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NATURAL RESOURCES MANAGEMENT RESEARCH EVOLUTION AND FUTURE PLANS

CIAT

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CONTENTS

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PART I OVERVIEW AND EVOLUTION

Introduction

In order to provide the Panel of the Internally Commissioned External Review of natural resources management research at CIAT with an up to date and comprehensive overview of natural resources management research this paper presents the overall strategy guiding the entire endeavor as well as reviews of specific strategies and projects in the four major research areas hillsides tropical lowlands land management and production systems and soils management

CIAT's Mission

CIAT's mission statement for the 1990 s reformulates its guiding principles introducing significant modifications from the previous version

> 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)

Salient changes in this statement include mention of the natural resource base and lasting increases in output Explicit recognition of these concepts reflects an enhanced commitment to tackle environmental problems that extend beyond the concern to achieve immediate increases in food production Henceforth CIAT's concern is not just how to adapt agricultural practices to environmental stresses but also managing the stresses that agriculture imposes on the environment

As indicated by its mission statement CIAT remains fundamentally concerned with human welfare Hunger and environmental degradation are clearly two of the most serious threats to sustained human welfare Improvement of agricultural productivity and natural resource management are inseparable and essential components of successfully achieving food security and environmental sustainability They therefore constitute the key elements in CIAT's research strategy

A New Research Agenda Natural Resources Management

CIAT's strategy for the 1990 s is to complement its longstanding and effective programs on crop and germplasm research with new efforts directed at improving natural resource management This new focus requires that CIAT take into full consideration the impact of agriculture on the environment Such a commitment involves a number of changes in the research agenda

First the organizing principles of CIAT's research are no longer solely crops or plant species but now also include complexes of natural resources delineated geographically as agroecosystems which are landscape units with commonalities both in their environmental characteristics (soils climate) and also in terms of their land use patterns that is commonalities in the socio-economic management of these environments

Second greater attention is given to studying the underlying biophysical processes associated with agricultural land uses While in the past CIAT research has tended to focus on the agronomic or economic outcomes of production systems understanding the processes driving these systems is now an explicit concern

Third these processes are studied not just in terms of their immediate effects but as importantly for their longer term consequences that accumulate over many years

Fourth the objective of this research is to insure that agriculture does not degrade the resource base either on or off the farm rather than just to improve agricultural productivity by enhancing the adaptation of agriculture to its environment CIAT research now examines the biophysical processes linking agriculture and the resource base including for example changes in the productivity of soils generation of pollutants loss of biodiversity and effects on global warming

Fifth consequences of agricultural management practices are appraised from the perspective of social costs and benefits affecting a wide set of stakeholders including those who are users off farm of resources that are affected by farm decisions Restricting analysis to the point of view of the private profitability to individual farm decision makers will not result in sound resource management

Finally understanding of the impact of natural resource management requires assessment not just at the field or farm level but also of how individual decisions at this level aggregate to affect landscapes or watersheds

Clearly this new research agenda is in many senses broader and more challenging than the classical research agenda of improving crop productivity It involves both

agriculture and the resource base the long term as well as the short term resources both on and off farm multiple stakeholders as well as individual farm decision makers and consequences not just locally but in the aggregate

Evolution of CIAT's Natural Resources Research Agenda

This new research agenda has roots deep in CIAT's past CIAT was conceived in the late 1960 s as an agricultural research institute for the neo-tropical lowlands Although the earlier international agricultural research centers had been established with a commodity focus (IRRI rice CIMMYT maize and wheat) the conception behind the foundation of CIAT (and at the same time IITA in west Africa) was to take a systems approach to agricultural development for a particular resource base in a specific region

CIAT subsequently decided to undertake the improvement of beans cassava pastures and rice because of their importance in the region Initially these commodity priorities were complemented with a systems approach that was pursued through a Small Farm Systems Program However in the late 1970 s it was felt that this program lacked focus and that the systems perspective would better be integrated into the existing commodity programs

Awareness of the need to sustain the natural resource base while increasing food production became heightened worldwide in the late 1980 s Issues such as conserving biodiversity global warming pollution and soil degradation seized a prominent position on global agenda both because they threatened the sustainability of agriculture and also because some agricultural practices exacerbated these problems

CIAT therefore reexamined its research portfolio to respond to these issues After intense debate it was decided in CIAT's strategic plan that the appropriate response was to explicitly address natural resource management in its own right rather than just to strengthen a sustainability perspective in commodity research Although many of the outputs of CIAT commodity research contribute to sustainable agriculture and although genetic improvement of crops is an essential component of sustainable agricultural systems nonetheless it is clear that a broader systems approach is required in order to assure that the productivity of the natural resource base is preserved

A New Model of Research

To successfully undertake research of a broad systems nature that assures the preservation of the natural resource base a new research model is required The approach of the International Centers (IARCs) has been heavily influenced by the importance of plant breeding in their genesis In general terms the traditional approach of IARCs was to assemble the full complement of interdisciplinary expertise

and resources needed to make significant autonomous advances through a systems approach to plant genetic improvement The principle research output was improved germplasm that was physically delivered to clients mainly public sector national agriculture research institutes (NARIs) The IARCs also supported the strengthening of NARIs by offering them training to help the NARIs be effective in their roles of adaptive and applied research A sequential division of labor tended to emerge with the IARCs withdrawing from adaptive and applied research in order to concentrate on strategic germplasm research

This model is not fully appropriate for natural resources management research Due to the complexity derived from the need to deal with a hierarchy of systems and as well as with off site and long term effects a single research institute like CIAT can not possibly assemble the full complement of expertise and resources needed to make comprehensive research advances Interinstitutional collaboration in the research process is therefore much more an integral aspect of the essential nature of natural resources management research than was ever the case for germplasm based research Natural resources research must be carried through multi institutional consortia or other mechanisms in which CIAT is not solely responsible for strategic research

Consequently research partnerships have played a central role in the emergence of natural resource management research at CIAT While these are treated in detail in the discussion below of Program research strategies research partnership is a vital element running through the entire NRM research agenda

Forest margins research is carried out in close collaboration with two EMBRAPA centers in Brazil (CPATU and CPAF) It is linked both to the IICA sponsored PROCITROPICOS regional network and to the Global Alternatives to Slash and Burn program coordinated by ICRAF and involving CIFOR and IFPRI

Savannas research is carried out in Colombia in direct partnership with CORPOICA and in Brazil with EMBRAPA (mainly CPAC and CNPAF) This research is linked regionally to PROCITROPICOS and locally to universities Internationally it involves IFDC CIMMYT and ICRISAT

Hillsides research in Central America was initially centered on a regional consortium with CATIE and IICA, and currently is tied to NARIs in Honduras and Nicaragua (DICTA and INTA) as well as local universities Internationally CIMMYT and IFPRI are close collaborators In Colombia CIAT has catalyzed partnership through the CIPASLA consortium involving eight national institutions five NGOs and a variety of local farmers committees

Research in these consortia involve CIAT in interactions with a much wider range of institutions than the traditional public sector national agricultural research institutes which often do not have the breadth of disciplinary interest or expertise to fully complement other partners in the consortia

While working with a broader array of partners provides a valuable opportunity for accelerating NRM research progress it is certainly a more challenging task to reach consensus around and implement a research agenda This requires an enhanced commitment to participatory planning and new operational modes In particular the project approach to organizing research is seen as having great merit in planning clear objectives assigning clear responsibilities for specific activities and providing a framework for resource allocation and monitoring progress

Not only does CIAT work with a wider range of national and regional partners in order to be effective in NRM research but also CIAT needs to collaborate more closely with advanced research organizations (AROs) and other CGIAR centers While both can be and are incorporated as partners together with national institutes in research consortia relations with other Centers merit special attention due to ongoing changes in the CGIAR system

The CGIAR is in the process of the design and implementation of Systemwide Programs to bring IARCs together to work towards common objectives CIAT is serving as the convener of two such systemwide initiatives the Latin America ecoregional program and the systemwide soil water and nutrient management program (SWNM)

CIAT is catalyzing an ecoregional research program for Tropical America to exploit commonalities and economies of scale in training methods development and information exchange among the forest margins savanna and hillsides agroecosystems research consortia This is resulting for example in joint projects to integrate ICRISAT's sorghum research into the savannas and to work with IFPRI and ISNAR on methods for research prioritization as well as to links with the ILRI led systemwide livestock initiative and the systemwide soil water and nutrient management program (SWNM) The latter is discussed below in the section on the Production Systems and Soils Management research

