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NATURAL RESOURCE MANAGEMENT RESEARCH AT CIAT

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INTRODUCTION

The cornerstone of CIAT's *Strategic Plan for the 1990's and Beyond* was the integration of its longstanding programs for rice, bean, cassava and forage germplasm development with a major research effort on resource management. This was based on the expectation that the Green Revolution paradigm which has shaped the CGIAR's research agenda for almost three decades, needed to give way to new technology design strategies based on ecological performance criteria in an agroecosystem context (CIAT, 1991). This is an approach now widely subscribed to and recommended at the highest levels of the CGIAR (System Review Panel Report, 1998).

This paper provides an overview of natural resource management research at CIAT in the period 1996-9, since the reorganization of the Center's entire research program into projects. The paper is intended to be read in conjunction with the log frame or research plan for CIAT's natural resource management research provided in Figure 1, and refers to research carried out in both research directorates. Detailed descriptions of the projects and their progress reports can be obtained elsewhere (CIAT's Mid-term Plan 1998-2000). The paper can be read as a technical complement to the description of the places and people benefiting from CIAT's natural resource management research provided for the general and donor audience by the publication *Weaving Threads into Cloth* (CIAT, 1996). It is intended to provide a framework in which readers can understand both cross-project research linkages and the more detailed CIAT project log frames and research reports. The paper is therefore, divided in sections which correspond to the different elements of the log frame, and which address the following questions:

- *What is the justification for the research and its expected impact?* A brief introduction to the history of natural resource management research at CIAT, and its strategic priorities for the decade 1991-2000 is provided by way of background. Next CIAT's vision and goal for natural resource management research, which refer to the expected development impact of the research are discussed; followed by the research purpose which refers to the expected future use of the research outputs.

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- *What are the essential conditions for success of the research plan?* This section corresponds to the important assumptions in the log frame.
- *Who are the stakeholders or clients for the research?* Impact depends on use of the research outputs or products by stakeholders. In addition, one of CIAT's guiding principles is "doing research together" with stakeholders who are research partners. A brief definition is given of the stakeholders referred to throughout the log frame.
- *What are the research outputs or products?* Each output is summarized in the log frame and described in the paper with examples.
- *How are the research outputs produced?* This question is addressed in the sections on research strategy and organization. While not explicitly described in the log frame, these cover essential features of the research process and the project structure at CIAT.
- *How is progress of the research towards achieving its expected impact assessed?* Impact assessment for natural resource management research at CIAT is briefly described.

WHAT IS THE JUSTIFICATION FOR THE RESEARCH AND ITS EXPECTED IMPACT?

A short history of natural resource management research at CIAT

CIAT's mission statement was reformulated in 1991 to include "preserving the natural resource base" as one of the guiding principles of the Center. Improving agricultural productivity and natural resource management are inseparable and essential components of successfully achieving food security and agricultural sustainability, in turn the basis of human welfare which is CIAT's fundamental concern (CIAT Strategic Plan, 1991).

CIAT was founded over 40 years ago as an agricultural research institute for the neo-tropical lowlands (along with IITA in West Africa) and--in contradistinction to the commodity Centers IRRI and CIMMYT founded earlier--to take a systems approach to agricultural development for a particular resource base in a specific region. It was

later that the commodity focus emerged, with early impact in rice research followed by beans, cassava and forages. In the late 1980s a major study was initiated to identify the priority agroecosystems in which CIAT might successfully have impact from an area-based or ecoregional approach. This analysis factored in the probabilities of success for CIAT's commodities, in particular forages. Hotly debated at the time because of the exclusion of the semi-arid agroecosystem notably in Meso-America and north-east Brazil where most of Latin America's rural poor live, three agroecosystems were spatially defined as priorities for a new research agenda (Jones et al 1991).

In 1992-3 three programs were established for the Savannas, Hillsides and Forest Margins and a fourth on Land Use. It was expected that these four programs would grow steadily over the 1990's from 2% of CIAT's core funded budget to 42% in 2001 fuelled by growth in the funding base to support 30 core funded scientists. However, over 1989-1996 there was a real decline in funding at CIAT. This led to the absorption of the Forest Margins Program (which had never been operational) by the Topical Lowlands Program. A semi-formalized matrix of competency groups (called scientific resource groups) and Programs was introduced to spread scientific capacity across the remaining four commodity programs and two agroecosystem programs. The Land Use Program was then transmuted into a scientific resource group (CIAT, 1995).

In 1996 CIAT adopted project-based management of its research program, the organization it has today. Sixteen projects were formed and all programs were closed. The projects were organized according to the CGIAR activity areas: saving biodiversity (projects SB1 and SB2); improving productivity (projects IP1 to IP5, including beans in Latin America and beans in Africa, cassava, rice and forages); protecting the environment (projects PE1-PE5, including IPM, soils, sustainable systems, hillsides, land use); and strengthening national programs (projects BP1, SN1 to SN3, including impact assessment training, small scale industry, and participatory research). Reflecting the need for intense cross-project teamwork across two clusters of projects related to germplasm improvement, and natural resource management, two research directorates were established in 1996 with a commitment to implement a center-wide integrated natural resource management research approach.

In 1997-8 a vision statement and log frame for natural resource management research were developed in a year-long process of team work by the natural resource management project managers and

research director, in conjunction with the development of log frames for CIAT as a whole, for germplasm improvement and for the individual projects (CIAT's Mid-term Plan 1999-2001).

