May - 2 June	Thika Kenya	4	Uganda, Ethiopia, Kenya
1993	Farmer Participatory Methods for Soil Fertility Research	26 April - 7 May	Bukoba, Tanzania	9	Ethiopia, Kenya, Madagascar, Tanzania, Uganda, Zaire
	Pan-Africa Working Group on Bean Entomology (2nd meeting)	20-22 Sept	Harare, Zimbabwe	8	Tanzania, Kenya, Mauritius, Sudan, Uganda
1994	Pan-Africa Multidisciplinary Bean Research Methods Course	April-May	Kenya	31	Ethiopia, Kenya, Uganda, Malawi, Tanzania, Madagascar, Zaire
	Pan-Africa ANSES Meeting	May	Kampala Uganda	12	Uganda, Tanzania, Kenya, Malawi, Madagascar, Rwanda, Zaire, Sudan
	Pan-Africa Working Group Meeting of Bacterial and Viral Diseases	June	Kampala Uganda		

Major Bean Program Events in RESAPAC (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	Great Lakes Regional Project Review and PPO Workshop	4-9 March	Kifugi, Rwanda	Bean Program Leaders from NARs	
	Workshop on participatory approaches to evaluate multilocation trials in Rwanda	16-18 May	Rwanda	24	Great Lakes Region
	Great Lakes Regional Workshop on variety release, production and distribution of bean seed	2-4 November	Goma, Zaire	30	Rwanda, Burundi, Zaire
	National Seminar of Planning of On-Farm Research	6-11 November	Rubona, Rwanda	25	Organized jointly by ISAR, GTZ, USAID, CIMMYT and CIAT
	Fifth Great Lakes Regional Seminar for Bean Improvement	13-18 November	Bujumbura, Burundi	25	Bean researchers from Rwanda, Burundi, Zaire
1990	National Seminar on Production and Distribution of Bean Seed	8-9 February	Ngozi, Burundi	32	Researchers and Technicians
	Workshop on Farmer Participatory Research	20 March- 3-5 April	Bukavu Zaire	50	Farmers
	National Seminar on Analysis of On-Farm trials	14-19 May	Ruhengeri Rwanda	26	A follow event to the one in November, 1989, jointly organized by ISAR, GTZ, USAID, CIMMYT, CIP and CIAT
1991	Breeding Strategies Workshop	17-20 January	Kigali, Rwanda		Breeders, pathologists, agronomists, CIAT, Breeders from Estern Africa
	Sixth Great Lakes Regional Seminar for Bean Improvement	21-25 January	Kigali, Rwanda		Bean researchers from development projects
	Workshop on Farmer Participatory Research	21-29 August	Butare, Rwanda	22	10 bean researchers 12 scientists

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1992	Great Lakes Regional Project Review and PPO Workshop	April	Rwanda	24	Rwanda, Burundi, Zaire
1993	Climbing Bean Research and Development	14-17 June	Rwanda	5	Kenya, Madagascar, Tanzania

Major Bean Program Events in EABRN (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	Agricultural Economics/FSR Training Workshop	24-25 Jan	Holetta, Ethiopia	13	Research Stations
	Agronomy and Soils Training Workshop	20-25 Feb	Holetta, Ethiopia	49	Agronomists/Soil scientists
	On-Farm Trials Management for Extension Staff	15-16 Feb	Kachwekano Uganda	10	Extension workers and researchers
	Regional Course in Weed Management	20-30 March	Uganda	25	Graduate Agronomists and technician Uganda, Kenya, Ethiopia, Tanzania
	Bean Research Training Methods Course for Technicians	30 October 10 November	Uganda	26	Technicians from Uganda and Somalia
	National FSR Program Review/Orientation Workshop	12-17 November	Uganda	52	sponsored by CIAT, MFAD/USAID and CIMMYT
1990	Economics Training Workshop	22-26 January	Holetta, Ethiopia	19	Economists
	Second Regional Workshop on Bean Research in Eastern Africa	5-8 March	Nairobi, Kenya	53	Kenya, Mauritius, Tanzania, Sudan, Somalia, Ethiopia, Uganda and CIAT
	Farmer Participation in Research Training Course	3-10 May	Nazret, Ethiopia	21	Economists and Agronomists from Research Stations
	Bean Research Methods Training Course	5-16 November	Thika, Kenya	26	East Africa
1991	IAR/CIMMYT/CIAT Economic Analysis and FPR Training Workshop	22-24 January	Ethiopia	17	Economists

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
	Working Group Meeting on Bean Anthracnose	18-21 February	Ambo, Ethiopia	7	Pathologists Rwanda, Uganda, Tanzania, Kenya
	Training Workshop on Cropping Systems Research Methodologies	11-15 March	Ethiopia	20	Agronomists
	Crop Management Research Training	March-August	Kenya	6	Agronomists from Kenya, Uganda, Mozambique, Malawi, Tanzania
	National Horticultural Research Programme Review Workshop	5-10 May	Thika, Kenya	66	63 scientists, 3 farmers
1992	Ethiopia National Review Workshop on Socioeconomics Research	January	Ethiopia	20	Graduate economists from IAR
	Ethiopian Workshop on Participatory On-Farm Research for Extension Staff	15-20 Feb	Ethiopia		For NGOs and government extension staff
	Training of Trainers for Agricultural Research	24-29 Feb	Ethiopia	21	
	Working Group Meeting on Soil Fertility Research for the Maize/Bean Cropping System of the Eastern African Highlands	1-4 Sept	Thika Kenya		Agronomists and soil scientists from Ethiopia, Kenya, Tanzania, Uganda
	Statistics and MStat Regional Training Course	8-18 Sept	Kenya	6	Kenya, Uganda
1993	Multidisciplinary Workshop on Bean Research in Eastern Africa	April	Thika Kenya	43	Kenya, Uganda, Tanzania, Ethiopia, Sudan, Mauritius, Madagascar
1994	Eastern Africa Breeders Workshop	June	Kampala Uganda		Kenya, Uganda, Ethiopia, Tanzania, Rwanda