In summary because natural resources management research deals with landscape systems not just farming systems let alone single crops a wide variety of expertise from a number of institutions needs to be brought together to make progress on a common research agenda Although this implies higher transactions costs for CIAT it remains the only viable mode of operation that promises success in NRM research

Genesis of a Research Strategy

Preserving the natural resource base associated with agriculture in the neo-tropics is clearly a vastly ambitious agenda CIAT can be effective only by having a clear focus on selected strategic elements of a broader agenda multi institutional agenda Therefore during the development of CIAT's Strategic Plan for the 1990s a major study was conducted to identify research problems and opportunities in natural resource management research in the neo-tropics (Jones et al 1991)

This study utilized a geographic information systems approach to first define homologous environments in the neo-tropics which were then disaggregated into agroecosystems which are defined by common land use patterns within a given environmental class Agroecosystems were then prioritized for research based on the severity of resource problems potential contribution to alleviating poverty and to agricultural growth and the feasibility of CIAT making a significant impact

Three agroecosystems were targeted for attention the hillsides the forest margins the savannas All face serious problems of soil degradation and erosion of biodiversity induced by increasing intensification of land use They share the characteristic of acid soils Further all CIAT commodities are important in at least one agroecosystem and tropical forages is important in all both because of the role of pastures as the main land use and also because of the potential of tropical forages for soil conservation and regeneration

Prior work on acid tolerant rice cassava and forage legumes and grasses as well as on crop-pasture systems is highly relevant to the savannas and forest margins Similarly prior work on small farmer decision making erosion control in cassava and bean cropping systems as well as on forages is highly relevant to the hillsides In addition to building on earlier work in specific commodities CIAT had already established core competencies in geographical information analyses and in methods for farmer participatory research that also lent strength to the new initiatives in resource management CIAT's new land resource strategy for the 1990s thus emerged in significant part out of its established comparative advantages in the late 1980s

Besides the geographic focus on three prioritized agroecosystems CIAT also defined a dual subject matter or thematic focus on production systems and land use strategies Production systems research linked to CIAT's commodity research aims to generate management technologies and integrate them into productive and sustainable systems This requires research that includes an understanding of the processes underpinning production systems as well as their long term and off farm consequences

Land management research studies the aggregate effect of production systems and land use on resources in a landscape context emphasizing the influence of policy on land use at the agroecosystems level as well as interactions among agroecosystems It seeks to generate information and methods that contribute to the development and appraisal of land use options

Conceptually then CIAT's strategy embraces a systems approach that extends from research at the gene or plant level through processes at the field level up through cropping and farming systems to a wider watershed or landscape level all of which are influenced by the institutional and policy environment At all levels resource decisions are made in the context both of biophysical relations and the socioeconomic situation Understanding is needed therefore of both biophysical and socioeconomic dimensions at all levels of the systems hierarchy

Convinced hat such a comprehensive systems approach is needed for successful management of natural resources CIAT nonetheless recognizes limitations in its capacity to address this entire set of issues Thus research partnerships with other institutions are an integral part of CIAT's natural resource research strategy CIAT is constantly alert for opportunities to combine efforts with others both to insure a coordinated effort that is comprehensive and also to avoid duplication of effort CIAT's research strategy can not therefore be solely internally defined but must be worked out in an interinstitutional dialogue with partners and stakeholders

A Strategy for Natural Resources Management Research

CIAT's strategy for improving natural resource management involves research on four interrelated themes

Germplasm adapted to environmental stresses

Prototype sustainable production systems

Understanding of processes affecting the resource base

Land use systems in policy and institutional context

Drawing on CIAT's existing strength in germplasm improvement both in classical breeding and biotechnology new germplasm components are being developed that can contribute to improved resource management The availability of new germplasm options can often be a critical factor in inducing the conversion from a conventional degrading system to new production systems that are both more productive and more sustainable Examples of the potential of improved germplasm are many forage

legumes that can help regenerate degraded soils rice varieties adapted to the acid soils of the lowlands that can create income flows to be invested in improving the land resource bean varieties with enhanced nitrogen fixing capacity cassava varieties that establish rapidly to improve ground cover and reduce the threat of erosion

It is though the entire system of farm management that determines the state of natural resources not just the choice of individual germplasm components alone Consequently design testing and evaluation of new prototype farming systems is a second important element in CIAT's natural resource management research strategy Because of increasing population pressure on the resource base the further penetration of the market economy as infrastructure improves and resource degradation processes that are often unperceived by farmers current production systems in CIAT's priority agroecosystems are generally not in long term equilibrium Consequently there is both the opportunity and the need to utilize the insights of science to develop new future oriented systems adapted to changing circumstances The objective is to generate 'win win technologies that result in both increased agricultural productivity as well as improved resource management

The development of new agro-pastoral systems for the savannas has made great progress and continues to be a major effort Such systems offer the promise of recapitalizing the soil through improved nutrient cycling thereby constituting a 'win win technology that increases agricultural productivity while enhancing the resource base

Similarly in the forest margins CIAT is working to develop production systems that make it attractive for small holders to intensify production on already cleared land rather than by continuing to fell more forest for additional land

In the hillsides long term strategic research aims to elicit the principles for the development of transition systems which enable farmers to gradually transform their production systems from dependence on monocropped or intercropped short season annuals with little or no livestock into improved systems with a major role for perennials

Research to understand underlying processes in production systems as they affect the resource base is a third major area of research Since many consequences of agriculture on the environment occur either cumulatively over time or off the farm it is essential to have an understanding of processes affecting the resource base For example construction of models to understand complex interactions between soil chemical physical and biological processes in sequential or agropastoral systems provides crucial insights about the long term consequences of alternative management systems that typically will not be observed in the short run even in on farm trials Identification of easily observable indicators of subtle and gradual processes is also an important objective

Many resource outcomes of agriculture occur either off farm or at a landscape or watershed level rather than at a field or farm level Thus CIAT's fourth area of natural resources research addresses the spatial and intertemporal dynamics of land use emphasizing linkages between socioeconomic and environmental variables in order to understand wider landscape and off farm affects Such studies serve a number of purposes including the elucidation of trends in resource use and status identification of benchmark sites for research and the extrapolation of results

A dominant reality in the neo-tropics is rapid change in land use with associated impacts on the natural resource base Monitoring analyzing and understanding these changes are therefore important concerns for natural resource management research The development of georeferenced information systems is a major effort In addition there is a pressing need for the refinement of a variety of methods to appraise and manage land use changes Such methods include sustainability indicators dynamic simulation models and techniques for aggregating and disaggregating across different scales of analysis

Both farmer production decisions and land use changes are strongly influenced by the policy and institutional context Because natural resources so often involve multiple stakeholders and external costs they can not be managed solely in an individual decision making framework Much of the information that CIAT develops in its study of land use changes is relevant in a policy context Furthermore given CIAT's commitment to research in the forest margins there is no doubt of the need to at least monitor policy changes that affect colonization in the forest margins Beyond that CIAT has a particular interest in community resource management especially in the hillsides where water and forests are often community managed Despite having a modest appreciation of how far it can go into the policy arena nonetheless it is CIAT's view that it must play at least a limited role in devising and appraising relevant policy options that would affect land use Moreover changes in land use can not be understood without some reference to the policy and institutional context

Organizational Evolution

The bold vision of CIAT's 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 It was anticipated that these four programs would grow steadily over the next decade climbing from 2% of CIAT core resources in 1991 to 42% in 2001 It was projected in the CIAT strategic plan that by 1996 there would be 30 core funded senior scientists in the natural resource programs In 1992 leaders were recruited to start these four programs

The implementation of this vision of four essentially self sufficient interdisciplinary programs was predicated on obtaining 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 Thus over this period there was a real decline in resources at CIAT This shortfall in anticipated resources created major tensions within CIAT and is inextricably associated with further organizational changes discussed below

CIAT's initial response to the resource shortfalls was to press on with the building of the new natural resources programs and accelerate downsizing in the germplasm programs thereby unintentionally fostering an internal environment in which many perceived competition between germplasm and natural resources research at CIAT

Despite a strong commitment of senior management to the new natural resources initiative continuing shortfalls in funding and the need to foster more effective cooperation among CIAT scientists led CIAT to reorganize itself in the November 1993 Action Plan This plan introduced Projects and Scientific Resource Groups (SRG) as important new organizational features while reducing the number of CIAT programs from eight to six by phasing out the Forest Margins and Land Management Programs

In addition the divisional structure of Natural Resources Division and a Germplasm Division each comprised of four Programs and headed by a Deputy Director was broken down in order to foster tighter research integration A single Deputy Director of Research was appointed to oversee all research An Associate Director of Natural Resources reporting to the DDG Research was named to give leadership to natural resources research in its formative stage