Strategic priorities for CIAT's natural resource management research 1991-2000

A priority for CIAT's natural resource management research is the intensification of production in fragile, high-stress environments characterized by sustainable seasonal water deficits and major soil constraints, in particular acidity and degradation. We address the problems of these environments both through resource management research and germplasm improvement. Protecting these environments is closely linked to improvements both in rural livelihoods linked to high value markets and crops, and in policies which affect land management (CIAT's Medium Term Plan 1998-2000).

Three priority agroecosystems were selected for CIAT's natural resource management research by a major study (Jones et al 1991): forest margins, savannas and hillsides (Figure 2). The selection was based on the expected magnitude of the natural resource management impact (Pachico et. al 1997), and the likelihood of CIAT being able to make most progress towards the goals of equity, growth and sustainability of the resource base (CIAT Working Document 144, 1994). All three are characterized by low fertility soils, often acidic with deficiencies of P, Ca, Mg and other nutrients; fragile ecologies with valuable biodiversity under increasing pressure from agriculture; and the potential for direct or indirect effects on poverty alleviation through agricultural productivity increases.

Priority problems, constraints and opportunities were identified for each agroecosystem and are summarized here (for more detail see CIAT, 1995a):

- *Savannas Agroecosystem*

A fragile and precious natural resource rich in flora and fauna, the savannas of tropical America extend over 250 million hectares located in Brazil, Colombia, Venezuela and Bolivia, an area which is also perceived as the last agricultural frontier and a huge potential "bread basket" for meeting world food needs in the 21st century through its production of livestock, rice and soybeans. While three-quarters of the savannas are still in native vegetation, human settlement is leading to

rapid resource degradation as these grasslands are exploited for extensive cattle grazing. About 35 million hectares are sown to introduced grasses on large farms with low-input, land extensive management, and about 60 percent of this area is overgrazed and degraded. In areas with access to urban markets, farm size is declining and agriculture is intensifying, including perishable vegetables and intensive dairying. As land is cleared for cropping rice or soybeans in fallow rotation systems, agricultural expansion is producing problems of soil erosion, soil chemical and physical degradation, pest build-up in monocropped areas, siltation and contamination of major rivers including high levels of organo-chlorides and organo-phosphates, destruction of the gallery forests and loss of bio-diversity.

Important opportunities for research impact in the savannas include the introduction of improved land management options combining sustainable agro-pastoral systems with soil conservation practices. More intensive dairying and production of perishables in the peri-urban areas are also targets for the introduction of conservation practices. Introduced grass-pastures act as a net sink for atmospheric carbon, sequestering huge amounts of this element below ground. Enhancing and marketing this environmental service could be an incentive for adoption of environmentally sound land management. Good information and sound planning to target the adoption of improved land management is vital in the savannas to avoid the destructive effects of unfettered agricultural expansion. Decision support to individual farmers and local entities responsible for land management is an important research opportunity.

- *Forest Margins Agroecosystem*

Rapid frontier expansion has been a major problem in the forest margins agroecosystem since the 1960's, as forests are replaced with slash and burn agriculture combined with extensive cattle grazing. Defined as land within 30 kilometers of a navigable waterway or permanent road, there are about 44 million hectares of forest margins in tropical South America. The contribution of tropical forest clearance to biodiversity loss and global warming has been amply discussed elsewhere.

The opportunities for research impact in the forest margins are primarily for policy-oriented research of two kinds. First, analysis of the dynamics of land clearance and the intensification of land use, together with modeling to assess different scenarios for the

stabilization of slash and burn agriculture, can provide decision support to planning and promoting sound land management options. Second, policy-oriented, participatory experimentation with prototype sustainable agro-pastoral systems can provide a model for the type of process needed to achieve the development and adoption of improved land management.

- *Hillsides Agroecosystem*

Over half the land in the mid-altitude (between 500-3000 meters elevation) hillsides of Central America and the Andes is experiencing rapid degradation. Of the total area of approximately 96 million hectares, 53 million are already affected by deforestation, overgrazing and destructive farming practices. The hillsides are an important food producing agroecosystem supplying 40-60 percent of food, especially perishable goods, in some regions. The hillsides support over 150 million people, of whom about 25 million are rural, and most of whom earn incomes from small farm production, farm laboring and off-farm employment in rural areas and small towns, and who live in conditions of severe poverty. Also dependent on the hillsides and negatively affected by the serious environmental degradation of this agroecosystem, are sizeable downstream urban populations and lowland irrigated agriculture, both of which draw water and energy from hillside watersheds. Throughout the Andean region a major portion of hydroelectric power is generated in the hillsides and these reservoirs suffer rapid degradation as they silt up from upstream soil erosion. Lowland flooding, agrochemical pollution, coastal estuary siltation, and biodiversity loss are all external or "off-site" effects of hillside degradation.

Opportunities for research impact in the hillsides are associated with the need for more sustainable livelihood strategies for small farmers, the semi-landed and laboring poor via the introduction of income generating opportunities which reduce poverty and provide an incentive to invest in sustainable land management. This requires decision support to collective planning of resource management because so many of the potential resource management interventions in the hillsides involve multiple stakeholders with competing uses for the same resource, not only on-site but off-site as well. New land management options must generate high value products, increase returns to labor on farm and have strong forward linkages to post-harvest employment in agroindustrial activities.

Vision

CIAT's vision is to contribute with other partners to the development of ecologically healthy and economically productive landscapes in the hillsides, forest margins and savannas of tropical America. Here the farm families, communities and policy makers whose decisions affect these landscapes are involved in participatory land use planning which enables them to use their natural resources for developing "paths out of poverty"... for more intensive, efficient and competitive farming, related agro-industrial enterprises, and the provision of environmental services (the protection of biodiversity land, air and water) that provide an incentive for sustainable land management.