Major Bean Program Events in SADCC (1989-1994)

Year	Name of Event	Date	Place	Number of participants and/or countries and/or disciplines	
1989	First SADCC/CIAT Regional Bean Research Workshop	4-7 Oct	Mbabane, Swaziland	45	from the 9 countries of the SADCC Region
	SADCC Bean Research Methods Training Course for Research Assistants	20-31 August	Malawi	19	Malawi, Zambia, Zimbabwe
	Ninth SUA/CRSP and Second SADCC/CIAT Regional Bean Research Workshop	17-22 Sept	Morogoro Tanzania	76	66 from Africa (10 countries) 10 from USA
1991	SADCC/CIAT Phase II Planning Workshop	6-8 March	Mangochi, Malawi	17	Tanzania, Malawi, Zambia, Zimbabwe, Lesotho, Swaziland
	SADCC On-farm Bean Research Methods Training Course	3-14 June	Lyamungu, Tanzania	29	For field assistants

Biotechnology Research Unit
List of the most important planning conferences, internal reviews and expert meetins: 1990 - 1994

	Title	Date, Place	Participants
1.	Planning for a Bean Advanced Biotechnology Research Network (BARN)	Sep. 1990, CIAT, Colombia	50 scientists from USA, Europe, Latin America and Africa
2.	Biosafety meeting for preparing CIAT guidelines	June, 1990, CIAT, Colombia	CIAT scientists from different programs and units
3.	Experts meeting on cassava post-harvest deterioration	Dec. 1991, Rome, Italy	Scientists from FAO, CIAT, IITA, CAMBIA and NRI
4.	First Scientific meeting of the Cassava Biotechnology Network	Aug. 1992, Cartagena, Colombia	128 scientists from 29 countries
5.	In depth review of the Biotechnology Research Unit, 1988-1992	Dec. 1992, CIAT, Colombia	Dr. G. Persley, from the World Bank as external reviewer with Drs. M. Wolfe, and R. Flavell from the CIAT Board of Trustees
6.	Expert meeting on International Rice Blast Effort	April 28-29, 1993 Santa Roca, Colombia	Scientists from CIAT, IRRI, Purdue Univ., Cornell Univ., DUPONT Co.
7.	First International BARN workshop	Sep. 1993, CIAT, Colombia	100 scientists from 16 countries
8.	Latin American Workshop on Anther Culture for Rice Breeding	Feb. 1994, CIAT, Colombia	18 scientist from 9 Latin American countries
9.	Andean region biosafety meeting organized with IICA, USDA, CORPOICA, and Dutch Goverment	June, 1994, Cartagena	30 scientists from 5 andean countries, USA, Holland, Colombia, and other Latin American countries
10.	Progress review of the Biotechnology Research Unit by CIAT BOT members	July, 1994, CIAT	Drs. R. Flavell and M. Wolf
11.	Second Scientific meeting of the Cassava Biotechnology Network	Aug. 1994, Bogor, Indonesia	150 scientists from 28 countries

Major planning conferences, internal reviews, expert meetings, etc. Cassava Program. Period 1989-1994

I. Program

1. Event: Internal program meetings to formulate the Cassava Program strategy for incorporation into CIAT's Strategic Plan

   Date: Sept. - Dec., 1990 Venue: CIAT, Cali
   Participants: CIAT cassava researchers
   Output: CIAT in the 1990s and Beyond: A Strategic Plan. CIAT. April 1991.

2. Event: Internal program meetings to formulate the Cassava Program Operational Plan 1992-1996

   Date: Jan. - Mar., 1991 Venue: CIAT, Cali
   Participants: CIAT cassava researchers
   Output: Program Plans and Resource Requirements 1992-1996. CIAT. May 1991.

3. Event: IITA-CIAT meeting on cassava research

   Date: 29-31 October, 1991 Venue: IITA, Ibadan
   Participants: IITA and CIAT cassava researchers
   Product: Internal report

4. Event: Cassava Program intensive 5yr review

   Date: 30 Nov. - 6 Dec., 1991 Venue: CIAT, Cali
   Participants: CIAT scientists and Management, Dr. Don Plucknett and members of the Program Committee of the Board of Trustees
   Product: CIAT Cassava Program 1987-1991. CIAT. October 1992.

5. Event: Internal program meetings to formulate the Cassava Program Operational Plan 1993-1998

   Date: Jan.-Mar., 1992 Venue: CIAT, Cali
   Participants: CIAT cassava researchers
   Product: Program Plans and Resource Requirements 1993-1998. CIAT. May 1992.