In the Action Plan Programs were defined as the internal focal point for project planning budgeting implementation and evaluation Programs were designed to foster goal orientation around a set of interrelated problems and opportunities defined either in terms of multidisciplinary teams organized around commodities or agroecosystems

The Forest Margins Program which scarcely ever became operational due to budget constraints and personnel problems was 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 was converted to the Land Management SRG thereby leaving unclear whether a program driven research agenda for land use studies would be developed or whether this research would focus more narrowly on activities that support the agenda of the other CIAT programs

Scientific Resource Groups (SRGs) were introduced in the Action Plan to increase the collaboration across programs among scientists who share common interests in specific thematic or methodological issues The SRGs are designed to encourage

innovation within various disciplines as well as to provide a critical mass of disciplinary based talents in a structure where project areas or programs may not always have an adequate internal critical mass Moreover the SRGs are intended to develop the Center's strategic research capacity by mobilizing scientific talents across programs on methodological issues of broad application

Scientific Resource Groups do not though by explicit decision of the CIAT Board of Trustees implement projects All projects are housed either in Programs or Units SRGs exist to foster scientific excellence in research and to assist Programs but Programs drive the research agenda Staff and research budgets are assigned to Programs although all internationally recruited staff are also members of an SRG SRGs have only modest funds to cover transactions costs

The Land Management SRG is currently an institutional anomaly in that it is considered an SRG but it implements projects has assigned budget and staff and its internationally recruited staff are exclusively appointed to the LM-SRG Thus operationally the LM-SRG behaves as if it were a Program

The Production Systems and Soil Management Scientific Resource Group is the other SRG that is associated with Natural Resources Management research at CIAT

To improve planning implementation and monitoring research efforts were systematically reorganized into a project framework Projects became the central mechanism for the setting of priorities the allocation of resources and progress reporting While projects are intended to be flexible tools for conducting research the Programs are designed to be the internal source for the expression of demand prioritization and the allocation of resources Programs define missions and objectives that are implemented through projects

Initially the project structure in agroecosystems research was defined in terms of where the research was carried out Thus there were two hillsides projects one for Central America and the other for the Andes At the same time there were three tropical lowland projects the Cerrados of Brazil the llanos of Colombia and the forest margins of Brazil However this project structure risked giving undue emphasis to location specific aspects of research as well as inhibiting the development of common research approaches across sites Thus in early 1995 the project structure was reorganized along thematic lines

Table 1 illustrates how the project structure addresses the key issues in both the hillsides and the tropical lowlands agroecologies Note that the germplasm components are derived from a variety of projects housed in the commodity programs while both the two agroecosystems programs each have a suite of projects that address issues at the production systems processes and land use levels

Although the classic commodity programs were designed to be and still tend to be essentially self standing entities with an internal capacity to deliver the bulk of the disciplinary expertise that they need with most scientists working full time exclusively in one program of which they are a member this is much less the case in the new project approach as it is being applied in the natural resources area A large proportion of resource management scientists work either in inter program projects or even in projects in different programs This represents a significant evolution in CIAT's internal operations and culture that is still unfinished

PART II HILLSIDES AGROECOSYSTEM RESEARCH

Overview In the analysis conducted for the CIAT strategic plan highest priority was assigned to research on the hillsides of Central America and the Andes This agroecosystem is a priority for several reasons it is suffering serious degradation of natural resources it is a major locus of poverty it continues to be important to the food and agricultural economy of the region producing up to 40% of food in many countries for many countries in Central America and the Andes increased destruction of the lowland tropical forests is the major alternative to intensification in the hillsides

Deforestation loss of biodiversity land degradation and degradation of downstream water resources are all increasing problems for natural resource management in the hillsides While not a universal phenomenon in the hillsides many case studies have documented that soil erosion is a cause of major problems in the hillsides Not only does erosion undermine agricultural productivity and hence livelihoods of hillsides families but also it can cause significant downstream resource problems for hydroelectric generation irrigation systems and urban/industrial water supplies Since in many watersheds the downstream costs of soil erosion are greater than the on site costs improved management of hillsides resources requires a multiple stakeholder approach to internalize costs of degradation

Agricultural land suffers degradation not just from erosion but also due to depletion of soil nutrients as fallows shorten cropping intensifies and more marginal lands are brought into cultivation Pressures to expand cultivated land in the hillsides is leading to rapid deforestation that may risk genetic erosion as great as that occurring in the lowland forest both because the proportion of montane forest that has already been destroyed is higher and also because biodiversity may be greater in the hillsides While there are more species per hectare in the lowland forests there is a greater degree of species endemism in the montane forests and in many plant families there is a richer diversity in montane than lowland flora because of greater environmental variability (Forero 1994)

The mid altitude hillsides of Central America and the Andes cover 95 000 000 ha of land much of which is already intensively cultivated and 25 000 000 of which is already highly degraded Over half the land in ' s agroecosystem is estimated to be experiencing rapid degradation This agroecosystem supports over 20 000 000 rural people most of whom earn low incomes from small farms Thus the hillsides agroecosystem is characterized both by problems of severe poverty and serious degradation of the natural resource base

Program Goal The goal of the Hillsides Program is to improve the welfare of the hillside farming community by developing sustainable commercially viable agricultural production systems

Program Research Strategy This goal clearly frames the improvement of hillsides natural resources in the alleviation of the poverty which drives so much of this degradation The overall approach is to break this linkage first through the identification of technology options that increase agricultural productivity and incomes and second by introducing innovations in the community management of resources The Program is implementing four interrelated projects to achieve these results

Processes of soil degradation and regeneration

Prototype systems for ecologically sound intensification

Participatory research methods

Decision support systems

These projects are now discussed in turn

1 Hillsides Soil Processes Project

Rationale Better understanding of the processes of soil degradation and regeneration and their causes could significantly improve resource management There is a widespread sense that the hillsides soils resource is being severely degraded and there is an ongoing energetic effort often spearheaded by NGO s to promote soil conservation and regeneration practices Nonetheless the record of successful adoption is poor In large part this is due to the lack of well researched principles to aid the selection of suitable practices adapted to specific edaphic and socioeconomic conditions

Processes determining soil regeneration in acid and moderately acid tropical hillsides soils are poorly understood and the relationships between changes in soil properties and productivity has scarcely been researched 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 Finally more accurate estimates of the effects soil degradation on productivity and their spatial distribution can provide a baseline for assessing new technologies help determine research needs and assist policy makers in the design of policy instruments

Research Strategy The payoff is expected to be high for strategic research to improve the capacity to target soil conservation recommendations and to extrapolate research results A framework for characterizing the current and future status of the soil resource has been developed which recognizes the concepts of partial area focus hierarchal systems and small area spatial heterogeneity

The framework proposes that evaluation of the soil resource for environmental reporting needs large area and small area assessment with the goal of targeting activities and outputs by identifying the 10 percent of the area that causes 90 percent of the problem (partial area focus) Second that large areas like watersheds are internally organized into productive systems that have functions and priorities distinct from embedded small area systems like individual farms (hierarchical systems theory) Finally hillsides ecosystems are characterized by spatial heterogeneity over small areas This spatial heterogeneity is arguably the single most important factor controlling management decisions of agro-silvo-pastoral ecosystems in hillside environments and is the justification for the partial area concept

Current Highlights In the northern part of the department of Cauca Colombia a hierarchical system of land units predominantly embedded watersheds have been delineated The underlying frequency and spatial distributions of soil chemical properties and changes in soil quality due to effects of historical land use have been studied Historical soil analysis records made available by the Secretary of Agriculture of Cauca have been converted into a database which permits the analysis of temporal and spatial effects of long term land management A study to classify soil macrofauna biodiversity across a range of land management is nearly completed An appraisal of soil quality in terms of estimates of the irreversible loss of soil productivity expressed as potential yield is in it fourth cycle Contrary to expectations sites with long histories of cultivation show soil quality improvement rather than degradation

In Honduras databases of farm survey data supplied by the coffee federation have been georeferenced to create a GIS on which spatial and temporal correlation analyses have been initiated For example we tested the hypothesis that the main factors affecting coffee yields were climate gradient and soil quality Spatial analysis indicated no autocorrelation of yields which causes rejection of the hypothesis Other hypotheses related to indicators of resource quality are currently being tested across a wider geographic area with the help of the coffee federation