Goal

The goal of CIAT's NRM research is to contribute to the generation and use of environmentally sound and economically viable options for improved land management and productivity increase by stakeholders.

Purpose

The purpose of CIAT's natural resource management research is to develop both germplasm-based technology that can improve low management and productivity and information-based technology together with the key tools, skills and organizational models that make possible the use of this technology; and to promote their application by stakeholders.

WHAT ARE THE ESSENTIAL CONDITIONS FOR SUCCESS OF THE RESEARCH PLAN?

The impact of CIAT's NRM research depends critically on effective long-term partnerships. Donors must be willing to invest overseas development aid (the source of CIAT's 'core' funds) in CIAT's NRM research over 10-15 years to obtain the full impact of a stream of improved germplasm, production system components, databases, GIS tools and capacity building which are important international public goods targeted to low-income client groups, and which complement what other public and private sector suppliers provide. For this impact to be achieved, national policy-making cannot be pejorative to improving land management or to participatory land use planning involving decision-support, and should be open to new ways of doing this. Our approach assumes that governments in low-income countries and regions of Latin America will continue their current commitment to

devolution of land use planning and land management to local bodies, whether private or public sector, and will continue to need advanced technology and capacity building for this purpose.

WHO ARE THE STAKEHOLDERS OR CLIENTS FOR THE RESEARCH?

Stakeholders in CIAT's NRM research include clients who are direct users of the research outputs, or who are indirect users or beneficiaries; and partners who are involved in doing research with CIAT.

Three types of decision-makers about natural resource management are direct users of CIAT's research products or outputs:

- community-based (including individual farmers)
- local government
- national or international

Direct users include international, regional and national agricultural (NARS) and environmental (NERS) research and capacity-building organizations, including international NGOs and the statistics and census departments of national planning bodies who generate and use agricultural and environmental information. Direct users at the local scale are individuals and groups, including farmers, as well as municipal and community-based natural resource management organizations (CBOs).

The impact of natural resource management research occurs across scales in hierarchical systems, whether across plots, slopes, catchments, river basins and coastal ecosystems; or across the genetic level within species, among species in a plant community and across plant communities in an ecosystem. Understanding cross-scale effects is therefore, fundamental to making effective interventions to improve resource management, whether these are technical, managerial or policy interventions. The clients for CIAT's research as well as the types of research outputs, and the impact these outputs are expected to achieve are therefore defined in relation to different scales, as illustrated in Figure 3.

CIAT's research outputs are developed primarily in and for stakeholders in the hillsides, forest margins and savannas agroecosystems of Tropical Latin America. There is a global demand for some of the research outputs, in particular the decision support

tools and research methodologies which are not specific to Latin America or can be readily adapted for use in Asia and Africa.

The CIAT vision focuses on poverty alleviation and protecting the natural resource base on which sustainable agriculture and the livelihoods of the rural poor depend. Poor rural farmers are therefore, an important group of beneficiaries but not the only ones. A significant and growing proportion of rural income in low-income countries in Latin America and Asia depends on activities other than farming, and includes for example post-harvest processing and rural agroindustry (Renkow, 1999). Rural livelihoods in developing countries are beginning to benefit from the demand for environmental services such as decreased agrochemical pollution, forest protection, improved water quality, and watershed management. This points to the importance of a broad definition of indirect beneficiaries of natural resource management research to include those involved in "value added" activities in rural area, and those " off-site " including urban users of environmental services provided by sustainable agriculture.

Partners in CIAT's NRM research include international advanced research and teaching institutes with environmental or agricultural mandates, national and international geographical research organizations, and private sector suppliers of information technology (both hardware and software). In the area-based or reference site research there are numerous NARS, NERS, NGO and CBO partnerships.

WHAT ARE THE RESEARCH OUTPUTS OR PRODUCTS?

CIAT's natural resource management research outputs are the following:

- improved land management options
- decision support tools
- indicators of sustainability
- natural resource management information and technology components
- organizational models
- improved capacity for resource management research

CIAT's most important natural resource management research products are public goods of global relevance. Examples are:

- decision-support tools such as the *Flora Map* and *Indicators of Rural Sustainability*
- germplasm adapted to low P soils
- participatory research methods and organizational models such as *the CIAL methodology*
- information organized in strategic GIS databases such as *The Honduras Atlas(1998)*

DESCRIPTION OF RESEARCH OUTPUTS

Improved Land Management Options

CIAT's contribution to natural resource management in Tropical America focuses on improving land management by integrating stakeholder-based land use planning and assessment with the use of sustainable, intensifying production systems which help to protect and conserve the natural resource base-- land, water, air, and biodiversity.

Environmentally sound and economically viable improvements in land management are achieved at a multi-farm or landscape scale. Improvement in land management at a landscape means that:

- areas of a landscape at risk must be defined and protected
- the trade-offs among different uses for any given area of a landscape must be assessed
- multiple goals need to be incorporated into the definition of "improved" land management, in particular productivity gains & conservation.

Improving land management therefore involves collective decision-making and action by multiple stakeholders who need to understand and respond to both on-farm and off-farm effects of changes in management.

Research cannot prescribe a cure for poor land management. However, research can provide stakeholders with land management options; and more importantly, research can help stakeholders to design their own locally suitable land use options.