3. Event: Workshop on Food Policy and Agricultural Technology to Improve Diet Quality and Nutrition

Date: 10-14 Jan., 1994 Venue: Annapolis, U.S.A.
Participants: Cassava researchers from CIAT, CIMMYT, IRRI, AVDRC, IFPRI, USAID and other U.S. labs.
Product: Project proposal: Exploring the genetic potential for improving iron, zinc, iodine and vitamin A content of cassava.

4. Event: International Workshop on Cassava Safety

Date: 1-4 Mar., 1994 Venue: IITA, Ibadan
Participants: Researchers from IITA, CIAT, National Programs in Africa, Asia and Latin America and advanced labs in Europe and the USA.
Product: Recommendations for future research on cyanogenesis in cassava.

III. Project Area: Gene pool development

1. Event: Meetings with Brazilian researchers for the formulation and subsequent annual planning and evaluation of the special project "Cassava Germplasm Development for the Drier Tropics and Subtropics of Africa, Asia and Latin America"

Dates: Formulation: Jan.-June, 1990 Venue: CIAT, Cali and Brazil
Yearly planning and evaluation:
1 week, Aug/Sept. 1991-1994 Venue: Brazil
Mid-project evaluation:
1-2 June, 1993 Venue: CIAT, Cali
Participants: Researchers and extensionists from Brazilian National and State organizations and CIAT Cassava Program scientists
Product: Project proposal and yearly reports

2. Event: Second meeting of Panamerican Cassava Breeders

Date: May, 1990 Venue: CNPMF, Cruz das Almas, Brazil
Participants: National Program Breeders and CIAT cassava scientists
Product: Proceedings: Documento de Trabajo No.112. CIAT, 1992

3. Event: Joint CIAT-IITA planning meeting on germplasm development

Date: 30 Aug. - 1 Sept., 1992 Venue: CIAT, Cali
Participants: CIAT and IITA cassava scientists

Product: Internal report

4. Event: Third Meeting of Panamerican Cassava Breeders

Date: 4-8 Oct., 1993 Venue: INIVIT, Villa Clara, Cuba
Participants: National Program breeders and CIAT cassava scientists
Product: Publication: Interfase entre los Programas de Mejoramiento, los Campos de los Agricultores y los Mercados de la Yuca en Latinoamérica. Documento de Trabajo No. 138. CIAT. 1994.

Note: For meetings of Asian cassava breeders see VI. Institutional Development

IV. Project Area: Integrated crop management

1. Event: Meetings to formulate, plan and evaluate the special project "Ecologically Sustainable Cassava Plant Protection in South America and Africa"

Dates: Formulation: May, 1991 Venue: CIAT, Cali
Planning: 15-30 April, 1993 Venue: CNPMF, Cruz das Almas, Brazil
Planning and evaluation: 29 Aug. - 2 Sept., 1994 Venue: CNPMF, Cruz das Almas, Brazil
Participants: Scientists from CIAT, IITA and CNPMF/EMBRAPA, and external evaluators (for the 29 Aug. - 2 Sept., 1994 evaluation meeting) Also Brazilian State extension personnel
Output: Project proposal document and annual reports and work plans

2. Event: Meetings to formulate, plan and evaluate the special project "Soil Conservation in Smallholder Hillside Farming on the Andean Inceptisols through Cassava-Forage Legume Intercropping"

Dates: Evaluation: 24-31 May, 1992 Venue: CIAT, Cali
Evaluation: 4-14 June, 1992 Venue: CIAT, Cali
Formulation: June-Aug., 1992 Venue: CIAT, Cali
Participants: Scientists from CIAT, the University of Hohenheim, and Colombian collaborating institutions, and external evaluators (for the 1992 evaluation meetings)
Output: Project proposal document (second phase) and annual and final reports of activities (first phase)

3. Event: Meetings to formulate and plan the special project "Improving Agricultural Sustainability in Asia: Integrated Crop-Soil Management for Cassava-Based Production Systems"

Dates: Formulation: 15-17 June, 1992 Venue: Kuala Lumpur, Malaysia
Planning: 25-29 July, 1994 Venue: Rayong, Thailand
Participants: CIAT and Asian national program scientists and extension personnel
Output: Project proposal and internal planning document

4. Event: Integrating the management of pests, diseases and weeds of cassava in Africa

Date: 27 June - 1 July, 1994 Venue: Kampala, Uganda
Participants: Pest and disease management specialists from international, regional and national programs
Output: Proceedings and action plan (in preparation)

V. Project Area: Market development

1. Event: Workshops to present and obtain feedback on the manual "Product Development for Root and Tuber Crops"

Dates: 6-13 April, 1991 Venue: ICTA, Guatemala
22 April - 1 May, 1991 Venue: PRCRTC, Philippines
28 Oct. - 1 Nov., 1992 Venue: IITA, Ibadan
Participants: National program, CIAT, CIP and IITA scientists
Product: Product Development for Root and Tuber Crops, Vol.I - Asia, Vol. II - America Latina, Vol. III - Africa
Product Development for Root and Tuber Crops - a Manual (in edition)

2. Event: Expert consultation on roots, tubers, plantains and bananas in animal feeding, organized by FAO

Date: 21-25 Jan., 1991 Venue: CIAT, Cali
Participants: Specialists in processing and the use of root, tubers, bananas and plantains in animal feed, FAO, CIP and CIAT scientists
Product: Report and recommendations