2 Hillsides Prototype Systems Project

Rationale The second Hillsides project on prototype systems addresses the deficiency that most current research on hillsides agriculture consists of site specific or single problem specific experimental work The Hillsides Program aims to derive principles of broad strategic validity both through its own field trials and also by bringing together and systematizing existing data from a large number of experiences In particular research on integrated crop/livestock systems has been weak

Research Strategy Long term research will be conducted to elucidate principles for the development of transition systems that enable farmers to gradually transform their production systems from dependence on monocropped or intercropped short season annuals with little or no livestock to systems with a major role for perennials including forage grasses and legumes as well as trees Such prototype systems must articulate with market opportunities to achieve acceptance

An important distinction between the strategy of this project and traditional farming systems research and its variants is the definition of system boundaries Traditional farming systems research focused on developing technologies for archetypical representative farms with the goal of approximating closed systems Economic variables were assumed to be exogenous and microeconomic factor analysis was the analytical tool of choice

Systems as considered in this project are open Research focuses on quantifying fluxes between systems and their environments Outputs of this project are targeted for the priority geographic areas and populations defined according to the partial area concept The target area is likely to be multiple-farm and the analytical tools of choice are ex ante predictive models

Current Highlights This project is unique in that it represents an initial move by CIAT towards a matrix approach organized around projects involving cross program responsibilities Research strategy and operational funds come through the Hillsides Program while technical leadership for research in Colombia rests with scientists deputed part time to the Hillsides Program from the Lowlands Program

Current activities include a well developed market research study based upon the hypothesis that pressure for change towards more sustainable land management results from expanding market opportunities In addition input-output functions for sustainable production practices are being defined in field trials with the aim of supplying the technical coefficients for decision support planning models

In Honduras the focus is on mulches and field trials and observations are elaborating the temporal and spatial effects of macuna continuing work begun by CIMMYT and Cornell University Also in Central America a study examining the adoption results of

about thirty projects focusing on conservation technologies is being carried out The objective is to test hypotheses about prerequisites for adoption using the pressure-state-response indicator model

3 Hillsides Participatory Methods Project

Rationale While the prototype systems and the soil processes projects are clearly related both also gain significantly through linkage to the participatory methods project Since conditions in the hillsides agroecosystem are so diverse effective decentralized systems for adaptive research are essential Moreover the factors determining acceptability of new systems or conservation practices are so varied and complex that client evaluations of these options are essential particularly where multiple stakeholders with different problems and objectives are involved

Research Strategy Better methods for participatory research and development to improve the design and adoption of technology is a social technology which complements soils and production systems research assisting for example in the evaluation and identification of superior technologies Methods are needed to insure that all and particularly the poorest segments of a given community have a voice in community driven R&D Additionally ways of strengthening community based diagnostic analytical and goal formulating capacities need to be identified

As the research focus moves from agricultural production*per se* to the broader issue of resource management many decisions are no longer made by individual farmers but by groups Hence methods for technology assessment have to be recast into a multiple stakeholder context in order to take into account and reconcile differing and sometimes conflicting interests For this reason significant resources are committed to designing and evaluating multiple-institutional community action groups

Current Highlights Activities related to this project include internationalizing earlier CIAT work on local farmer research committees (CIALs) funded by the Kellogg Foundation Training in promoting farmer led research has been carried out for Bolivia Brazil Colombia and Peru An evolution of the concepts has resulted in experiments with higher level organizations of multiple-stakeholder consortia both in Cauca Colombia and in Central America A major goal was achieved when the Colombian consortium was able to attract operational funds from national government sources

Another important activity resulted in development of a methodology for defining farm typologies according to a farmer-derived locally relevant social index of family 'wellbeing We have high expectations that classifying farmer households based upon this local social index will be significantly more relevant and useful for planning than the traditional methods of grouping according to rules based on simple parameters like climate elevation soil quality and farm size

4 Hillsides Decision Support Systems Project

Rationale The Hillsides Program s fourth project on decision support systems integrates elements from the soils systems and participatory projects As regional local and community based groups grapple with natural resource management issues they will need new information and decision support systems to facilitate collective evaluation and action

Research Strategy Strategic concepts incorporated into the framework of this project are a partial area focus systems applications and stakeholder participation in a guided workshop mode for analysis and compromise planning An important element of this project is the study of model assumptions about representative stakeholders For practical reasons units of analysis of supply and demand sources for goods services and resources may be considerably aggregated for example into a few representative typologies This simplification however almost always overstates resource mobility and is therefore biased against the more impoverished stakeholders By emphasizing participation of all interested stakeholders minimum data needs for analysis are defined on demand by the need to resolve contentious issues raised by stakeholders and not a priori by the tools of experts

Models will be developed of how land use practices affect resource quality in watersheds Methodologies will also be developed that incorporate stakeholders values into optional changes and enable them to 'visualize the consequences of alternatives Data and results from the soils systems and participatory projects would need to be integrated into these decision support systems

Current Highlights With significant collaboration from the CIAT Land Management group numerous GIS coverages and analyses including those based on remote sensed imagery have been realized both in Cauca Colombia and in Honduras Due to the degree of spatial heterogeneity found throughout the hillside ecoregion new sophisticated analytical techniques are being developed to create climate grid files digital terrain models and land use models Prototype studies are applying systems applications for ex ante land management analysis at the regional scale (laderas model) sub-watershed scale (aegis+) micro-watershed scale (topog irm) and farm scale (dssat farm model) In addition work is beginning on linking data based applications with knowledge-based applications (ales) The program is supporting training in systems applications at three Colombian universities and there is a high level of interest within several government agencies both in Colombia and Central America

PART III TROPICAL LOWLANDS RESEARCH

Overview In the view of some like Norman Borlaugh (Borlaugh N E and C R Dowswell 1994) the neotropical savannas constitute the last significant agricultural frontier in the world whereas for others it is a fragile and precious natural resource rich in flora and fauna and located in the basin of major American rivers The savannas of tropical South America extend over 250 million hectares and include the Cerrado (180-205 million ha) the llanos of Colombia (17 million ha) and of Venezuela (28 million ha) and large areas of Bolivia (14 million ha)

Over the last 40 years of so the neotropical savannas have been settled and therefore have been heavily intervened by human action (Vera et al 1992 and Tropical Lowlands Annual Report 1994) This has led the Cerrados for example to supply about a third of Brazil s rice and soybeans total production and 10-15% of its maize while at the same time housing approximately 30-40% of its national cattle herd Current estimates of sown grass pastures in the neotropical savannas amount to 40 50 million hectares while annual cropping varies between 10 and 12 million hectares per year In some countries sugar cane tree plantations and various other annual crops constitute major land uses Land distribution in the neotropical savannas is highly skewed as elsewhere in Latin America Nevertheless more than 50% of the farms in the Cerrados are less than 50 hectares in size

Although the situation is rapidly changing inappropriate technology has been used in much of the above areas Erosion soil chemical and physical degradation build up of pests in monocropped areas are common problems The impact of land use on flora and fauna have been scarcely assessed but constitute a major problem area given that the savannas are rich in both (for example the flora of the Cerrados may amount to 10 000 species) Furthermore there is abundant anecdotal evidence and also some quantitative estimates of significant contamination and siltation of major rivers (e g the Parana San Francisco and Orinoco rivers) as well as point estimates of unacceptable high levels of organo-chlorides and organo-phosphates in fish of some of these rivers Similarly the savannas are a major source of oil for some countries with subsequent road and other infrastructure development and further and rapid settlement and agricultural intensification

Rapid frontier expansion occurred also in the Forest Margins areas beginning in the 1960s Between 1970 and 1985 the rate of deforestation in the Brazilian Amazon was estimated at 1 5-2 0 million ha per year However there is still considerable opportunity for influencing future land use patterns since only 6% of that area has been cleared In the FM land concentration is lower than in the savannas but still high with a Gini coefficient of 0 79 in 1985 with small farms coexisting with large landlords Shifting cultivation by small holders was estimated to account for 32% of deforestation in 1980 There are large differences in land use patterns in cleared areas between countries and between regions within countries As an example 29% of the

cleared areas was dedicated to agriculture and 57% to pasture in the states of Acre and Rondonia Brazil in 1985 The consequences of this type of intervention in the tropical humid forests have been amply discussed in the literature and do not need further elaboration here

Program Goal The overall goal of the program is to develop and test a diverse set of sustainable land use forms for the acid soil savannas and forest margins of tropical America

Program Strategy Ideally these alternative land uses developed by the Program will combine increased productivity with preservation and even enhancement of the resource base and with improved equity It is realized of course that this ideal combination may be unattainable or only partially so and that if that is indeed the case tradeoffs have to be identified and quantified so that policy makers and society will be able to take decisions on a more informed basis Consequently the strategy to achieve the Programs goal revolves around three major inter related project areas