Research can also help stakeholders to choose those options that will improve productivity and help to conserve the natural resource base. Sustainable improvements in land management require options to be accompanied by the decision-support tools and information

stakeholders need to understand tradeoffs, monitor the outcomes of changes and adapt the resultant land management over time.

Improved land management options as a research output are produced as a synthesis of research drawn from across the whole center such as :

- GIS and modelling of resource dynamic
- Rural agro enterprise options for new production systems
- Agro-silvo-pastoral system experiments
- Improved germplasm
- Soil improvement

The main mechanism for a synthesis of research results drawn from across the center are the systems experiments conducted in ecoregional reference sites, (the "Interprogram", "Culticore" and "SOL-Supermarket of Technological Options"-- experiments coordinated by CIAT Projects PE2 and PE3). These landscape-scale agro-silvo-pastoral experiments involve long-term strategic research on combinations of technology, principally germplasm and soil management related technologies. The principal objective is to intensify and stabilize production and to improve the efficiency of resources flows in the landscape. Improved land management options are sought which can be dynamic and responsive to changing biotic and abiotic stress, technology, markets and policy environments.

Experimentation with land use options incorporating combinations of technologies provides data for bioeconomic modeling and GIS-linked scenario analysis. Extrapolation of land use options developed in ecoregional reference sites is a key strategic research issue addressed by the development of methods and GIS tools for site similarity analysis (PE2, PE3, PE4, and PE5 annual reports).

The systems experiments use results from research on component technology, such as soil improvement strategies (linked to the SWNM Program) IPM system components, CIAT's commodity research in beans, cassava, rice and forages, partners research on livestock, fruits and vegetables. In practical terms, component technology is linked to systems experiments through "satellite" experimentation at the same sites. Component technology research is also conducted in large-scale projects as in the case of forages in Central America and Asia (annual reports of IP5, FSP, PE5, and Tropileche).

Research generating improved land management options through systems research uses results from agro-enterprise development, in particular market opportunity identification methodology development and training with partners, which supplies options for introducing new high value species into systems. These are potentially important in the search for highly productive but ecologically sound systems. An important working hypothesis of CIAT's research for improving land management is that the development of small-scale rural agroenterprises will provide income and incentives for the adoption of ecologically sound land management and protective use of the landscape. Rural agroenterprise research is designed to support species diversification in sustainable production systems at the landscape scale, by identifying opportunities for organized groups of small farms to specialize in high value products which promote conservation farming.

The development of land use options with a high probability of being adopted requires early involvement of farmers in the research. CIAT's research on developing methodologies for farmer participation includes participatory monitoring and evaluation of the systems experiments and of farmers' adaptations of elements from these, to provide feedback for the design of new land management options.

CIAT's research uses geographic information systems and land use modeling to understand and monitor changes in land use together with its effects on the environment and poverty at continental, national and landscape scales of analysis. Research on the dynamics of natural resource management including the analysis of off-site effects at different hierarchical scales (including the catchment scale), is carried out through long-term studies on changes in soil and water quality and biodiversity under different management systems in the forest margins, hillsides and savannas. GIS models and databases are used for appraising land management options including innovations in sustainable production systems and land use policy alternatives which are too large and complex for an experimental approach, and for monitoring their effects.

- *Decision Support Tools*

CIAT's Natural Resource Management research is developing a wide range of decision support tools designed for individual and collective use at farm, community, local government, national and international levels of decision-making and research. Examples are:

(1) Field and farm scale decision support.

- Diagnostic kit of soil quality indicators related to soil health
- A decision support system for soil recuperation and conservation
- Participatory methods for technology evaluation with farmers linked to GIS databases

(2) Landscape scale for community, municipality or watershed resource management decision support.

- Guide on participatory methods for the identification and classification of local indicators of soil quality at the watershed scale
- group software for multistakeholder planning of land and water resource management; bioeconomic, stochastic and other models for scenario building e.g., the Spatial Water Balance Model
- participatory methods for stakeholder analysis, resource mapping and monitoring
- tools, methods and information for input to an expert system for small agro-enterprises

(3) Ecoregional, national and international scale decision support

- GIS tools for biodiversity mapping to support in situ and ex situ conservation planning including the Climate diagram and Clustering tool which can be incorporated into other software packages, e.g., Flora Map
- GIS tools for epidemiological mapping in pest management
- interactive digital information systems for agroecosystem assessment, poverty mapping and land use planning, e.g., The Honduras Atlas (1998)
- GIS tools for extrapolation, e.g., sampling methodology, site similarity analysis
- Toolkit of methodologies for integrating data across geographic scales tested, adapted and developed from scratch, e.g., self-organizing maps.

Decision support tools are developed in the process of doing problem solving research with partners, some of whom are providers of advanced techniques and who also assist in dissemination; others of whom are representatives of future users. An example of coproduction is the translation and distribution of the *Mapmaker Popular* GIS software in Spanish by CIAT and Mapmaker Ltd.

Decision support tools are developed with one or more user-friendly interfaces, suitable for the type or types of future users who have been involved in the development and testing of the tool. Most decision support tools are integrated into training carried out initially by CIAT and subsequently by partner institutions, so that the tools are disseminated together with training in the skills needed to use them.

For more detail on the development of Decision Support tools at CIAT refer to the leaflet of the Decision Support Working Group.

Indicators of Sustainability

Indicators of Sustainability are a special subset of decision support tools where CIAT focuses on providing decision makers at international, national and local scales of decision-making with a unique capability to assess and monitor the impact of changes in land management. This work is carried out with continental and regional networks of partners: recent applications are the development of multi-scale sustainability indicator systems for Latin America; another for Central America; and a local one linked to the savannas ecoregional reference site in Meta Department, Colombia for use by the departmental government to monitor the impact of land use policies.

