The Ecoregional Program for Tropical Latin America (TLAP) :

enhancing agricultural research effectiveness in Tropical America

Progress Report

Convening center: CIAT

Participating countries: Brazil, Bolivia, Colombia, Costa Rica, Ecuador, Honduras, Nicaragua, Peru, Venezuela

Participating international organizations: CATIE, CIAT, CIFOR, CIMMYT, CIP, CIRAD, ICRAF, ICRISAT, IFDC, IFPRI, ILRI, ORSTOM, PROCITROPICOS

Specialist organizations from: Germany, The Netherlands, and USA

Donors: EU, SDC, and BID

August 1997

CIAT
...nternacional de Agricultura Tropical
...ional Center for Tropical Agriculture

Contents

Executive Summary

The Ecoregional Program for Tropical Latin America (TLAP)

The Challenge

Improved crop and forage cultivars and management practices over the past 30 years have contributed to raising the potential for increasing food production in the main agroecosystems of tropical Latin America. However, other problems have emerged in:

(i) increasing degradation of the resource base of vegetation, soil and water and atmosphere,
(ii) continuing economic inequities among social groups,
(iii) lack of basic data and guidelines to influence policy initiatives to resolve these issues and
(iv) a reduction and realignment of resources for R & D due to opening up of national economies.

People and communities must be participants in the changes needed to ensure more sustainable development. This means involving both socio-economic and biophysical scientists in research on natural resources and development of new technologies with the participation of local farmers and communities. Because resources are limited, there is a need to focus on research areas that will exert most leverage for beneficial change or development.

The solution to improved natural resource management requires a multi-disciplinary approach and close collaboration among organizations. The agroecosystems are themselves diverse. Hence a regional approach to identify common problems, develop solutions and principles for technology and policy options is seen as an efficient use of limited resources.

This involves developing wider partnerships and integrating research efforts of international and national organizations. This ecoregional approach is now widely accepted but still in an evolving stage of development.

The Ecoregional Program for Latin America - chronology

CIAT was invited by the Consultative Group on International Agricultural Research (CGIAR) to develop a strategic alliance among international centers and national programs for research on sustainable land use in tropical Latin America. We consulted widely with our international and national partners over the last three years on developing this collaborative approach to sustainable development of agriculture. The main outcomes of these meetings were:

(i) ecoregional research should focus on the area of natural resource management

(ii) the ecoregional program should both support and complement existing agroecosystem research consortia in the forest margins, hillsides, savannas and high Andes

(iii) complementation would include enhanced capacity for prioritization and design of natural resources research, improved methods for site selection and extrapolation to similar sites

(iv) there should be a mechanism to link policy analysis with strategic research and technology developments

Organizations agreed in principle to assign some of their own resources to this ecoregional research and together to seek additional funding to complement existing research.

Special Proposal - Enhancing agricultural research effectiveness in Tropical America

CIAT submitted this proposal in support of the TLAP to the Technical Advisory Committee (TAC) of the CGIAR on behalf of other participants. The following components were approved for funding in 1996/1997.

***Purpose*:** To enhance the effectiveness of agricultural and natural resource management research in tropical America by improving the capacity to define productivity problems, to develop solutions to these problems, and to extrapolate results across the agroecosystems and the region as a whole.

Output 1. Enhanced cross country/agroecosystem analysis

***Specific objective*:** To improve the capacity for priority setting and extrapolation of results through development of comprehensive environmental and agricultural data bases for the Forest Margins, Hillsides, High Mountain, and Savanna Agroecosystems in tropical America.

The output will allow several key issues to be addressed:

- rates of change in resource degradation and agricultural productivity
- improved site selection for research and for extrapolation of results
- enhancement of collective decision making on land use practices and policy
- conservation of biodiversity through in-situ conservation

Activities to date:

Latin American Crop Density Mapping. Mapping has commenced of major crops such as wheat, maize, potatoes soybeans and sorghum and the grazing lands in addition to updating the information for the CIAT mandate crops, beans, cassava and rice. This is being done in collaboration with Ministries of Agriculture and other government organizations. In conjunction with this effort, a map has been constructed of administrative boundaries of Latin America so that data can be stored in vector GIS format. However, as the vector format has deficiencies in plotting distributions within administrative units and for modeling, a conversion will be made to a raster format using a vector to raster redistribution model developed for population analysis. Methods will be checked against more conventional methods and verified by experts in each country.

Land degradation survey. A literature survey was conducted and a database established of experts working on various aspects of natural resource management. From an initial mailing list of 900 professionals, 200 have been selected and have accepted the invitation to participate in the land degradation survey. Participants have been sent a master base map constructed from secondary data. They are being asked to identify areas on the maps that correspond to different levels and types of degradation.

Collaborative projects have been initiated with the Ministry of Social Welfare, Ecuador, on poverty mapping and with the Institute of Statistics and Information (INEI), Peru on mapping activities and the environment. CIAT also participated as a moderator for an Internet discussion group on land degradation facilitated by the Bolivian Center for Remote Sensing of Environment (ABTEMA).