3. Event: Meetings to formulate, plan and evaluate the special project "Adding value to the Products and Byproducts of Small- and Medium-Scale Cassava Processing Industries in Latin America"

Dates: Formulation: Sep.-Oct., 1991 Venue: CIAT, Cali
Evaluation: 17-18 Jan., 1994 Venue: CIAT, Cali

Participants: Collaborators from CIRAD, ORSTOM, University of Valle, State University of Sao Paulo, University of Buenos Aires

Product: Project proposal and annual research report

4. Event: Meetings to formulate and evaluate the special project "Production and Marketing of Cassava Flour in Colombia"

Dates: Formulation:
3rd phase: Oct.-Dec., 1990 Venue: CIAT, Cali
Evaluation: Every September Venue: CIAT, Cali

Participants: Collaborating partners from FUNDIAGRO, DRI and CIAT scientists

Product: Project proposal and annual research reports

5. Event: International Meeting of Cassava Flour and Starch (joint CIAT-CIRAD organization)

Date: 11-14 Jan., 1994 Venue: CIAT, Cali

Participants: Researchers, private sector personnel from Latin America, Africa and Asia

Product: Proceedings (in edition)

VI. Project Area: Institutional development

1. Event: Participation in planning and evaluation of national cassava research programs

Dates: Paraguay 1989, 1990 Venue: Asunción, Paraguay
Ecuador 1989, 1992, 1994 Venue: Portoviejo, Ecuador
Colombia 1989, 1990, 1991, 1992 Venue: Montería, Colombia
Brazil 1993 Venue: Cruz das Almas, Brazil

Participants: National program research managers and scientists

Product: National cassava research plans

2. Event: Meetings of the members of the Cassava Biotechnology Network

Dates: (a) Scientific meetings
1st: 24-28 Aug., 1992 — Venue: Cartagena, Colombia
2nd: 23-26 Aug., 1994 — Venue: Bogor, Indonesia
(b) Steering Committee
Yearly, 1992, 1993, 1994 — Venue: Various

Participants: Researchers from advanced labs and national program scientists, CIAT and IITA cassava scientists

Product: Proceedings CBN I, Proceedings CBN II (in edition)
Annual project work plans

3. Event: Meetings of the Southern Cone Cassava Development Network

Dates: Formulation:
15-16 Oct., 1990 — Venue: Asunción, Paraguay
29-30 May., 1991 — Venue: Santa Cruz do Sul, Brazil
Executive Committee:
24-25 April, 1992 — Venue: Asunción, Paraguay
9-10 Feb., 1993 — Venue: Curitiba, Brazil

Participants: National program researchers and extension personnel from S. Brazil, N. Argentina and Paraguay

Product: Joint projects between regional cassava research and development institutions

4. Event: Meetings the Asian Cassava Research Network

Dates: Workshops
3rd: 22-27 Oct., 1990 — Venue: Malang, Indonesia
4th: 1-5 Nov., 1993 — Venue: Trivandrum, India

Advisory Committee Meetings
15-17 June, 1992 — Venue: Kuala Lumpur, Malaysia
24 Aug., 1994 — Venue: Bogor, Indonesia

Participants: National program researchers and CIAT scientists

Products: Proceedings 3rd workshop: Cassava Breeding, Agronomy and Utilization Research in Asia
Proceedings 4th workshop: Cassava Breeding, Agronomy and Technology Transfer in Asia (in edition)

5. Event: Participation in Asian national cassava research workshops

Dates:	China 19-24 Oct., 1992	Venue: Hainan, China
	Vietnam 29 Oct. - 1 Nov., 1992	Venue: Hanoi, Vietnam

Participants: National program research managers and scientists, CIAT regional and HQ scientists

Product: Workshop proceedings (in edition)

6. Event: Meetings of the Integrated Projects Network (Latin America)

Dates:	17 Sept. - 4 Oct., 1990	Venue: Cali, Colombia
	22-26 July, 1991	Venue: Portoviejo, Ecuador
	28 Sept. - 2 Oct., 1992	Venue: Fortaleza, Brasil
	10 Jan., 1994	Venue: CIAT, Cali

Participants: Researchers and extensional personnel involved in integrated cassava projects from Colombia, Brazil, Ecuador, Bolivia, Argentina, Paraguay

Product: Trained national program personnel and initial proposals for a project to extend the integrated project concept to Africa.

Genetic Diversity Area

Genetic Resources Unit

2. List of reports of major planning conferences, internal reviews, expert meetings

A. General Overview or Policy Matters

1991 Annual Report Genetic Resources Unit. In Depth Review 1987-1991. December 1991. 110 pages.

1991 Assessment of the Genetic Resources Unit. December 1991. Henry Shands, Consultant. Final Report to the CIAT Board of Trustees Program Committee. 9 pages

1994 Stripe Study of Genetic Resources in the CGIAR. TAC Secretariat Food and Agriculture Organization of the United Nations (FAO). March 1994.

1994 Conservation of Genetic Resources: CIAT's Role In Germplasm Research. Document prepared by the Genetic Diversity Scientific Resource Group. CIAT, July 1994.

B. Beans Germplasm

1993 International Workshop of the *Phaseolus* Beans Advanced Research Network (BARN). September 7-10, 1993. Cali, Colombia.