CIAT also develops indicators to measure its own and partners' research impact in selected ecoregional benchmark sites. This work is at an early stage. It is designed to provide a learning process evaluation system based on iterative cycles of measurement and evaluation. Once tested at CIAT, it is expected to meet a broad-based demand in the region for assistance with assessing the impact of changes in land management.

Technology components and Information for Improving Land Management

Technology components and information are the building blocks for the decision support and improved land management outputs described earlier. Among the most important components are:

- Crop-forage component technologies characterized for resource use efficiency in acid soils, and for sustainable systems compatibility
- Practices for managing crop residues, plants as biofertilizers, improved fallows, soil macrofauna and soil erosion

- Options for sustainable use of feed resources in crop-livestock systems
- Low P tolerant beans and multipurpose legumes
- IPM components characterized for sustainable production system compatibility
- Databases with assessments of farmer objectives and gender differentiated criteria for acceptance of new technologies
- Post-harvest technologies for small rural agro-enterprise
- Atlases with large collections of GIS coverages
- Continental, national and reference site scale strategic databases (e.g., climate, soil fertility, topography, population, poverty indicators, land degradation, potential agricultural productivity)
- Soil and land databases of ecoregional reference sites with land degradation risk and constraint maps

CIAT's research on agro-pastoral components for intensifying sustainable production systems focuses using improved forages and is deploying multipurpose legumes as biofertilizers, forage, cover crops, fencing and firewood. Especially important are dual-purpose milk-meat systems for smallholders, which are vital for raising productivity and incomes, thereby giving farmers the incentives and capital for investment in protective land use and soil fertility maintenance.

CIAT's soils research focuses on maintaining and improving soil fertility for intensifying sustainable production systems, in particular, crop-livestock systems, along a continuum of intensification in different agroecosystems (i.e., from low-intensity frontier agriculture to high intensity peri-urban farming in savannas, forest margins, and hillsides). The management of soils characterized by low phosphorus availability in association with germplasm development is a priority in this work.

Intensification of sustainable production systems requires careful management of the ecology of insects and micro-organisms in relation to both soils and plants, an area of research for CIAT's soils and integrated pest management projects which has important cross-scale effects, requires collective management and decision-making, and involves the development of decision-support and participatory research approaches.

- *Organizational Models*

CIAT's natural resource management research, like all its research, is carried out through consortia, networks or strategic alliances. Whereas

networks bring together similar partners, consortia for natural resource management bring together diverse but complementary partners. Strategic alliances are formed for long-term commitment based on collaborative advantage.

Multi-institutional consortia are a necessary platform or forum for using decision-support for participatory land use planning. CIAT catalyses and monitors the formation of these consortia in its reference sites as a research activity to produce guidelines for users who need to organize a forum for using decision-support. Guidelines are an essential tool for replication and scaling up these organizational models.

Participatory research methods for organizing farmer research committees (CIALs) to work at the community and landscape scale are developed, tested and disseminated internationally through training materials and training of trainers. Strategic research on how to scale up and extrapolate results of participatory research is an important feature of this work.

CIAT's partners have expressed strong demand for guidelines for organizing small-scale rural agroindustries, which create incentives for conservation farming. CIAT's role is to support and catalyze partners to do the research needed to draw lessons from experience by developing case studies which systematize experience with different organizational models, both successful and unsuccessful, for agroenterprise production projects.

Improved Capacity for Resource Management Research

CIAT's capacity building is designed to enhance impact through the use of its research products. Capacity building is carried out in a number of different ways including courses, in-service training, student theses, and training of trainers with networks, consortia and national systems. CIAT's natural resource management focuses on building capacity in: integrated soil management; use of decision support for community-based watershed management; sustainable production systems; GIS data management and analysis; small scale agroindustry development; and participatory research methods.

HOW ARE THE RESEARCH OUTPUTS PRODUCED? CIAT'S STRATEGY FOR PRODUCING NATURAL RESOURCE MANAGEMENT RESEARCH OUTPUTS

Integrated natural resource management research at CIAT

Defining an approach to integrated natural resource management research is of rising concern in the CGIAR system (TAC, 1996; System Review Panel Report 1999). CIAT's approach is broadly consistent with that recently recommended for the CGIAR (CGIAR INRM Report 1999). The main features of this approach at CIAT are:

- Cross scale research from macro (ecoregion) to micro (ecosystem), to achieve a comprehensive analysis of interactions among people, land and water and their on-site and off-site effects on productivity and the long-run viability of the natural resource base, with a focus on landscape scales of analysis.
- A focus on interactions between germplasm-based technologies, resource management technologies, social technologies and policy to design innovations and achieve impact
- Use of interdisciplinary research incorporating ecological perspectives focussed on specific problems and outputs
- Use of an area-based or ecoregional approach combining strategic and adaptive research, gender-sensitive participatory action research, training and development in an efficient division of labor with partners in reference sites, where these jointly develop, test and disseminate research products to achieve development impact.
- Combinations of indigenous knowledge and innovative science

Cross-scale research is a basic feature of the approach. Figure 3 illustrates the relationship of NRM research outputs to different scales.