Population data for natural resource and agricultural development. Population data was collected for the continent and linked to other digital maps. One of the problems encountered, as with crop data, is that data across countries is not standardized. Corrections are being made to bring data to a common date and to allow for uniform comparisons such as urban-rural, gender and age.

Economic model for assessment of research priorities. Models are being developed for the agro-ecological zones defined through GIS analysis. Models of each zone are being used to characterize current and planned research.

Output 2. Methodology for Watershed or 'Partial Area' Level Research

Specific objective: To develop more effective methods for identifying and prioritizing natural management research at the watershed level in the Central American Hillsides, Forest Margins, High Mountain and Savanna agroecosystems.

The outputs will be used for:

- defining and solving productivity and sustainability problems within a specific watershed,
- transferring information across watersheds within an agroecosystem and
- analysis at a higher level of aggregation.

This research is closely linked to existing research consortia in the four agroecosystems and to research being conducted by other Systemwide Programs such as Alternatives to Slash and Burn, Livestock and Soil, Water and Nutrient Management. Research programs will often merge and thus coordination is used to ensure complementarity or collaboration.

Activities to date:

High mountain agroecosystems. Under this project, a study has commenced to utilize radar images to improve the elevation model in the GIS database in the Angel and Encanada watersheds, Carchi, Ecuador, with collaboration of ECOCIENCIA. This is necessary because of the difficulty of using satellite images in areas of high cloud incidence. Land use is being mapped. Critical studies are being focussed on water use including the consequence of clearing areas of natural high altitude grassland (paramo) on the hydrological water balance and the efficiency of use of irrigation water. It was found that infiltration of water into cultivated crops was increased in comparison to that in the paramo. A comparison is now planned between forest and managed lands. Models are being used to estimate the trade off between production, conservation and equity with respect to different levels of water retention in the paramo.

Central American Hillsides. A decision support model is being developed to assist decision-makers in quantifying the effects of erosion in land use planning. Slope and ground cover are the dominant indicators of soil erosion risk. The first is estimated from a digital terrain model and potential overland water flow calculated. Inclusion of ground cover obtained from remote image analysis provides a more accurate approximation. For areas of high risk, soil erodability parameters are obtained by strategic soil sampling of sites identified from the preceding analysis. Using process level crop models to test the outcomes of selected land use scenarios extends analysis of erosion risk further.

Forest Margins. Socio-economic characterization is being carried out at the Pucallpa reference site through a survey of local farmers and analysis of satellite and radar images over the period 1972-1996. Changes in plant biodiversity and carbon emissions are being estimated and ecological studies are being made on the resilience of different vegetation systems. A land use model is being developed based on farmer decision-making rules.

Savannas. Improved-grass pasture and crop production systems have expanded rapidly in the savannas but soil degradation has become a major problem. In order to understand and reverse this process, nutrient dynamics and soil physical characteristics are being studied under different crop-pasture-green manure sequences, in long term trials, to develop indicators for land use sustainability. Process models are being modified for the tropical conditions of the savannas. Some form of crop-pasture rotation appears imperative to maintain desirable soil physical and soil biological characteristics.

Output 3. New technology components

***Specific objective*:** To develop new sorghum cultivars for the acid soil savannas

Activities to date:

1200 introductions have been screened for disease resistance and selected lines are now being evaluated at three sites that have varying levels of soil Al saturation. An improvement program has been commenced.

Training has been provided to national scientists from Colombia and Venezuela.

Output 4. Strengthened NARS capacity

***Specific objective*:** Involve NARS partners in the development of data bases, methods, models and information systems.

This will be achieved through:

- International workshops
- Training on an individual basis
- Evaluation of the utility and adaptation of methods and models by NARS scientists
- Provision of bibliographic and information services

***Activities to date*:**

Training in methodology. A workshop was held in Nicaragua of national scientists involved in GIS studies in Central America to coordinate these activities.

Individual training. Several scientists from have spent short periods of assignment with the Land Management and GIS units.

Ecoregional Research – an evolving program

CIAT and its partners are involved in a more comprehensive research program of ecoregional research in Latin America than those areas specifically approved for funding by TAC under the initial TLAP proposal. In particular, this applies to germplasm improvement, to in-depth studies on soil nutrient and macrofauna dynamics, and to integration of germplasm improvement and natural resource management through system-based farmer participatory technology development.

Increasingly, the overall natural resource management effort in Latin America is being focused on the Central American Hillsides, the Forest Margins in Peru and the Savannas in Colombia, and in particular, the main reference sites, while that of CONDESAN led by CIP has reference sites in four Andean countries. This work on the reference areas and agroecosystems is linked through GIS referenced data bases being developed for the whole continent. There is also a collaborative regional program on policy research with IFPRI.

The main reference sites for the Ecoregional Program are:

- Forest margins	Pucallpa, Peru
- Hillsides	Central America – La Ceiba, Yoro, Danli (Honduras), Matagalpa (Nicaragua)
- Savannas	Llanos, Colombia and
- High Andes	Cajamarca (Peru) (through the CONDESAN initiative led by CIP)

There are also associated sites for each agroecosystem, viz. Forest Margins (Yurimaguas, Iquitos in Peru; Acre, Rondonia in Brazil); Hillsides (Cauca in Colombia); Savannas (Uberlandia in Brazil) and CONDESAN has other principal sites in Bolivia, Colombia, Ecuador and Peru.