C. Cassava Germplasm

1992 First International Workshop on Cassava Genetic Resources. CIAT, Cali, August. 1992.

1992 First International Scientific Meeting of the Cassava Biotechnology Network. Cartagena, Colombia. 1992.

D. Tropical Forages Germplasm

1994 Second Meeting of the Working Group on Tropical and Sub-tropical Forage Genetic Resources at CIAT, Cali, Colombia. April, 1994.

List of Meetings and Consultation - Hillsides Program

1. "Agricultura sostenible en las laderas Centro Americanas. Oportunidades de colaboración interinstitucional. Coronado, San José, Costa Rica 13-16 Agosto, 1991. Participants (approx. 90) were regional, national, NGO and IAR's active in agricultural research and rural development in Central America.

2. Taller de consulta para investiación en las Laderas de América Central, Managua, Nicaragua 27-28 Agosto 1993. Participants (approx. 22) from NARs, NGO's, regional and IARCs, with emphasis on Honduras and Nicaragua.

3. Meeting of the steering committee called the Consultative Group (GG) for the Central American Hillsides Project (CAHP). La Lima, Cortés, Honduras, May 18-20, 1994.

4. Taller Interinstitucional sobre Agricultura Sostenible en Laderas, November 1992, CIAT, Palmira. Participants (50) from NGO's, NARs, NRM agencies and community organisations with active programs in Río Ovejas watershed, Cauca, Colombia.

5. Informe del Taller de Planificación "Programa de Desarrollo Sostenible en Laderas" (Proladeras). CIAT, Palmira, Marzo 15-19, 1993.

6. Workshop on Land Quality Indicators for the Lowland, Savannas and Hillsides of Tropical America. CIAT, Palmira, June 6-10, 1994.

7. Planning workshop for CIAT-CONDESAN special project in Ecuador 2-6 April, 1994, Quito, Ecuador. Participants (20) prepared a special project document for joint project in a highland-mid-altitude hillsides watershed.

LAND MANAGEMENT SRG

Meetings with major influence on the direction of the LM SRG

1. Workshop on Land Quality Indicators, jointly organized by CIAT (LM) and the World Bank, June 6-10, 1994. External participants included experts from the World Bank, CIMMYT, IBSRAM, IICA/GTZ, FAO, AGRI-CANADA, IFPRI and USDA-Soil Conservation Service.

   It led to the reinforcing of the interest on indicators work at the LM SRG (who contributed a paper jointly with CIMMYT) and to the preparation of three project proposals to the World Bank.

2. Participation in the International Workshop on Agroecosystem Health, Ottawa, June 19, 1994. It led to discussion regarding cooperation between CIAT and the University of Guelph to open a new line of research on tropical agroecosystem health at CIAT.

3. International Workshop on the neotropical savannas of South America - Organized by CIAT, with the participation of representatives of NARDS, governmental and non governmental organizations dealing with agriculture or the environment from Bolivia, Brazil, Colombia and Venezuela, and from two research institutes at Wageningen (Holland). CIAT, 25-29 July, 1994. It led to the joint development of an important proposal for the Dutch cooperation.

4. UNEP & IUFRO International Workshop in cooperation with FAO. (On developing Large Environmental Data Bases for Sustainable Development; Nairobi, 14-16 July, 1993). The meetings in Norway and Nairobi strengthened cooperative links with UNEP/GRID, FAO and CIAT and led to a wider network of data exchange with other agencies. This placed CIAT as one of the lead centers in environmental databases and GIS.

5. CGIAR/UNEP/GRID Workshop on GIS data for the CGIAR center (Oslo-Arendal, Norway, 21-25 September, 1992.

6. Workshop on Agro-ecological Characterization, classification and mapping. (Rome, 14-18 April, 1986). This workshop subsequent intercenter working groups indicated CIAT's decision to develop comprehensive environmental databases and mapping techniques. They laid the basis for fruitful intercenter exchange of data and methodologies.

RESOURCE MANAGEMENT EVENTS

Title	Date	Participants	
EXPERT CONSULTATION			
"The future Agriculture Development in context Tropical America, implications for CIAT's Strategy".	3-4 Sept. 1990 - CIAT	27	Argentina, Brazil, Colombia, Costa Rica, Chile, Italy, United Kingdom, USA, Uruguay.
"Dialogo sobre la futura colaboración entre los ONGs y los Centros Internacionales de America Latina y el Caribe".	13-16 April 1992 - CIAT	25	Brazil, Bolivia, Canada, Colombia, Chile, Mexico, Peru, IBPGR, CIMMYT, CIAT
"Donor Consultation meeting on CIAT strategy for Resource Management Research"	4-5 February 1993 - Washington	11	UNDP, FORD Foundatio USAID, World Bank, IDB, IDRC, WRI.