Ecoregional research

CIAT was founded as an ecoregional research Center for the tropics of Latin America, and is convening Center for the LAC Ecoregional Program. Ecoregional or area-based research is the "demand side" of the research: the priority ecoregions selected by CIAT for NRM research (hillsides, forest margins and savannas) are the context for stakeholder identification, problem prioritization and formulation of research agenda. Each ecoregion's research agenda is defined in annual planning with projects in CIAT and with partners outside CIAT including systemwide programs, other Centers, NARS and NERS which

are the suppliers of technology, information and expertise to address this agenda.

The ecoregional approach permeates the whole natural resource management research program of the Center, while the Ecoregional Program provides a small node for information exchange, networking and the promotion of cross-center exchange of experience and lessons learned on topics of common relevance (Ecoregional Program for Latin America, 1999 Report).

Area-based problem identification and the articulation of research demand and supply is replicated at the ecoregional reference sites in annual planning with partners in those sites.

Ecoregional reference sites

The ecoregions defined for CIAT's research cover large geographical areas and populations in Latin America: savannas cover 245 million hectares for example; tropical hillsides include approximately 100 million and forest margins approximately 44 million hectares. For this reason it is necessary to conduct research in reference sites in conjunction with partners to develop tools and recommendations for extrapolation.

CIAT did not select ecoregional reference sites, to represent a golden mean or "average" conditions in an ecoregion. Instead the variability of the ecoregion is taken into account and along the continuum of that variability, different types of sites are selected. Nor does CIAT attempt to work in all types of sites. Instead CIAT focuses in the types in which CIAT has a comparative advantage or is more likely to make a strategic breakthrough, with respect to the importance of the area for impact on poverty and the potential of CIAT's contribution in that environment (e.g., the range of adaptation of relevant CIAT germplasm).

Conducting research such as the interinstitutional systems experiments in ecoregional reference sites enables CIAT to carry out early testing of improved land management options in close contact with future users and other stakeholders. Ecoregional reference sites are a field laboratory at the "local" scale (i.e., watershed or municipality in Figure 2) where all the relevant research and development partners work together in multi-institutional consortia for improving land management and achieving other development goals important for the partners, for example DEPAM in Pucallpa, Peru;

CIPASLA in Cauca, Colombia, and CAMPOS VERDES in San Dionisio, Nicaragua. These sites also serve as a training ground for replication of successful approaches and results.

Extrapolation and replication of results

Two main approaches are used to enable results obtained in ecoregional reference sites to be replicated elsewhere. The first is the development of methods and GIS tools for extrapolation: for example, tools for site similarity analysis which enable the user to select a site (e.g. a watershed), define an extrapolation domain of many sites (watersheds) with respect to this site, and to estimate the probability with which these sites are in fact comparable. Another important class of tools enable the user to evaluate the usefulness of indicators at different scales for defining and comparing extrapolation domains, for example indicators of poverty, soil erosion or agricultural intensification.

The second approach to replication is process oriented and implemented through training, in large part carried out by CIAT's existing partners who train new partners in new sites with support from CIAT. The specific problems identified, technology components tested and the land management options derived from replicating the new research process may be different from those in the ecoregional reference sites. However, the same approach is applied using landscape scale systems experiments , CIAT's GIS tools, participatory methods ,and organizational procedures. The recent advances in the Hillsides project in training are an example of this approach.

Organization into projects

Projects are the primary means by which CIAT delivers its research outputs. In practice, many of the research outputs described above are produced by cross-project collaborative research, drawing on the competencies installed in the different projects i.e. breeding, entomology, soils, agronomy, GIS participatory research etc. Strategic cross-project initiatives such as the work in the three-ecoregional reference sites, impact assessment for NRM and the decision-support-working group meet formally for joint planning and for sharing results at least twice a year.

Relationship to CGIAR Systemwide Programs

In contrast to the area-based ecoregional research approach which formulates a research agenda or demand for research, the CGIAR systemwide programs provide a supply of expertise which exceeds that available in CIAT or any other single Center. CIAT's natural resource management research draws on the several CGIAR systemwide programs: SWNM program, PRGA program, IPM program and Livestock program for example, to strengthen capacity especially in the ecoregional benchmark sites. CIAT participates in systemwide programs in which it has a strong international leadership in the program's field of research: this helps CIAT to maintain its expertise at the cutting edge in that field, and to disseminate its research, outputs or products widely.

Important global public goods are produced by CIAT in conjunction with a leadership role in CGIAR systemwide programs. These include:

- research on the integrated management of tropical soils in the Americas with a focus on the use of multipurpose legume germplasm, particularly in acid, phosphorus-fixing soils linked to the CGIAR Soil Water Nutrient Management Program;
- research on pest and disease control such as the international whitefly project linked to the CGIAR Integrated Pest management Program;
- decision support for community based watershed management and participatory research methods for evaluating technology with farmers linked to the CGIAR Participatory Research and Gender Analysis Program.

Relationship between strategic and adaptive research, capacity building and working in partnerships for development impact at CIAT

CIAT's research is demand driven, but primarily strategic in nature. As a result attention to short-term, location-specific research is a spin off from work on a broader research agenda; or is part of methodology development which needs testing in a specific situation in order to be useful to clients.

Senior research capacity is concentrated at the strategic end of the research continuum. Scientists also are involved in making sure research results are developed into research products that are useful to clients e.g. the Flora Map.

CIAT recognizes the importance of making sure its research products are used in order to achieve impact . This requires CIAT scientists to contribute to building the necessary interinstitutional partnerships and to participate in capacity building. Once well-defined, partnership building and capacity building functions performed initially by senior scientists are increasingly devolved to associate-level staff, and to partners.

HOW IS PROGRESS AND EXPECTED IMPACT ASSESSED?