> The study of the dynamics and trends of land use patterns leading initially to biophysical and socioeconomic characterization of both agroecosystems identification of representative sites and extrapolation domains and later to modeling alternative scenarios
>
> Understanding of the biophysical and socioeconomic processes that affect resource management following a holistic approach at various degrees of resolution depending upon the specific processes under study
>
> Development and testing of alternative prototypes of agropastoral and agro-silvo-pastoral systems based on the understanding developed above

It was recognized from the outset that these objectives are too ambitious for a single Program and even for CIAT as a whole Therefore implementation of research projects in each of the above areas has implied close collaboration with a wide range of government and non-government institutions listed in various CIAT's documents (EPMR 1994 Funding Request 1995)

Up until the beginning of 1995 the Program had several projects in each of the above subject matters grouped for each of the main agroecologies namely Cerrados Llanos and Forest Margins (Funding Request 1995 and Program and Budget 1994-1995) These were consolidated at the beginning of the year such that there is a single Dynamics of Land Use project across the tropical lowlands a single Mechanistic Understanding of Soil Processes in Agropastoral and Sequential Crop Production Systems with subprojects for the Llanos and Cerrados respectively and a single

Prototype Sustainable Cropping Systems with subprojects for the Llanos Forest Margins and Cerrados respectively It is anticipated that this reorganization will lead to improved coordination and standardization across sites Each of the Program s projects will now be discussed in turn

1 Tropical Lowlands Dynamics of Land Use Project

Rationale This is a truly inter program project developed and implemented in collaboration with the Land Management SRG The overall purpose is to provide the basis for developing technologies and policies that contribute to sustainable agriculture by studying the dynamic processes underlying patterns of land use On a more short term basis this project has been developing databases on the spatial and temporal dynamics of land use which allow a detailed biophysical and socioeconomic characterization of the target agroecosystems identification of experimental sites and a gradually improving definition of extrapolation domains

Current Highlights A detailed characterization was carried out for approximately 60% of the Cerrados areas for which there is sufficient and consistent secondary information based on over 30 biophysical and socioeconomic variables (C Mueller H Torres and G Martine 1992 P G Jones M Rincon and L A Clavijo 1992) This was complemented by a further socioeconomic analysis was executed by a contracted NGO Both these studies were led by the Land Management SRG and involved a CIAT interprogram working group and Brazilian researchers from several different institutions They led to identification of high priority representative sites in the Cerrados Among these CIAT and EMBRAPA-CPAC choose Uberlandia to begin field work pending further and ongoing detailed analyses based on Rapid Rural Appraisals field Surveys and interviews with qualified informants and collection and analyses of additional secondary data

Detailed Rapid Rural Appraisals were carried out in several candidate areas for research on the Brazilian forest margins area namely areas in the states of Para Maranhao Acre and Rondonia These studies were carried out by interdisciplinary and interinstitutional teams and were supported by analyses of secondary data satellite images etc (M Avila 1994) It led to the selection of the stretch of land extending between Rio Branco Acre and Theobroma Rondonia as the initial site for research on the Forest Margins by both the TLP and the Alternatives to Slash and Burn global project

Ongoing but highly advanced studies on the dynamics of deforestation and its underlying causes and more generally on the dynamics of land use are being conducted by CIAT's Land Management SRG and TLP in the Acre-Rondonia site

Other ongoing studies in various stages of implementation are being conducted for selected areas within the Cerrados and Colombian Llanos As indicated above most

of the initial characterization is led by the Land Management SRG but involves continued consultation and collaboration with TLP staff

2 Tropical Lowlands Mechanistic Understanding of Soil Processes Project

Rationale The aim of this project is to improve the biophysical efficiency of agricultural production such that the efficiency of use of both internal and external inputs is maximized and environmental effects are minimized Ensuring maximum efficiency requires quantitative knowledge of underlying processes such as nutrient cycling and changes in physical and biological soil properties The project therefore seeks to quantify soil and soil/plant processes associated with changes in primary biomass productivity in contrasting land use systems that extend from no external input native savanna to intensive crop systems supported by medium levels of external inputs This project interacts most closely with the prototype sustainable cropping systems project described below

Due to resource constraints it has only been implemented in two savannas sites so far The set of experiments that form part of this project have been designed and implemented with EMBRAPA CPAC in Brazil and with CORPOICA, IFDC and CIRAD in Colombia Scientists from various other institutions are also involved in assessing other specific parameters (EPMR 1994)

Current Highlights It has been found that some deep-rooted introduced forage grasses can contribute substantial amounts of organic matter to the soil particularly when associated with productive well adapted legumes (Fisher M et al 1994) Although many questions about this phenomenon remain unanswered it does support the hypothesis that agropastoral systems that involve planned rotations of annual crops and perennial forage species contribute to soil enhancement and may even have positive effects in terms of global warming

A forage phase in the crop sequence has been shown to lead to increase soil biological activity increased soil fauna biomass and maintenance of its species diversity increased VMA infection potential and beneficial effects on nutrient partitioning in soil organic matter

Much improved and sensitive methods for soil organic matter and P partitioning have been tested and adjusted for acid soils These methods though more time consuming and expensive than traditional ones provide a much better understanding of P dynamics and appear to have more predictive power

A clearer and more quantitative understanding of N cycling in acid tropical soils generally low in organic matter has begun to emerge The relative roles of N cycling via faeces urine and litter has been quantified and a simple N cycling model with considerable predictive power has been developed

As implied above these research activities are long term and are therefore expected to provide more and significant outputs in the near future such as models of nutrient cycling and of physical and biological soil degradation and rehabilitation These models and the improved understanding that they represent will constitute the basis for the design of sound land use systems and policy

Various meetings workshops and seminars with scientific counterparts of Bolivia Brazil Colombia and Venezuela have insisted on the need that CIAT not only engages in this type of experimentation but that it also play a leading role as recognized by PROCITROPICOS (Minutes 1994)

3 Tropical Lowlands Prototype Sustainable Cropping Systems Project

Rationale In the present context cropping systems include both pastoral and perennial plantations components as well as annual crops Numerous alternative cropping systems are practiced by farmers throughout the lowland tropics these systems are under rapid evolution in response to changing economic and environmental conditions and rapidly changing technologies

The project seeks to build on existing farm-based systems in order to generate technologies land management strategies and policy options for the sustainable agricultural development of the target regions Research activities are supported by knowledge generated in both of the previously cited projects which provide the socioeconomic and geographic context and the required understanding of biophysical processes respectively

The project includes biophysical and socioeconomic monitoring of extant land use systems and on farm participatory evaluation of alternative systems These types of activities have been implemented with various degrees of intensity in three sites the Uberlandia region in the Brazilian Cerrados the area of influence of Puerto Lopez in the Colombian Llanos and the colonization projects of Pedro Peixoto (Acre) and Theobroma (Rondonia) in the Brazilian Amazon In all cases numerous other institutions are involved

Current Highlights A reliable method that combines use of SPOT images and ground measurements has been developed and tested in the Colombian Llanos to assess the extent and intensity of degradation of native savanna plant communities in response to various management practices Long term monitoring of fixed points is providing quantitative evidence on the relative resilience of different plant communities and may lead to identify keystone species as well

The yield and economic advantages of the (low external input) rice-pasture prototype system has been amply demonstrated Soil enhancement under this system has also been shown Nevertheless the precise niche(s) for this type of system still needs to

be defined Derived prototypes using new acid soil tolerant varieties of maize and soybeans are being tested

The positive effects in terms of land use and food production of integrating crops and cattle production have been documented for a small number of on farm case studies Nevertheless it is clear that these systems are management intensive

New and varied crop and forage germplasm has been introduced to the Acre-Rondonia site with the aim of diversifying and stabilizing agriculture in the deforested areas under the hypothesis that if successful the process should lead to decreased incentives for continued deforestation

Organizational Evolution The TLP resulted from the merging in late 1993 of the former Savannas and Forest Margins programs originally proposed in CIAT's Strategic Plan and implemented in mid 1992 (Tropical Lowlands Program 1994)

The Savannas program had its origin in the long presence of CIAT in the area through research carried out by the Rice Program and the former Tropical Pastures Program Savannas land resources as well as those of the rest of the South American tropical lowlands had been extensively characterized from a biophysical point of view by work carried out by the former Agroecological Studies Unit (AES) in the late 70 s and early 80 s