A comprehensive program is being developed at each of main reference sites in the areas of:

a. Consultation or development of a framework for guiding decisions on R & D interventions
b. Socio-economic characterization and analysis of land use dynamics
c. Germplasm evaluation
d. FPR technology development and investigation of land use alternatives
e. Soil, water and nutrient management dynamics under different forms of land use
f. Investigation of new agro-enterprise alternatives
g. Assessment of economic and environmental impact
h. Policy analysis

Role of CIAT

CIAT acts as a facilitator to catalyze efforts of IARC's in the priority agroecosystems working within a framework for regional priorities set by the different countries in the region as a whole and by national organizations for the reference sites. The key to synergy is through the development and acceptance of a common vision, definition of objectives and collaboration in the activities needed to achieve this vision.

Within CIAT, the mechanism for coordinating the Ecoregional Program operates at two levels, regional consultation and information sharing and agroecosystem problem solution. The Director, Regional Cooperation, maintains close liaison at the national levels of government providing information on the Program and obtaining feedback on government priorities. The Director, Resource Management, is responsible for translation of this feedback into setting of priorities and coordination of activities within the Center and between organizations at each reference site.

The Ecoregional Program for Tropical Latin America (TLAP) :

enhancing agricultural research effectiveness in tropical America

The Challenge

Improved crop and forage cultivars and management practices over the past 30 years have contributed to raising the potential for increasing food production in the main agroecosystems of tropical Latin America. However, other problems have emerged.

The main concern is that these productivity increases will not be sustainable due to increasing degradation of the natural resource base of vegetation, soil and water. National funds for natural resource research are limited except in Brazil. There are difficulties in defining the principal sustainability problems and in access to appropriate methodology to deal with them. In turn methodology development depends on having basic data organized in accessible databases. Then there is a need for guidelines to influence policy makers once there are apparent solutions to resource degradation.

Another concern is the continuing economic inequity among social groups in tropical Latin America and association of resource poor farmers with degraded land or settling in marginal lands that are sensitive to resource degradation. There needs to be a mechanism to involve people and communities in the changes needed to ensure more sustainable development. This means involving both socio-economic and biophysical scientists in research on natural resources and development of new technologies with the participation of local farmers and communities.

Research on natural resource management tends to be site specific. Therefore mechanisms and methodologies are needed that will allow results to be extrapolated to similar areas. This can most readily be achieved within well-defined agro-ecological zones. Also as resources are limited, there is a need to focus on research areas that will exert most leverage for beneficial change or development.

It is evident that the solution to improved natural resource management requires a multi-disciplinary approach. The agroecosystems are themselves diverse. Hence a regional approach to identify common problems, develop solutions and principles for technology and policy options is seen as an efficient use of limited resources. An ecoregional approach will allow us to fill gaps in the coverage of natural resource management, to rationalize inputs by different institutions that focus on specific mandates and to provide a framework for coordinating activities within an agro-ecoregion.

This involves developing wider partnerships and integrating research efforts of international and national organizations. This ecoregional approach is now widely accepted but still in an evolving stage of development.

The Ecoregional Approach

The Ecoregional Program for Tropical Latin America (TLAP) is based on strengthening ongoing CGIAR research activities that draw on strategic global research and linking these in partnerships with national programs in order to address the technical and human dimensions of sustainable productivity in priority agroecosystems. Four agroecosystem consortia provide an essential framework for the Ecoregional Program.

- the CONDESAN network for the high altitude Andes in which CIP has served as the lead center for the CGIAR system and CIAT, ILRI and CIMMYT are participants.

- the Alternatives to Slash and Burn (ASB) Program focussing on the margins of the lowland tropical forests. ICRAF is the lead center for the CGIAR and CIAT, CIFOR, IFPRI and ILRI are participants.

- the Central America Hillsides Program in which CIAT is serving as lead center for the CGIAR. CIMMYT and IFPRI are CGIAR, and CATIE and IICA regional participants.

- the Savannas Consortium which operates under the umbrella of the IICA sponsored PROCITROPICOS consortium. CIAT serves as the lead center for the CGIAR and ICRISAT and IFDC are participants.

The TLAP provides a platform for interaction between CGIAR, regional and national organizations in the four agroecosystems and, in particular, at reference sites in these agroecosystems. Regional research comprises compilation and analysis of continental databases and policy analysis. The agroecosystem research is focused on reference sites in each of the agroecosystems. These are Pucallpa, Peru, for the Forest Margins, a transect across Honduras and Nicaragua for the Central American Hillsides, the Llanos, Colombia for the Savannas and sites in Bolivia, Colombia, Ecuador and Peru for the High Andes.

Research in the CGIAR is also coordinated through Systemwide Programs. Those with activities in tropical Latin America include the Livestock Program, convened by ILRI, the Soil Water Nutrient Management Program jointly convened by CIAT and IBSRAM, the Participatory Research and Gender Analysis Program convened by CIAT and the Integrated Pest Management program convened by IITA. Where possible research within these Systemwide Programs is also focused on the reference sites for the TLAP.