CIAT's research products are expected to contribute to improvements in land management which are associated with:

- increases in per capita income and seasonal food availability for the rural poor;
- agroecosystem resilience maintained or improved through enhanced plant and soil-water-nutrient use efficiency and appropriate planning of land use;
- better management of negative externalities or off-site effects of farming on the environment.
- greater capacity of community-based, local government, national and international decision makers to carry out participatory land use planning to promote improvement in land management
- the creation of incentives for improving land management, eg. income generated from environmental services to society at large.

CIAT recognizes that the impact of its research outputs is accomplished almost entirely by working with partners. At best, CIAT can produce research outputs which are tested and validated with future users so that the probability of widespread use is high, and can promote their ample use through regional cooperation and capacity building, in a way that is targeted at poverty reduction and environmental protection. Impact assessment can document the extent to which CIAT's natural research outputs are in use, and analyze whether there is any plausible relationship between use of the research outputs and poverty reduction or environmental conservation. However, these development impacts are long-term processes, driven by many complex causes outside the control of CIAT and its partners (Pachico et al 1997).

The ecoregional reference sites provide a "field laboratory" for methodology development and long-term monitoring and evaluation studies of the use of CIAT's research outputs by stakeholders, and for

exploring relationships between use, direct effects like changes in land management, and development impacts like poverty reduction and environmental protection. The reference site impact assessment studies are managed by the CIAT Impact Assessment Unit in collaboration with the Ecoregional Program, and implemented by an impact assessment task force for used in 1999 with members drawn from all the projects actively working in the reference sites (Pachico, Imbach and Ashby, 1999). The task force has developed a Research design and data collection was initiated in spring 1999.

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Figure 3. Relative importance of spatial scales and levels of decision-making about natural resource management to CIAT's NRM research outputs.

Spatial Scale	Field	Farm	Landscape/ Watershed	Ecoregion	National	International
Principal level of decision-making and main stakeholders	Farmers	Farmers on communities	Municipalities, community-based organizations, related national policy makers and researchers	Municipalities, community-based organizations, related national policy makers and researchers	Natural researchers, policy makers and conservation agencies	International donors, Banks and NGOs. CGIAR Center
NRM outputs						
1. Improved land Management	✓	✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓	✓ ✓ ✓
2. Decision Support tools	✓	✓ ✓	✓ ✓ ✓	✓ ✓	✓	✓ ✓ ✓
3. Indicators for Sustainability	✓	✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓ ✓
4. Technology Components and information	✓ ✓ ✓	✓ ✓	✓	✓	✓ ✓	✓ ✓ ✓
5. Organizational Models	✓	✓	✓ ✓	✓ ✓	✓	✓ ✓ ✓
6. Improved Capacity for NRM research	✓	✓ ✓	✓ ✓ ✓	✓	✓ ✓ ✓	✓ ✓ ✓

- ✓ = some relevance
- ✓ ✓ = significant relevance
- ✓ ✓ ✓ = very high relevance

FIGURE 1
CIAT Area Log-Frame

CIAT
Area: Natural Resources
Manager: Jacqueline Ashby

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>Goal</p> <p>Stakeholders generate and use environmentally sound and economically viable options for improving land management and productivity</p>	<p>CIAT NRM research outputs used by stakeholders to improve land management and productivity</p>	<ul style="list-style-type: none"> Decision-makers and other members of stakeholder organizations familiar with CIAT NRM research outputs. 	
<p>Purpose</p> <p>Knowledge, tools, technologies, skills and organizational principles that contribute to improved land management are developed and applied by stakeholders</p>	<ul style="list-style-type: none"> Use of CIAT NRM Research outputs in at least 3 reference sites in 5 years is related to changes in land management associated with increases in per capita income and food availability; improved soil-water-nutrient use efficiency; increased biodiversity in production systems; and stakeholder participation in land use planning. Use of the CIAT NRM research outputs beyond the 3 reference sites in the 3 target agroecosystems (savannas, hillsides, forest margins) by stakeholders within 5 years. CIAT NRM research outputs applied by at least 3 other institutions outside the LAC region by the end of the 5th year. 	<ul style="list-style-type: none"> Projects, plans and reports of national public sector agencies, donors, NGO's and community-based organization in the 3 reference sites and mandate agroecosystems which refer to use of CIAT NRM research outputs. 	<ul style="list-style-type: none"> Continued donor support CIAT's partners are willing to use these research outputs to improve land management. Pejorative policy does not persist