The stock of knowledge on the Forest Margins area was less and was primarily based on research undertaken by the former Tropical Pastures Program in the Peruvian Amazon (Ucayali department) and to a lesser extent the Napo department in Ecuador and Caqueta department in Colombia all of which used intensively the studies developed by the AES mentioned above

Merging those two programs was a pragmatic decision based on CIAT's financial difficulties experienced in the 1992 1993 period It made sense strategically in that both agroecosystems share a number of geographic and biophysical characteristics most notably acid soils of low fertility and that there is spatial continuity between them In effect all of the savanna countries namely Bolivia Brazil Colombia Guyana and Venezuela are also Amazonian countries This has implied that throughout much of the present century both agroecosystems have interacted closely as consequence of the movement of large segments of population along the savanna humid forest transition zone In countries such as Bolivia Brazil and Guyana this transitional area is currently subjected to rapid rural and urban development (Smith et al 1994)

Institutional relations The Program s strategies and research activities are only a small part of the set of actions required to achieve sustainable development of the tropical lowlands The Program is therefore actively developing collaborative studies

with a diverse suite of national international regional R&D institutions Formal projects and networks (i e the Agropastoral Research Network MAS etc) as well as numerous informal linkages have been and continue to be established (EPMR and Tropical Lowlands Annual Report 1994) Only few major partners can be listed here including CIAT Sta Cruz CORPOICA EMBRAPA and FONAIAP as national research institutions in Bolivia Colombia Brazil and Venezuela respectively universities such as National University U Javeriana and Technological University of the Llanos in Colombia UNELLEZ and U San Bolivar in Venezuela the Federal University of Uberlandia in Brazil Hohenheim and Gottingen universities in Germany Colorado SU Cornell and Ohio SU in the US and U Complutense in Spain various NGOs such as several cooperatives in the Cerrados farmers and cattlemen associations in Colombia and Venezuela ISPN in Brazil international institutions like IFDC TSBF and CIRAD regional consortia like PROCITROPICOS and international consortia like ASB

PART IV LAND MANAGEMENT RESEARCH

Overview Agricultural land use is highly dynamic in tropical Latin America with its rapidly changing agricultural frontiers The sustainability of food production is intimately tied to the forms of land use which are also related to important problems of environmental degradation from soil erosion to biodiversity loss with local regional and global impacts In Latin America sustainable development depends critically upon sustainable land use

The basic research themes of land management research focus around understanding land use changes the determinants and impacts of land management and the implications of land use changes for technology development and diffusion The major outputs are information and analysis that are useful for influencing policy making and contributing to the identification of the required design profile for sustainable technology

Goal The overall goal of the Land Management SRG is to improve the management of land resources in tropical America in a sustainable way

Research Strategy The achievement of this goal requires the causal analysis of trends in land use identification of systemic interlinkages and mechanisms and entry points for action and policy 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 incorporating aspects of both production and environmental quality and their evolution

The study of the patterns and dynamics of land use and the identification of indicators embrace not only the outcomes of land use but also the impacts of new technologies and policies on land use and the environment

Based on these studies policy alternatives for improved land use can be assessed and new policies that contribute sustainable and productive land uses can be identified CIAT generates policy relevant scientific information and assessment and works with local national and regional decision makers To this end CIAT is generating links with governmental and research organizations in the areas of agriculture the environment and development planning in a number of Latin American countries as well as with the private and NGO sectors

A systems perspective is used overall The research areas require an interdisciplinary core competence which at the moment is only partly achieved The scales involved belong mostly to the level of the farming system and above landscape agroecosystem and region Only in exceptional cases (namely the tropical climate database) has a global scale has been used

Land management research focuses mainly on three target agroecosystems savannas hillsides and forest margins Some of the projects have an ecoregional scope and some are of a methodological nature

The major clients of the land management research are policy makers at the national and regional levels and the NARD's CIAT's research on technology generation also benefits from land management research

The research strategy will be discussed in detail through the description of three major research themes which are supported by activities that involve the maintenance of the GIS laboratory facility including the updating of existing digital maps and data bases With the exception of the Land Management Scientific Resources Group SRGs do not implement projects As a consequence the names of its projects as appearing in the Annual Report 1994 reflect cost-centers rather than the scientific thrusts of the Group Strategic Themes will be used here to organize and explain the strategy and activities of the LM-SRG

1 Analyzing land use patterns at regional and continental scales

2 Understanding and anticipating trends in land use

3 Indicators of sustainable land use

Collaborative research with other CIAT Programs and Units is an important mode through which land management research is realized in the three major thematic areas The Land Management SRG collaborates extensively with projects of other

CIAT's Programs Units and Scientific Resources Groups In most cases the research falls clearly within the three research themes above Collaboration with Tropical Lowlands and Hillsides projects has been clearly focused on land use issues Collaboration with germplasm programs has also been significant on the issues of germplasm spatial distribution and germplasm environment mapping This work has involved the development of some specialized techniques The major research themes of t Land Management SRG are now discussed in turn

1 Analyzing Current Tropical Land Use Patterns at Regional and Continental Scales

Rationale It is widely recognized that because of the current rapid economic changes the pressures from the structural adjustment policies and other reasons the time-horizon of the political decisions adopted by the governments of the region has become drastically shortened This fact conspires against taking into account the ecological costs of agricultural development projects and policies costs that often reach their peak in the medium and long term

The problem is aggravated by the lack of scientific data that allows comparisons among geographical areas and countries the assessment of the production potentials for sustainable land use in relation to production obtained under current practices as well as integrated estimates of the economic resources needed to implement a sustainable development pattern in the region

One of the major limitations is due to the fact that agricultural production and yield statistics are usually provided according to political and administrative boundaries bearing little or no relation to the ecological units determining some of the major productive opportunities and limitations This situation seriously hinders the possibility of integrating ecological and economic considerations in the search for new sustainable production systems

Research Strategy An overall analysis of land use patterns in relation to environmental factors is therefore necessary at a range of scales and precision This requires building on the existing CIAT spatial databases and identifying further sources of data to enable a characterization of the region and an ability to study and map sustainability issues at these scales An understanding of land use dynamics is critical in incorporating the human factor in the analysis hence socioeconomic data has to be incorporated in the spatial databases

This theme concentrates on researching and understanding the relationships between existing land use patterns ecological and agroecological zones impacts of current land use on sustainability and potential environmental opportunities for sustainable land use

Current Highlights *Priority agroecosystems* The definition of the three priority agroecologies for CIAT using a GIS approach involving environmental social and economic variables as well as CIAT's commodity priorities The process led to the selection of the cleared margins of rain forests the well watered hillsides and the tropical savannas as priority areas for CIAT's resource management research This constituted a significant contribution to CIAT's Strategic Plan

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 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 complemented 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

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 was 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

Latin America protected areas A digital coverage of legally protected areas native reserves and national parks for Latin America was prepared and published including an environmental classification of those areas Climatic agroecologic and life zone maps were overlaid on the protected area coverage and an inventory of protected areas was produced showing their area for each environmental class The inventory highlighted the fact that montane rainforest dry tropical forests highlands and agriculturally productive lands have diminishingly small areas undisturbed and they are at a much higher risk than the larger tropical Amazonian rainforests

Resource degradation and land use in Latin America A new updatable digital map as an aid to planning for sustainable agricultural development 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 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 is to be used 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 information on land use and land degradation will be overlaid by the maps of natural ecozones to detect ecological conflicts or opportunities Socio economic data will assist in the analysis of poverty and its environmental associations

2 Understanding and Anticipating Trends in Land Use

Rationale There is a widening consensus in that many of the present patterns of land use in tropical America are destroying the ecological base for development and at the same time generating social problems and gross economic inefficiencies

While knowledge about individual causal factors affecting the rates nature and consequences of land use changes has been accumulating the complex interlinkages between the different types of factors (human and ecological) are much less understood Yet their interplay is what determines the total system s response Attempts to change some causal factors in isolation have often been ineffective or worse they have backfired

A systemic approach and the identification of different key situations could greatly help to devise new kinds of intervention to sustainability based more in the simultaneous application of gentle actions along a whole causal circuit rather than on a massive intervention upon on isolated factor or set of factors

Furthermore if fast and drastic whole-system restructuration can occur in the systems determining land use (as suggested by the evidence arising from studies on the behavior of complex systems) then it becomes of practical importance to understand which are the factors or processes defining the likelihood of those deep changes The degree to which those structural changes can be anticipated is also very relevant Situations approaching the threshold of structural changes should be treated specially both in technological and policy terms The knowledge gained along the described lines could contribute to the generation of new styles of land use management