Listado de Reuniones de Planeación donde se han sacado conclusiones con respecto al Programa de Arroz

Fecha	Lugar	Documento	Instituciones Participantes
2-7 enero 1989	Chile	Informe de Viaje R.S.Zeigler	INIA CIAT
8-11 feb. 1989	Guatemala	Informe de Viaje C.P. Martínez	ICTA CIAT
18-26 feb. 1989	Cuba	Informe de Viaje C.P. Martínez	IIA CIAT
8-14 abril 1989	Chile	Informe de Viaje C.P. Martínez	INIA CIAT
9-14 abril 1989	Brasil	Informe de Viaje R.S.Zeigler	IRAT-IRRI IRRI EMBRAPA-CNPAF CIAT
10-21 abril 1989	Brasil Perú	Informe de Viaje F. Cuevas-Pérez	CNPAF/IRRI INIAA CIAT
24-26 abril 1989	Ivory Coast	Informe de Viaje R.S.Zeigler	IRRI WARDA CIAT
4-11 junio 1989	Cuba	Informe de Viaje C.P. Martínez, A. Pantoja	IIA CIAT
17-22 julio 1989	U. S. A.	Informe de Viaje L. R. Sanint	USA CIAT
4-6 oct. 1989	India	Informe de Viaje F. Cuevas-Pérez	IRRI CIAT
8-10 nov. 1989	Rep. Dominicana	Informe de Viaje F. Cuevas-Pérez R. S. Zeigler	CRIN CIAT
18-24 enero 1990	Brasil	Informe de Viaje E. P. Guimaraes	CENPAF CENARGEN CIAT
2-13 feb. 1990	Brasil	Informe de Viaje R. S. Zeigler	EMBRAPA/CNPAF IRAT CIAT
11-17 marzo 1990	Uruguay	Informe de Viaje F. Cuevas-Pérez	Programa Nacional CIAT

Fecha	Lugar	Documento	Instituciones Participantes
16-18 marzo 1990	Uruguay	Informe de Viaje R. S. Zeigler	Programa Nacional CIAT
6-12 mayo 1990	Perú	Informe de Viaje E. P. Guimaraes	INIAA CIAT
14 agosto 1990	CIAT	Memorando Informativo G.A. Nores	FEDEARROZ CIAT
4-19 enero 1991	IRRI	Informe de Viaje R.S.Zeigler	Filipinas Indonesia Singapur
7-11 enero 1991	IRRI	Minutas Informe Viaje R. S. Zeigler	CIAT WARDA IRRI
21-22 mayo 1991	Villavicencio		ICA CIAT FEDEARROZ
24-30 agosto 1991	Villavicencio CIAT	Minutas	CIAT WARDA IRRI
8 marzo 1991	C.I. La Libertad	Acta	Fedearroz ICA CIAT
14 abril 1992	Villavicencio		ICA CIAT FEDEARROZ
17-25 abril 1992	IRRI		CIAT (CMR) IRRI Purdue
5-10 sept 1992	CIRAD		CIAT (CMR) CIRAD
10 oct. 1992	CIAT		FEDEARROZ ICA
9-12 nov. 1992	IRRI	Informe Viaje M.D. Winslow	IRRI
29 nov- 7 dic. 1992	Brasil	Informe Viaje M.D. Winslow C.P. Martínez E.P. Guimaraes	TAC CPATB/EMBRAPA IRGA CNPAF CIAT
Sep.93	Montpellier, Francia	International Upland Rice Breeding Workshop Memorias	CIAT, IRRI, CIRAD-CA, EMBRAPA-CNPAF, ICA, WARDA, Asian NARDS

Fecha	Lugar	Documento	Instituciones Participantes
9-10 nov. 1993	Villavicencio, Colombia	Acta de Intención	ICA CIAT FEDEARROZ
13 dic 1993	CIAT	Memorando Informativo	ICA CIAT FEDEARROZ
14-25 feb 1994	CIAT	First Workshop "Anther Culture for Rice Breeding" Memorando y Manual	CIAT, Argentina, Brazil, Colombia, Chile, Uruguay Guatemala, Panamá, Venezuela. Sponsored by Rockefeller Foundation
25 feb 1994	CIAT	Memorando Informativo	CORPOICA ICA CIAT
25 mayo 1994	CIAT	Final Report on Needs Assessment F. Cuevas-Pérez	Several NARS
25 abril 1994	Caracas, Venezuela	Informe de Viaje F. Cuevas-Pérez	Colombia Venezuela
1 junio 1994	Bali, Indonesia	Informe de Viaje C.P.Martínez F. Correa	7th Meeting FR Int. Rice Biotec. Program
31 marzo 1994	Goiania, Brasil	Informe de Viaje	INGER-LAC Meeting

WORKSHOPS (TROPICAL FORAGES PROGRAM)