Currently, the Inter-American Development Bank (IDB) is initiating a mechanism to support agricultural research of international significance in the region. The proposed Capital Fund for Agricultural Research in the Americas will have interests in the region that extend beyond those of the CGIAR system. Nevertheless the CGIAR will maintain close linkages with this new Fund in implementation of research activities and as a major forum for the definition of research priorities from a regional perspective.

It is the above context that CIAT has been requested by the CGIAR to serve as convening Center for the Ecoregional Program for Tropical America. The convening role entails a responsibility to insure the facilitation of linkages among these diverse interests and activities without in any sense presuming to involve an overall coordination of their execution. This can be achieved by providing services that complement ongoing activities and encouraging linkages among them. There are major opportunities to exploit spillovers among these activities in terms of the development of common methods and data bases as well as the sharing of research sites, data, and other information.

Design Phase

Extensive consultation was carried out to design an ecoregional program that is responsive to the needs of stakeholders in Latin America.

1. In August 1994, a meeting of regional partners, that included participants from CATIE, CIAT, CORPOICA, IDB and IICA, was convened in San Jose, Costa Rica. The outcome was a proposal focussed on the hillsides of Central America to include the following outputs: (I) an updated map of target ecological zones, (ii) simulation models embracing agriculture and natural resource processes, (iii) relevant GIS data bases for the ecoregion, (iv) a small cadre of professionals trained in natural resource management strategies, (v) an ecoregional consultation mechanism, and (vi) organizational and funding arrangements for long-term ecoregional projects.

2. In December 1994, a second meeting was convened in Cali, Colombia in December 1994 with the participation of CIAT, CIMMYT, CIP, ICRAF, and IICA, to consider the comments of the Technical Advisory Committee (TAC) for the CGIAR on the initial proposal. This meeting recommended that the ecoregional proposal to TAC should reflect the need to support the various agroecosystems research consortia already operational in the region:

- Global Alternatives to Slash and Burn led by ICRAF
- CIP initiative for high mountain agriculture
- Central America consortium of CIMMYT/IFPRI/CIAT
- Savanna Consortium of PROCITROPICOS/IFDC/CIAT

In addition, it was agreed to introduce an ecoregional mechanism that would provide services to the agroecosystems research consortia as well as to conduct research on interactions among agroecosystems and develop a regional analytical capacity for prioritizing, targeting and extrapolating research and its results.

It was emphasized that the ecoregional mechanism would not be placed in a coordinating role "above" the agroecosystems consortia, but rather it would coordinate the provision of services for which there are central economies of scale (e.g. some policy research, continental scale data bases and models) It would also coordinate the development and implementation of research funded by the ecoregional program but implemented by individual consortia. This research would be part of an agreed agenda dealing with methods development, information exchange, cross agroecosystems research, and stakeholder strengthening.

3. In February 1995, these concepts were embodied in the proposal submitted to TAC. The proposal was again reviewed and included changes introduced by CIMMYT, CIP, ICRAF, IFPRI and IICA. Specifically, this proposal aimed to complement the existing consortia by assisting in national program strengthening as well as in the delivery of three research outputs:

i) Enhanced capacity for cross country prioritization and for design of natural resources research.
ii) improved methods for site selection and extrapolation among watersheds within agroecosystems.
iii) Methods for identifying and prioritizing natural resource problems at the watershed level.

4. In April 1995, a consultation meeting was held in Cali, Colombia, with NARS, regional institutions, and CGIAR Centers active in the four agroecosystems consortia. Participants included representatives from Brazil (EMBRAPA), Colombia (CORPOICA and the University of the Andes), Honduras (National Autonomous University), Nicaragua (INTA), and Venezuela (FONIAP and PALMAVEN). Regional institutions represented included CATIE, CONDESAN, IICA, PROCIANDINO, and PROCITROPICOS while international centers included CIAT, CIMMYT, ICRAF and IFPRI.

At this meeting there was full consensus on the utility of an ecoregional program that would support and act with the four participating consortia. It was made clear that the four consortia would operate under their existing governance and that an ecoregional program would be a mechanism for methods development and information exchange at the watershed, agroecosystem and regional levels.

The CGIAR Centers in the region agreed that the Ecoregional Program would act as a platform for a wide variety of inter-center collaborative research activities in Latin America and the Caribbean.

5. In July 1995, the proposal submitted by CIAT "An Ecoregional Approach to Enhancing Agricultural Research in Tropical America" was endorsed by TAC which welcomed "the spirit and focus of the proposal to support and foster externalities among a variety of research activities that have an ecoregional dimension." TAC recommended an allocation of funding of US $900,000 to initiate the program in 1996.

6. Based on this endorsement a further process of consultation was initiated with the four agroecosystems consortia to design a program to initiate in 1996.

For the Central America Hillsides, a meeting was held in Tegucigalpa, Honduras, in September 1995, among representatives of CIAT, CIMMYT, IFPRI and IICA to discuss activities for the Central American Hillsides. The meeting confirmed the approach mentioned above and decided to concentrate activities in Honduras and a workplan was developed with technical personnel.