The patterns of land use are influenced by many factors operating at different scales from the micro to the macro This issue is not restricted to the problem of aggregation across scales but it also includes the dynamical effects of the vertical cross scale causal linkages The treatment of the causal interactions between hierarchical levels in complex systems is a difficult methodological problem but of great practical importance The sustainability of land use may be influenced by events operating at different time and space scales and far away from the fields This is also considered essential both for the understanding of the role of the mutual interactions between the macro processes and the local patterns of land use and for the articulation between the 'top-down and bottom-up approaches to sustainable agricultural development

Research Strategy CIAT will develop the capacity to build and use complex dynamic intersectoral simulation models including nonlinear computer simulation models calculating changes in time of the state of systems including biophysical technological socio-economic and policy factors They will serve as tools for understanding and anticipating land use trends and for assessing possible policy options and to develop GIS-linked dynamic simulation models

The application to agroecosystem changes of the new Complex Systems neories will be explored (concerning self-organizing dissipative systems operating far from thermodynamic equilibrium hierarchical systems structural re-organizations chaotic behavior and strange attractors) The usefulness of the concept of agroecosystem health for agricultural research will be appraised

Methodologies will be developed to build up the capacity to perform land use scenario analysis (systematic identification and exploration of unfolding chains of events and branching points leading to different future land use patterns) at the regional and national levels

Current highlights *Diagnosis of Agricultural Land Use in Southwest Brazilian Amazon* This research was directed to characterize and analyze processes of deforestation in Acre and Rondonia in order to then identify test and adapt alternatives to slash and burn agriculture that would effectively reduce rates of forest conversion Activities included (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 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 Recent lower rates of deforestation seem to be responding to changes in those policies For areas with poor soils it may be impossible to slow deforestation by increasing productivity of rice

beans cassava and/or pastures by improving fallows or developing perennial crop based agroforestry systems For the very limited areas with better soils technological alternatives to slash and burn agriculture could be developed

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 (SSALLSSA) was completed with the formulation and submission of a 5 years project that is now being considered by the Dutch Ministry for Development Cooperation (DGIS) the same institution which supported it The project purpose is to identify and assess strategic and policy options for the sustainable use of the lowland savannas of South America 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 The project was designed through a participatory process and it was approved during a Workshop convened by CIAT 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 had the participation of high level representatives from national agricultural research centers agricultural ministries universities the private sector and NGOs and scientists from Wageningen and CIAT The project is given high scientific and political priority by the countries of the region

Simulation models of land use in the Cerrados and Forest Margins of South America Simple simulation models of land use for the Cerrados and Forest Margins were implemented The models calculate the transitions of between seven land categories in each agroecosystem in a yearly time step The models were run under alternative socio-economic and policy scenarios and the results were applied to the analysis of future trajectories of land use and their productive and environmental implications for the Inter Program Project Dynamics of Land Use reported by the Tropical Lowlands Program

Stochastic rainfall models Rainfall third-order Markov models for tropical areas have been developed which significantly improve prediction upon existing ones Those models are essential for agricultural risk assessment and they have been used by a collaborator in a major implementation for Burkina Faso and interfaced to the Famine Early Warning System of FAO Work is continuing on estimating the model parameters from data available in the climate database This will allow the construction of integrated coverages and contribute to the mapping of risk in cropping systems

3 Indicators of Sustainable Land Use

Rationale The setting of policies for sustainable land use in tropical America requires some way of measuring estimating and monitoring the degree to which the criterion of sustainability is being fulfilled While some indicators of specific conditions exist no satisfactory overall indicators of sustainable land use are yet available

One major priority is to develop test and apply a set of macro-level indicators of sustainable land use This requires a) developing a meaningful conceptual framework within which different classes of indicators can be identified (avoiding the pitfall of the shopping list syndrome) b) selecting and testing a set of specific indicators relevant for decision making and c) defining methods for using and combining the indicators in order to optimize their information value As sustainability is a systemic property rather than a property of any single component synthetic as well as analytical indicators will be required

On-going activities will be reinforced and negotiations with UNEP regarding the establishment at CIAT of a project for sustainability indicators for Latin America and the Caribbean are well underway The project will foster a wide participatory network including national and regional organizations and experts develop a regional framework enhance national and regional capacity to generate and use environmental sustainability information catalyze exchanges between producers and users of sustainability indicators and produce a bi annual report on the state of and progress towards sustainability in Latin America and the Caribbean This will not only represent a major step forward but it will also make available new sources of data to CIAT

At a more theoretical level it is expected that the envisaged activities in relation to Complex Systems could suggest new systemic indicators of sustainable level use

Current highlights *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 CIAT 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 LQI were discussed and proposed for the two agroecosystems As a follow up to the Workshop proposals for activities supported by the Bank have been prepared and are being discussed with the Bank

Assessing indicators of land quality for sustainable agricultural development in the latin american hillsides and savannas Many soil characteristics have been proposed as indicators of land quality Of these the soil organic matter is a prime candidate soil degradation is almost always accompanied by loss of organic matter However organic

matter loss usually occurs at the same time as the degradation it is thus of little predictive value The biological activity of the carbon pool may indicate incipient soil degradation before it becomes difficult to reverse This ongoing research is looking at the amount of soil carbon in different pools Highly labile carbon can be readily oxidized whereas stable carbon is left untouched by certain oxidants The ratio of the two measures can be used as an index of soil biological activity The study attempts to correlate such measures with more readily identified visual clues If this is successful these early signs may be detected by remote sensing

Organizational Evolution 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 Land Use Forest Margins Hillsides and Savannas The Land Use Program incorporated the former Agroecological Studies Unit (created in 1989) and it was formally initiated in 1992

As an outcome of the new Action Framework approved by the Board of Trustees five Scientific Resources Groups were created in February 1994 The Land Use Program became the Land Management Scientific Resources Group (LM SRG)

The CIAT wide External Program and Management Review in its Report of February 1995 recommended that the LM SRG be transformed either to a Program or a Unit depending on the orientation that CIAT considers more appropriate to its future It is expected that a decision will be adopted in the near future

Institutional Relations A major effort to create a network of new contacts with research institutions NGOs and international projects related to sustainable development and land use is being implemented Some of those contacts resulted in CIAT becoming a UNEP Collaborating Centre for International Environmental Assessment Reporting and Forecasting and in CIAT and the University of Guelph signing a general Letter of Agreement for cooperative activities New institutional contacts (additional to the habitual ones such as the University of Florida the Wageningen Institutes the World Bank the InterAmerican Development Bank the Ministries of Agriculture in Colombia and Latin America the Agricultural Research Institutes etc) 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 International NGO)
The United Nations University Tokyo

The International Institute for Applied Systems Analysis Austria
The Ministerio de Medio Ambiente Colombia
The Instituto Geografico Agustin Codazzi Colombia
The Colegio Verde (NGO) Colombia
The University of Kassel Germany
The Hohenheim University Stuttgart Germany
The National Geophysical Data Centre Boulder Colorado
The World Conservation Monitoring Centre Cambridge U K.
The United Nations Environment Programme (UNEP) Headquarters (Nairobi) and the Regional Office for Latin American and the Caribbean (Mexico D F)
The University of Washington Seattle
The University of Georgia GIS Laboratory Athens Ga
The University of Guelph Canada
The Dutch National Institute of Public Health and Environmental Protection (RIVM)
The Economic Commission for Latin America and the Caribbean (ECLAC)
Various Governmental Non Governmental and Private Sector institutions in Latin America in relation to the SSALLSSA Project and the Environmental and Sustainability Indicators Project

PART V PRODUCTION SYSTEMS & SOILS MANAGEMENT RESEARCH

Overview An integrated approach to soil-plant research 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 a deterioration in the natural resource base degrading soil and water resources increasing pollution and causing 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 This task requires an integrated research strategy that blends studies on biophysical constraints with socioeconomic and policy issues

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 substantially 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 These 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 socio-economic and policy context can be extremely important in determining how farmers manage their soil resources For example in the frontier areas of the savannas and the forest margins the price of land is relatively low thereby providing little incentive for investment in soils management since it is so cheap to simply clear new land At the same time due to high transport costs the use of inorganic fertilizers is extremely limited in frontier areas These and other factors dominate farmer decision making over their soil resources To improve soils management it is necessary to understand these socioeconomic factors and to take them into account in the design of management options

Research Group Goal The goal of the production systems and soils management Scientific Resource Group is to 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 (CIAT Action Plan April 1994)

Research Strategy· An integrated 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 approach is not valid for sustainable agricultural systems particularly in the tropics What is 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