1989-1994

Title	Venue	Dates	No. of Participants		Reports
Contribución de las pasturas mejoradas a la producción animal en el trópico. Seminario Internacional	CIAT	April 89			Working Doc No. 80
Strategic Plan - Tropical Pastures	CIAT	10-04-89 12-04-89	16	(3CIAT)	
Tropical Pastures Program - Consultation Meeting	Philippines, SE Asia	11-05-89 12-05-89	6	(1 CIAT)	Working Doc 81
Taller Desarrollo del Suministro de Semillas de Especies Forrajeras Tropicales	Atenas, Costa Rica	05-02-90 10-02-90	26	(3 CIAT)	Working Doc 77
Meeting on development of livestock-pasture production sustainable systems for acid soil savannahs in Tropical America	CIAT	14-06-90 15-06-90	12	(5 CIAT)	
Meeting of the Advisory Committee of the International Tropical Pastures Evaluation Network (RIEPT) on "On farm-pasture research"	CIAT	27-08-90 29-08-90	49	(19 CIAT)	Working Doc 124
Workshop on Nutrient Recycling in Pastures	CIAT	10-09-90 15-09-90	25	(17 CIAT)	
First Meeting of the RIEPT Amazonia	Lima, Peru	06-11-90 09-11-90	61	(11 CIAT)	Working Doc 75 (2 vols)
Internal Seminar on Biotechnology for the Tropical Pastures Program	CIAT	28-01-91 01-02-91	20	(20 CIAT)	
Avances en el desarrollo del suministro de semillas de especies forrajeras tropicales	Atenas, Costa Rica	29-04-91 03-05-91	21	(1 CIAT)	Working Doc 98
Meeting of the Advisory Committee of the International Tropical Pastures Evaluation Network - RIEPT	CIAT	21-10-91 23-10-91	11	(7 CIAT)	Minutes
Internal Program Review (1987-1991)	CIAT	December 1991	30	(25 CIAT)	Reports
Avances en los programas de suministros de semillas de especies forrajeras en Centro America	Comayagua, Honduras	02-03-92 07-03-92	12	(4)	Working Doc 122
Workshop of the Advisory Council of the International Tropical Pastures Evaluation Network, RIEPT, on "Expanding the availability of seeds of tropical forages species for both research and development"	Villavicencio Colombia	18-11-92 20-11-92	35	(10 CIAT)	Published book
Meeting of the Advisory Committee of the International Tropical Pastures Evaluation Network - RIEPT	Villavicencio Colombia	20-11-92	15	(3 CIAT)	Minutes
First Meeting of the RIEPT - Savannas	Brasilia, Brazil	23-11-92 26-11-92	73	(13 CIAT)	Working Doc 117
Internal review Tropical Forages Program	CIAT	December 1992	12	(12 CIAT)	No report

Title	Venue	Dates	No. of Participants		Reports
Regional meeting of Forage Seeds Project	Rockhampton, Australia	21-02-93 22-02-93	12	(4 CIAT)	Report
International workshop - The Biology and agronomy of forage *Arachis*	CIAT	25-05-93 28-05-93	28	(15 CIAT)	Published book
Taller evaluación de gramíneas y leguminosas en fincas: Diseño y ensayos y producción de semillas	Costa Rica & Panamá	06-06-93 17-06-93	17		Working Doc 133
Regional meeting of Forage Seeds Project	Los Baños, Philippines	04-10-93 08-10-93	15	(3 CIAT)	Report
Internal review Tropical Forages Program	CIAT	December 1993	12	(12 CIAT)	No report
Second meeting of the working group on tropical and subtropical forage genetic resources	CIAT	06-04-94 08-04-94	12	(4 CIAT)	Report
Internal Review Tropical Forages Program	CIAT	28-09-94 29-09-94	15		To develop
International workshop: Biology, agronomy and improvement of *Brachiaria*	CIAT	03-10-94 07-10-94	27	(16 CIAT)	To develop
Regional meeting of Forage Seeds Projects	Indonesia	24-10-94 28-10-94	18	(2 CIAT)	To develop

9 September 1994 (Workshop.lis)

TROPICAL LOWLANDS PROGRAM

LIST OF MAJOR CONFERENCES, REVIEWS ETC.

Date	Event
Sept. 10-15, 1990	Workshop on nutrient cycling in pastures. Eight international consultants invited to prepare critique of the proposed "core" experiment at Carimagua.
July 15, 1990	"Sondeo sobre viabilidad y limitaciones al uso de arroz y pasturas asociadas en los Llanos Orientales de Colombia: piedemonte y altillanura".
Jan. 15, 1991	Project Proposal "Agropastoral Systems for the Savannas of South America" submitted to Deutsch Bank. Would serve later as basis for IFDC-CIAT project and others.
Feb. 22, 1991	"Improved Technologies for Latin America's new Economic Reality: rice-pasture systems for the acid savannas" in Trends in CIAT Commodities, 1990. Working Document No. 74.
March 6, 1991	Savannas Working Group assembled.
April 3, 1991	First meeting of the Savanna Working Group.
April 26, 1994	Second meeting of the Savanna Working Group.
May 1, 1991	Rapid Rural Appraisal covers: (1) R. Verde, Goiás, cooperative COMIGO; (2) Diamantina, Sorriso, Lucas de R. Verde, MT; (3) Riberao Preto, SP; (4) Chapadao dos Gauchos, MS; (5) Triangulo Mineiro, MG.
May 10, 1991	Third meeting of the Savanna Working Group.
June 14, 1991	Initial contact of CIAT with ISPN (Instituto Sociedade, Populaçāo, Natureza).
Nov. 20, 1991 Brazil.	Trip report by P. Jones re land use information available in
Dec. 15, 1991	Publication in Trends in CIAT Commodities (1992) of "The Savannas of South America: Towards a Research Agenda for CIAT" by L.R. Sanint, C.O. Seré, L. Rivas and A. Ramírez.
Jan. 15, 1992	RRA report by L.R. Sanint, C. Sere, L. Rivas and A. Ramirez: "The Savannas of South America: towards a research agenda for CIAT". RRA done over the period 1990-91.