For the Savannas, a consultation was sought at agropastoral workshop in Santa Cruz, Bolivia, in September 1995, attended by some 40 researchers from National Agricultural Research Institutes, universities, NGO's and private industry from Bolivia, Brazil, Colombia, and Venezuela as well as scientists from CIAT and ICRISAT. A workplan and budget for 1996-97 was developed from these discussions.

Concurrent with the agropastoral workshop, a satellite meeting was held on sorghum improvement for the savannas with NARS representatives, ICRISAT and CIAT. CORPOICA of Colombia offered to host the program to be implemented with the technical assistance of ICRISAT and coordinated by CIAT. This is an example of the ecoregional program being used to draw on the global expertise of an international center to meet the specific needs of a particular agroecosystem.

For the High Andes, ecoregional research was planned at the meeting on Sustainable Mountain Agricultural Development Program organized by CIP in Lima, Peru, in October 1995, attended by representatives of CIAT and the CONDESAN consortium embracing the NARS of Bolivia, Colombia, Ecuador and Peru. Subsequently, in January 1996, a detailed planning meeting for research in the Rio El Angel site in Ecuador, site was held in Quito, Ecuador, with the participation of FUNDAGRO and FLACSO of Ecuador, and CIAT, CIP and IIMI from the CGIAR.

For the Forest Margins, consultation took place at a PROCITROPICOS meeting held in Pucallpa, Peru, in October 1995, to plan regional collaboration in research in the forest margins. Participants included scientists from Bolivia, Brazil, Colombia, Ecuador and Peru and from CIAT, ICRAF, and IICA. At this meeting, agreement was reached to coordinate a joint program of strategic research principally in Pucallpa, Peru, associated with the Global Alternatives to Slash and Burn Program.

7. The strategy of the Ecoregional Program was presented to PROCITROPICOS and PROCIANDINO for their comment and review at their meeting November 6-9, 1995 in Cartagena, Colombia. CIAT presented the overall ecoregional strategy while CIP presented the CONDESAN network as an example of an agroecosystems consortium within this framework. In addition, CIAT-IFPRI-IICA research on models for prioritizing agricultural and natural resource management research at a regional or continental basis was presented and endorsed.

8. Subsequently, in November 1996 a regional research priority setting workshop was organized by CIAT, IFPRI and IICA and held in Cali, Colombia. The meeting focused on the tools for setting priorities, past activities this area in the region and giving guidance on the optimum means of implementing prioritization studies at the sub-regional level. Four sub-regions and collaborating networks were identified to undertake studies: PROCISUR (southern South America); PROCIANDINO (Andean countries); PRIAG (Central America); and CARDI (Caribbean).

9. Attention was also given to linking emerging Systemwide Programs to the Ecoregional Program. CIAT represented the ecoregional program at the ILRI consultation on its Global Agenda held in October,1995, in San Jose Costa Rica and hosted a Systemwide Livestock Program (SLP) planning meeting in Cali, Colombia in December, 1995, to implement research on feeding systems for dual-purpose cattle (Tropileche Project). Research will conducted at ecoregional sites for the Forest Margins, in Pucallpa, Peru, and in the Central America Hillsides, initially in Costa Rica, but subsequently in Honduras and Nicaragua. In December,1995 a meeting of the acid soils research theme of the Systemwide Program on Soil Water Nutrient Management was held in Cali, Colombia. Research is being concentrated in sites in Colombia and Brazil that have already been identified as primary sites for the Savanna Research Consortium of the Ecoregional Program.

The Ecoregional Research Project

Program Goal

To improve management of natural resources devoted to agriculture in Tropical America in order to permanently reduce poverty and hunger, maintain resource quality, and increase agricultural productivity.

Project Purpose

To enhance the effectiveness of agricultural and natural resources management research in Tropical America by improving the capacity to define and understand productivity problems in agriculture; to develop and adapt suitable solutions to these problems; and to extrapolate results among agroecosystems through the development of geo-referenced information systems and analysis.

Overview

The central outputs of the Ecoregional Research Program focus on enhancing the capacity to prioritize, plan, target, and extrapolate research on natural resource management and agricultural productivity in Tropical America. It is attempting to achieve this by combining efforts at the local, national and regional levels, while taking advantage of inputs from the international agricultural research system.

Agro-ecosystems, defined as recurring patterns in land use, the bio-physical environment, and the socio-economic context, are useful units of analysis for the definition of common problems, the design of technological and policy options, and the interchange of research results for adaptation at the local level. Ultimately new technologies and practices are implemented at the local or watershed level, and natural resource degradation processes and limits to agricultural productivity emerge from specific conditions at the watershed level.

Thus, methods are needed to design solutions and prioritize problems at two levels, the agroecosystem level and the watershed or local site level. At the same time, methods are needed to enable information to be meaningfully exchanged across these different levels. Specific observations in particular sites in watersheds aggregate into common findings across agroecosystems, while agroecosystems recur over international boundaries giving scope for economies in the assembly of information and in the implementation of problem solving research.

The central outputs of this project will be improved methods for research planning and implementation at different levels. These methods will vary with scale but can be made communicated across scales and across countries by linking data and analysis to geo-referenced information systems and models. Strengthening national and local capacity to use such an approach will also a key output the project.