Given this change of scenario it is now recognized SOM dynamics play a key role in the management of soils and yet our knowledge is meager requiring further study and 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

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 in order to assess their impact on ecosystem function

As mentioned above plant germplasm adapted to soil constraints also play a key role in the development of sustainable production systems and CIAT has the largest collection germplasm tolerant to acid infertile soils toxic levels of aluminum including rice beans cassava and tropical forage grasses and legumes

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/policy 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 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

Operational and Organizational Issues In the design of CIAT's organizational structure as noted above an explicit decision of the CIAT Board of Trustees determined that Scientific Resource Groups do not themselves implement projects which are thus currently all implemented either by Programs or Units

Thefore the Production System & Soils Management Research Group has the responsibility to propagate the research approach discussed above through a variety of projects implemented in different Programs The SRG provides a forum to bring together the mix of disciplines needed to undertake the task of achieving increased production systems without degrading the natural resource base The group supplies the necessary cross-discipline expertise to ensure that technological developments are linked with social economic and policy issues The group has been quite active in the design of projects that are of cross program interest

The formation of a Soils Research Unit was proposed in the April 1994 revision to the Action Plan The External Program and Management Review endorsed the creation of a soils unit in its report to the CGIAR in February 1995 The unit would be comprised of scientists working on soil and water related research activities within existing CIAT programs and the PSSM It has yet to be decided if members of the SRU would physically form a unit along the lines of other CIAT units or if they are to remain within the programs they are currently assigned to In this respect the SRU may differ from other support units in not having senior staff exclusively assigned to the unit

As the bulk of the analytical work for soils and plant research is handled by Analytical Services with only specialized methodologies handled by individual scientists the inclusion of the analytical services labs and staff within the SRU is proposed with representation at unit meetings of the head of analytical services

The SRU would also be concerned with the maintenance and updating of analytical procedures for soil chemical and biophysical studies ensuring that CIAT scientists use wherever possible the same methodologies internally which are consistent with internationally accepted methods (e g the Tropical Soil Biology and Fertility group manual A handbook of methods) The unit will monitor developments in analytical methodologies for research in soils and water management including sampling procedures the application of geostatistics for spatial studies and potential linkages with GIS

The unit would have responsibility for the organization of the sharing of equipment (e g the minirhizotron root washing equipment) whenever necessary and procedures for this should be discussed and prepared by the group

The unit couldl act as a forum for center wide issues related to analytical procedures for soil and plant samples and field equipment for research and oversee the functioning of the existing analytical services unit to ensure cost effectiveness and efficiency The unit could provide advice to the CIAT Institutional biosafety committee on the safety procedures for potentially hazardous analytical techniques (e g toxic chemicals radioisotopes)

The SRU could bring together scientists with expertise in soil plant relations with emphasis on soil related activities such as soil organic matter dynamics soil conservation and nutrient cycling They would support the programs by participating in inter program projects involving soils related work in natural resource management

The soils unit would also be a natural point of articulation between CIAT and the emerging Systemwide Initiative on Soil Water Nutrient Management (SWNM) of which CIAT is the co-convener with IBSRAM This initiative is attempting to bring together the somewhat disparate efforts on soils research carried out by various CGIAR and other international centers Five priority global themes have been identified that are being linked to ecoregional priorities As well as serving as global co-convener CIAT is also the convening center for the research theme on managing acid soils which has been linked to the CIAT sponsored MAS (managing acid soils) consortium

PART VI TOWARDS THE FUTURE

The increased attention to natural resources management research in CIAT since 1990 is both a renaissance and a creative innovation It has been both welcomed and questioned

In order to assist the Internally Commissioned External Review of Natural Resources Management this paper has attempted to give a brief overview of natural resources management research at CIAT The paper touches on the issues motivating the effort on specific goals and objectives on clear strategies on collaborative organizational arrangements and it reports some signs of progress

There is no doubting the need to seriously address problems of sustaining agricultural productivity and the natural resource base associated with agriculture in Tropical America The motivating force behind CIAT's effort is thus clear and incontrovertible

Nor can it be doubted that improving natural resources management is a complex challenge CIAT has endeavored to respond with an appreciation of the full complexity of the issues involved while at the same time concentrating its limited efforts This concentration of force has been achieved in three dimensions spatial thematic and organizational

Geographically CIAT has restricted its efforts to three priority agroecosystems neglecting others with which it might logically have been concerned (eg seasonally dry and fertile lowlands) Thematically CIAT has directed its attention to germplasm improvement production systems and soils and land management from the perspectives of farmer decision making and policy Organizationally CIAT has attempted to involve other institutions to participate in implementing a joint research agenda whenever possible

In this geographic thematic and organizational context CIAT has defined a limited number of natural resource management research projects each of which has clear goals and strategies each of which has real prospects of making a significant impact

These projects have emerged from an exhaustive process of external consultation and internal reflection embodied in a vast number of planning documents A CGIAR External Program and Management Review has strongly endorsed CIAT's approach while suggesting some modifications It is timely therefore to reappraise these efforts one more time to ensure that CIAT is making the best possible contribution to improved resource management

Table 1 CIAT Projects Contributing to Priority Agroecosystems by level of Systems Hierarchy

	HILLSIDES	TROPICAL LOWLANDS
Germplasm	Forage Program Projects Bean Program Projects Cassava Program Projects	Forage Program Projects Rice Program Projects
Management	Prototype Systems	Prototype Systems
Resource Processes	Soil Degradation	Managing Acid Soils
LandUse/Policy/ Institution Land Use Dynamics	Decision Support Systems Participatory Research	Land Use Dynamics

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ACRONYMS

AES	Agroecological Studies Unit
AROs	Advanced Research Organizations
CATIE	Centro Agronomico Tropical de Investigacion y Enseñanza
CGIAR	Consultive Group on International Agricultural Research
CIAL	Comite de Investigacion Agricola Local
CIAT	Centro Internacional de Agricultura(International Center for Tropical Agriculture) Colombia
CIAT-Sta Cruz	Centro de Investigacion Agricola Tropical (Bolivia)
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CIPASLA	Consorcio Interinstitucional para una Agricultura Sostenible en Laderas
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le Development (France)
CNPAF	Centro Nacional de Pesquisa em Arroz e Feijao
CORPOICA	Corporacion Colombiana de Investigacion Agropecuaria
CPAC	Centro de Pesquisa Agropecuaria dos Cerrados
CPAF	Centro de Pesquisa Agroforestal(Rondonia Acre)
CPATU	Centro de Pesquisa Agroforestal da Amazonia Oriental
DICTA	Direccion de Ciencias y Tecnologia Agricola (Honduras)
EMBRAPA	Empresa Brasilera de Pesquisa Agropecuaria
FM	Forest Margins

FONAIAP	Fondo Nacional de Investigaciones Agropecuarias (Venezuela)
GIS	Geographic Information Systems
IARCs	International Agricultural Research Centers
IIASA	International Institute of applied Systems Analysis (Laxenburg Austria)
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi Arid Tropics
ICSA	Interamerican Council for Sustainable Agriculture
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IICA	Instituto Interamericano de Cooperacion para la Agricultura
ILRI	International Livestock Research Institute
INTA	Instituto Nacional de Tecnologia Agropecuaria(National Institute for Crops and Livestock Technology) Nicaragua
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research (Netherlands)
ISPN	Instituto Sociedade Populacao e Natureza (Brazil)
LM SRG	Land Management Scientific Resource Group
LQI	Land Quality Indicators
MAS	Managing Acid soils
NARIs	National Agricultural Research Institutes
NGOs	Non Governmental Organizations
NRM	Natural resource Management

OM	Organic Matter
ONG	Non Government Organizations
PROCITROPICOS	Programa Cooperativo de Investigacion y transferencia deTecnologia para los Tropicos Suramericanos
PSSM	Production System & Soil Management Research Group
R&D	Research and Development
RIVM	Rijksinstituut Voor Volksgezondheid En Milienhygiene (Bilthoven Netherlands) National Institute of Public Health and Environmental Protection
SALLSSA	Strategies for Sustainable Agricultural Land Use in the Lowland Savannas of South America a CIAT coordinated project
SOM	Soils Organic Matter
SRG	Scientific Resource Groups
SRU	Soils Research Unit
SWNM	Soil Water and Nutrient Management
TLP	Tropical Lowlands Program
TSBF	Tropical Soils Biology and Fertility Programme
UNEP	United Nation Environmental Programme
UNELLEZ	Universidad Nacional Experimental de los Llanos Occidentales Ezequel Zamora