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>Outputs</p> <p>1. Improved Land Management options</p>	<p>1.1 Documented trends in key indicators show a process of improvement in land management is starting in 3 reference sites, within the 5 years.</p> <p>1.2 Improvements in land management are associated with decision-making by stakeholders using CIAT's and partners' NRM research outputs in 3 reference sites.</p> <p>1.3 Improved land management options have been generated outside the reference sites with stakeholders in the 3 mandate agroecosystems (FM, HS, S), i.e., policy makers, private sector (including farmers), research management, development practitioners, communitybased organizations.</p>	<p>1.1 Annual report produced by CIAT and partners on trends in key indicators in each of the 3 reference sites.</p> <p>1.2 GIS images, participatory maps, photographic documentation of changes in land management over time in the 3 reference sites where CIAT and partners have intervened.</p> <p>1.3. Reports of annual planning meetings which CIAT and partners' research outputs are used in decision making about options for land use management</p>	<ul style="list-style-type: none"> • The genetic resources, farming systems components, (IPM, soils, agroforestry); databases, models and capacity are available in CIAT or through partnerships. • The required collaborative research partnerships can be achieved in the three benchmark sites.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>2. Decision Support (DS) Tools for Natural Resource Management; (bioeconomic models, GIS, participatory research methods, economic and market research tools, expert systems).</p>	<p>2.1 DS tools, produced by CIAT & partners have been tested with stakeholders and applied to decision-making about land management in 3 reference sites in the first two years of the planning period; DS tools adopted and their use extrapolated outside reference sites by stakeholders in the 3 mandate agroecosystems in LAC by at least 3 major NRM research or development programs or projects</p> <p>2.2 Methodology developed for improved extrapolation and targeting of information technology, germplasm and cultural practices within the 3 target agroecosystems.</p>	<p>2.1 Reports on training courses, workshops and professional meetings at which DS tools of CIAT and partners are tested.</p> <p>2.2 Reports of multi institutional planning meetings for reference site stakeholders (Forest Margins: CODESU; Hillside CIPASLA, CLODEST, Rio Calico; Savannas CORPOICA) making decisions about land use management options to test or recommend on reference sites; reports of regional agroecosystem meetings & other publications which refer to use of these DS tools; practitioners using the tools.</p> <p>2.3 Distribution lists of decision-support tools; records of downloading from CIAT home page.</p>	<ul style="list-style-type: none"> • CIAT's resources are allocated so as to maintain a comparative advantage in applying knowledge and methods to produce decision support tools which are important international public goods.
<p>3. Indicators of sustainability, for monitoring progress, for early warning; for providing feedback on effects of changes in land use management.</p>	<p>3.1 Decision Support Tool for Sustainability Indicators applied to monitoring key interventions of CIAT & partners in 3 reference sites.</p> <p>3.2 Sustainability indicators in use by at least 30 stakeholders outside reference sites by year 3.</p>	<p>3.1 Distribution for CD Rom for sustainability indicators.</p> <p>3.2 1998 Annual Reports listing indicators used by CIAT and partners in ecoregional benchmark sites.</p> <p>3.3 Reports documenting applications of CDR Rom for sustainability indicators.</p>	<ul style="list-style-type: none"> • Partnerships support to long-term research for monitoring changes in natural resource indicators.
<p>4. NRM Technology components and information.</p>	<p>4.1 Partners are using CIAT technology components and information about these in their research and on farms</p>	<p>4.1 Annual reports of CIAT & partners on trial results measuring environmental and productivity effects;</p>	<ul style="list-style-type: none"> • The policy environment encourages availability and use of NRM technology and information.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>5. Organizational models for decision-making about improving land use management.</p>	<p>to generate environmentally sound changes in land management in 3 reference sites</p> <p>4.2 Information derived from testing these components is available in databases with user friendly interface</p> <p>4.3 The potential for extrapolating results of testing combinations of components from Reference sites to other sites in the 3 LAC agroecosystems has been assessed</p> <p>5.1 Multi-institutional organizations are working in 3 reference sites, using principles of stakeholder participation identified through CIAT & partners' research within 3 years.</p> <p>5.2 CIAT's research results on principles of organization for improving decision-making for land management are</p>	<p>evaluations of post-harvest and market potential; FPR analysis of acceptability to users; ex-ante economic analysis of potential technologies for specified areas and beneficiary groups, in particular the poor; reports of ex-post adoption studies.</p> <p>4.2 Databases incorporating results from the research in 3.1.</p> <p>4.3 Annual reports and published results on analysis of similarity of reference sites to other areas.</p> <p>4.4 Published results and annual reports on analysis of probability of adaptation to similar biophysical environments in mandate agroecosystems.</p> <p>4.5 Reports and published results of analysis of the probability of acceptance by specified beneficiary groups, in particular the poor, in the 3 mandate agroecosystems.</p> <p>5.1 Organograms and minutes of regular meetings of multi-institutional organizations in reference sites (e.g. CODESU-DEPAM; CIPASLA, CODEST).</p> <p>5.2 Commercial book/referee journal publications and annual reports on principles of organization, invited talks which indicate international</p>	<ul style="list-style-type: none"> Partnerships, political and security conditions are conducive to stakeholder participation in NRM.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>6. Improved capacity for resource management research.</p>	<p>internationally recognized and being applied at a larger scale (in programs or projects) beyond the reference sites by year 5.</p> <p>6.1 In the 3 reference sites there will be at least 10 research "leaders", or a multidisciplinary team capable of leading:</p> <p>a) Stakeholder participation in NRM research and development; b) use of decision tools; c) development and use of NRM technologies; d) application of indicators to monitor progress and impact.</p> <p>6.2 Within 5 years there will be an institutional capacity to train research leaders in areas (a) thru (d) in CIAT or a partner institution.</p> <p>6.3 Stakeholders in the 3 mandate agroecosystems in LAC and beyond will use CIAT & partners training materials of (a) thru (d) in regular teaching and curriculum design.</p>	<p>recognition of CIAT & partners research.</p> <p>5.3 Published case studies of applications inside/outside the reference site.</p> <p>6.1 Consultant report on follow-up evaluation of trainees in use of CIAT & partners NRM research outputs.</p> <p>6.2 Documentation of regular CIAT, university or other NARS course or curriculum content, using the NRM research outputs of CIAT and partners.</p> <p>6.3 Reports of CIAT and partner training events involving participants outside reference sites.</p>	<ul style="list-style-type: none"> NARS and other stakeholders in NRM research have trainers and continuity of staffing to retain trained personnel.