Date	Event
Jan. 20, 1992	Visit to CIAT by C. Müller and H. Torres, Instituto Sociedade, Populaçâo E Natureza.
Feb. 11, 1992	Field visit to EMGOPA, CNPAF, Faz. Barreirao, Morrinhos (John Landers, AGRIPLAN), Caldas Novas, Marzagao, Araguari, Uberlândia, Faz. Sta. Terezinha, R. Verde (COMIGO), Goiania, Nerepolis, Anapolis.
Feb. 15, 1992	"Settlement and Agriculture in Brazil's Forest Margins and Savannah Agrosystems"" written by C. Müller, H. Torres and G. Martine, Instituto Sociedade, Populaçâo e Natureza, Brasilia.
March 10, 1992	M. Ayarza and collaborators from CPAC begin diagnostic study in the farm of Fernando, Uberlândia.
June 16, 1992	Field visit with BID réviewers (Alfredo Lopes, Abilio Pacheco) to CNPAF, Guapo, Faz. Bandeira, Est. Experimental de Zootecnia, EMGOPA, CPAC.
June 21, 1992	Field visit with BID reviewers (A. Lopes and Luis Arango) to Villavicencio, Pto. López, Matazul, La Libertad.
July 15, 1992	"Area classification and mapping for the Cerrados region of Brazil" is produced by P. Jones, M. Rincón, L.A. Clavijo, J. Macedo, and B. Pinheiro. Distributed to various Centers of EMBRAPA.
Aug. 18-21, 1992	First Agropastoral Workshop for Acid Savanna Soils. Villavicencio, Colombia. Financed by IDB. 25 participants from 10 institutions in Brazil, Colombia, and Venezuela. It was agreed to include common parameters in agropastoral research in the different countries in order to compatibilize comparisons across different countries for both pastures establishment and recuperation with crops.
Aug. 24, 1992	Workshop in Brasilia "Pesquisa em Sistemas Mistos Sustentaveis nos Cerrados".
Sept. 11, 1992	First meeting of the Savanna Program. Subjects discussed: (1) Workshop at Villavicencio of August 1992; (2) Workshop of Brasilia, August 1992; (3) possible workshop in Brazil, March 1993.
Sept. 14, 1992	Second meeting of the Savanna Program. Continued to discuss research strategies. Gave examples of what has been proposed for Uberlândia.

Date	Event
Sept. 17, 1992	Third meeting of the Savannas Program.
Nov. 25, 1992	Libardo Rivas pasa 2 semanas en CPAC, inicialmente para participar en sondeos que luego se postergan. Participa reunión Centros y analiza información secundario con Geraldo.
Feb. 12, 1993	Rapid Rural Appraisal of Uberlândia.
	March 15-19, 1993 Second Agropastoral Workshop for Acid Savanna Soils. Goiânia/Uberlandia/Brasilia, Brazil. Financed by IDB. 23 participants from 11 institutions in Brazil, Colombia, and Venezuela.
	Agreed on need for CIAT to carry long term strategic research on agropastoral systems, and lead the creation of an Agropastoral Systems Network together with PROCITROPICOS.
March 17, 1993	Workshop in Brazil, attended by Brazilians, Venezuela, Guyana, Suriname, Colombia.
March 20, 1993	Meeting of the Savannas Program in Brazil with M. Ayarza.
March 28, 1993	RRA of Campo Grande.
April 23, 1993	Project of the Universidad Nacional, Bogotá. Depto. de Biologia. "Aspectos Poblacionales de Fauna Mayor en los Llanos Orientales (Centro Nacional de Investigación Agropecuaria [CNIA], Carimagua, Meta, Colombia" by Prof. Miguel Angel Mejía.
June 1, 1993	Report of four RRA in Brazil by Ayarza.
Aug. 16-20, 1993	Workshop on integrated management of soil and plant resources of sustainable production on acid soils.
	The inauguration of the MAS (Management of acid soils) Consortium.
Oct., 1993	Planning meeting of Slash and Burn, Pto. Velho. RV, JIS, SF, MThung participated. ICRAF, EMBRAPA, CIAT, WRI, TSBF.
December 1993	Transfer of technologies for improved agro-pastoral production systems for savanna ecologies of S. America United Nations Development Program/FAO/CIAT/NARS. Project Development.
March 21-25, 1994	IX International Rice Conference for Latin America and the Caribbean, and V National Rice Research Meeting. Goiânia, Brazil.
March 23, 1994	Slash and Burn Global Steering Group meeting. Yaounde, Cameroon.
March 28, 1994	Steering Committee of MAS.

Date	Event
April 5-7, 1994	Workshop on Physical Aspects of the Soils from the Eastern Savannas of Venezuela. FONAIAP, El Tigre, Venezuela.
April 9, 1994	Curso Internacional Ecología de Sabanas: importancia, manejo, conservación.
June 6-10, 1994	Workshop on land quality indicators for the low-land savannas and hillsides of tropical America World Bank - sponsored workshop. 21 consultants (12 international experts including World Bank staff).
July 5-6, 1994	PROCITROPICOS meeting to finalize project on "Regeneration and sustainable management of degraded soils in savannas".
July 28, 1994	Meeting ICA-FENALCE-CIMMYT-CIAT to agree in a common strategy of research in agropastoral systems with the inclusion of the acid soil tolerant maize crop.
Sept. 19-23, 1994	Third Agropastoral Workshop for Acid Savanna Soils. Barinas, Venezuela. Financed by IDB. Agreed to unify the agropastoral activities on savanna soils of the region under a PROCITROPICOS-FAO-CIAT umbrella.