An associated set of outputs will be key technology components that are of priority interest to agroecosystems in the region. An example is sorghum germplasm for acid soils.

Output 1. *Enhanced cross country/agroecosystem analysis*

***Specific objective*:** To improve the capacity for priority setting and extrapolation of results through development of comprehensive environmental and agricultural data bases for the Forest Margins, Hillsides, High Mountain, and Savanna Agroecosystems in tropical America.

The output will allow several key issues to be addressed:
- rates of change in resource degradation and agricultural productivity
- improved site selection for research and for extrapolation of results
- enhancement of collective decision making on land use practices and policy
- conservation of biodiversity through in-situ conservation

Highlights

- Mapping commenced of mandate crops of other organizations – maize, wheat (CIMMYT), potato and sweet potato (CIP), sorghum (ICRISAT), soybean (EMBRAPA); and grazing lands with updates for beans, cassava and rice (CIAT).
- Database established of experts in natural resource management who are assisting in the estimation of land degradation; collaborative projects established with Peru and Bolivia
- Population data for LAC has been linked to digital maps.

Activities to date:

Sub-Output. *Latin American Crop Density Mapping*

Maps of crop distributions are critical for commodity studies, agro-ecological modeling, and numerous environmental applications. Perhaps the most basic need is to know how many hectares have been cultivated and where the cultivation has occurred. Agro-ecological modeling can help to determine if farmers are growing the most appropriate crops for the given biophysical environment. The crop distributions support modeling of climatic and other environmental changes and their effects on agriculture. For example, modeling of expected changes in crop distributions caused by global warming requires accurate maps of the current spatial extent of crops. Crop distributions will be critical for our continental-scale land degradation research. They will allow us to make the link between environmental degradation and agriculture.

In the past, CIAT has developed digital maps of crop distributions and densities for Latin America, Africa, and Asia, focussing on the CIAT commodities. In 1996, as part of the Ecoregional Project for Latin America, we have initiated a program to improve our contacts with crop data providers, update our previous crop distribution maps, map new crops, and automate the process for future updates.

The Land Use Project (LUP) is collecting the most recent crop distribution data at the best available geographic resolution for the 21 mainland Latin American countries. We established contacts with the Ministries of Agriculture and other government organizations that manage the crop data and other data related to agriculture and natural resources (**Table 1**). We collected some of the data during visits to the countries and other data by mail and through the Internet. The range of dates of the source data points out only one of the difficulties of merging data from individual countries. The geographic detail of the data also varies. For example, Honduras recently completed a relatively detailed agricultural census; in contrast, Costa Rica's last census

Table 1. Continental-level data collected for use in land use mapping

INFORMACION EXISTENTE DE CENSOS POBLACIONALES

PAIS	POBLACION				División Geográfica	Digital	Año de la Información
	Rural	Urbana	Hombre	Mujer			
CENTRO AMERICA							
BELICE			X	X	Departamento	X	1991
COSTA RICA			X	X	Municipio	X	1996
EL SALVADOR					Municipio	X	1992
GUATEMALA	X	X	X	X	Municipio	X	1992
HONDURAS	X	X	X	X	Municipio	X	1988
MEXICO					Municipio	X	1990
NICARAGUA	X	X	X	X	Municipio	X	1995
PANAMA					Municipio	X	1995
SUR AMERICA							
ARGENTINA					Municipio	X	1991
BOLIVIA			X	X	Municipio	X	1992
BRASIL			X	X	Municipio	X	1991
CHILE	X	X	X	X	Municipio	X	1992
COLOMBIA			X	X	Municipio	X	1993
ECUADOR	X	X			Municipio	X	1990
GUYANA			X	X	Departamento	X	1991
GUYANA FRANCESA					Departamento	X	1990
PARAGUAY					Municipio	X	1992
PERU	X	X	X	X	Municipio	X	1993
SURINAM			X	X	Departamento	X	1993
URUGUAY					Departamento	X	1993
VENEZUELA			X	X	Municipio	X	1990

Table 1. (*continued*)

INFORMACION DE CULTIVOS

PAIS	Area cultivada	Cantidad cosechada	DATOS		División Geográfica	Año
			Digital	Libros	Nivel	
CENTRO AMERICA						
BELICE	X	X		X	País	1994
COSTA RICA	X	X	X	X	País	1993-95
EL SALVADOR	X	X		X	Región	1994
GUATEMALA	X	X	X	X	Departamento	1989-95
HONDURAS	X	X	X		Municipio	1993
MEXICO	X	X		X	CD	1991
NICARAGUA	X	X		X	Departamento	1995
PANAMA	X	X		X	Municipio	1990-91
SUR AMERICA						
ARGENTINA	X	X	X		Departamento	1991
BOLIVIA	X	X		X	Departamento	1987-95
BRASIL	X	X	X		Municipio	1993
CHILE	X	X	X		Región y País	1979-94
COLOMBIA	X	X		X	Departamento	1993
ECUADOR	X	X	X		Departamento	1991-93
GUYANA	X	X	X	X	Región	1993-94
GUYANA FRANCESA	X	X		X	Comuna	1994
PARAGUAY	X	X		X	Distrito	1995
PERU						
SURINAM	X	X		X	Distrito	1990-91
URUGUAY	X	X		X	Municipio	1993
VENEZUELA	X	X		X	Entidad federal	1984-85

Table 1. *(continued)*

OTROS DATOS

CENTRO AMERICA											
PAIS	PIB	Ingreso Per capita	Tipo de Cambio	Imp/ Exp.	Indices Variac. Precios	Industria	Energía Mínima	Tenencia Tierra	Indice de desempleo	Otros Datos	Año
BELICE	X			X	X	X			X	X	93 libros
COSTA RICA	X	X		X	X	X		X	X	X	93 libros
EL SALVADOR				X	X					X	94 libros
GUATEMALA							X			X	94 libros
HONDURAS								X			93 digital
MEXICO								X			91 libros
NICARAGUA	X	X	X	X	X	X	X	X	X	X	94 libros
PANAMA					X					X	94-95 lib.
SUR AMERICA											
ARGENTINA		X		X	X	X	X	X		X	94 digital
BOLIVIA					X						libro
BRASIL										X	93-94 libro
CHILE											
COLOMBIA											
ECUADOR			X	X	X					X	68-82 libro
GUYANA	X		X	X						X	libro
GUYANA FRANCESA	X				X	X	X		X	X	94 libros
PARAGUAY											
PERU										X	libros
SURINAM											
URUGUAY											
VENEZUELA											

Table 1. *(continued)*

GANADERIA

	Bovinos		Porcinos		Aves		Equinos		Ovinos		Mulas-Asnos		
		Años		Años		Años		Años		Años		Años	
CENTRO AMERICA													
BELICE	X	(83-94)	X	(83-84)	X	(83-94)							Libro
COSTA RICA	X	(83-93)					X	(84)					Libro
EL SALVADOR	X	94 Depto	X	94 Depto	X	94 Depto							Libro
GUATEMALA	X	94 Depto	X	94 Depto					X	94 Depto			Libro
HONDURAS	X	95 Munic.	X	93 Munic.			X	93 Munic.					Digit.
MEXICO	X	91 U.deP.	X	91 U.deP.	X	91 U.deP.	X	91 U.deP.	X	91 U.deP.	X	91 U.deP.	Libro
NICARAGUA	X	95 Depto.	X	89-93	X	89-93							Libro
PANAMA	X	91 Munic.	X	91 Munic.	X	91 Munic.					X	91 Munic.	Libro
SUR AMERICA													
ARGENTINA	X	94 Depto							X	94 Depto			Digital
BOLIVIA	X	94 Depto	X	94 Depto									Libros
BRASIL													
CHILE													
COLOMBIA	X	81-94 País			X	81-94 País							
ECUADOR	X	94 Provinc.	X	94 Provinc.			X	94 Provinc.					Libros
GUYANA	X	93-94	X	93-94	X	94							Libros
GUYANA FRANCESA													Libros
PARAGUAY													
PERU													
SURINAM													
URUGUAY	X	Ent.Federal			X	85 Ent.Fed.							Libros
VENEZUELA													

was in 1984. Their current data is available only at the national level. Many countries provide sample data rather than census data. The sample data is derived by accepted international standards but must be carefully studied to assess its comparability to census data. We are investigating data quality problems in our efforts to reduce errors and provide meta-data.

In conjunction with the Ecoregional Program, a map of administrative boundaries of Latin America has been developed (**Figure 1**). The map was digitized from individual-country source data. It contains over 11,000 administrative units at each countries third administrative division. The crop data described above is provided at the 2nd and 3rd level administrative divisions. Linkage of the crop data to the digital administrative map is underway. **Figure 2** shows crop distributions of cassava, maize, rice and soybeans for Brazil. During 1997 efforts will be made to improve this data by converting it to the raster format.

The vector GIS format shown in **Figures 1 and 2** is an optimum format for handling the large amounts of crop data collected but is deficient for many purposes. It can store information for the administrative unit but cannot display the distribution of crops within the unit. Even more critical is the deficiency of the vector format for modeling purposes. Perhaps as much as 90% of GIS analysis and modeling is carried out using raster GIS. The LMU has thus recognized the importance of redistributing the vector data to a raster format. We have carried out some preliminary work on this in 1996. This type of conversion has not been attempted for agricultural crops. However Uwe Deichmann (1966) has developed vector to raster redistribution models for population data, as part of the UNEP/CGIAR Initiative on the Use of GIS in Agricultural Research.

In 1997, the LUP will use the population models as a guide for developing similar vector to raster models for crops. The models use secondary data such as roads, urban centers, river networks, large water bodies, topography, and vegetation cover to estimate the crop distribution within the administrative unit. For example, we can assume that urban areas, water bodies, and primary forests are not cultivated areas. Cultivated areas are likely to be found near roads, rivers, and on gentle slopes. We use the secondary data to create maps of the probability of cultivation. We then use the probabilities to distribute crop densities within administrative units.

The automated mapping methods for crop density will lead to more rapid updates in the future. The LUP has worked hard to enhance our contacts with data providers in individual countries. We will check these methods against more conventional methods of crop density mapping. Agricultural specialists in each country will verify the maps.

Sub-Output. *Land Degradation Survey and Natural Resources Studies*

Land degradation research has been started as part of the Ecoregional Program's goal to improve the management of land resources and enhance the environmental base for the development of Latin American countries. The research includes reviewing land degradation literature for Latin America, surveying experts on the state of land resources, and compiling a series of land degradation maps. The survey and maps will be the most comprehensive of their kind for Latin America. The project arose from a consensus view that current maps of land degradation were insufficient for research and development (R&D) planning. Our knowledge of the continental-scale distribution of land degradation problems is weak, which prohibits comparing and prioritizing different areas. The outputs from the research will provide the natural resource and agricultural R&D community with a tool to analyze land degradation and its relationship with natural resource development. It is one component of our effort to address environmental and agricultural linkages through a perspective based on landscape.

Figure 1. Administrative boundary map of mainland Latin America

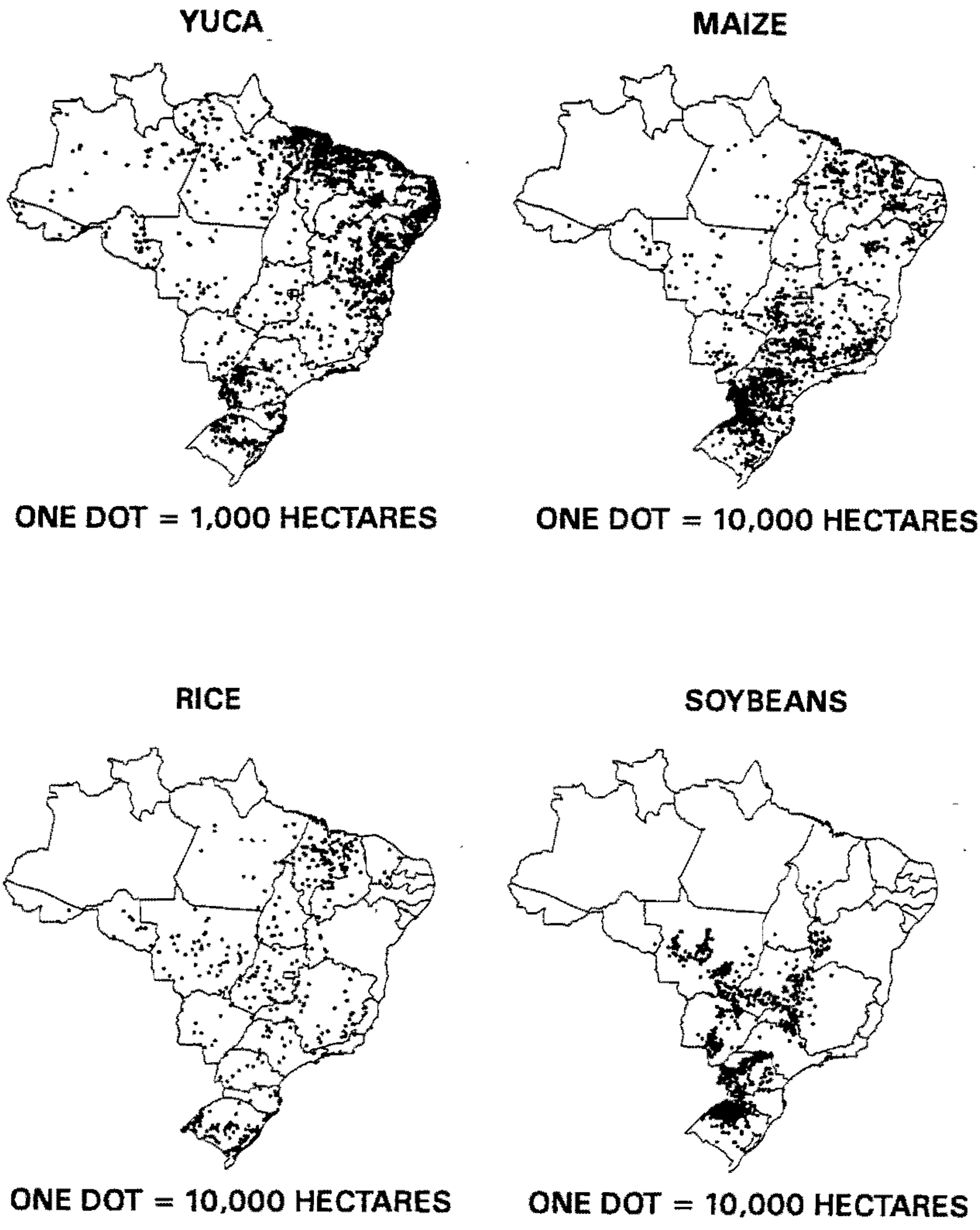


Figure 2. Distribution of cassava, maize, rice and soybeans in Brazil

We first searched the literature on land degradation. The subject has clearly received far greater attention in Europe, the Mediterranean, and the Middle East as shown by an impressive number of studies. Our bibliography for Latin America now holds over 150 references. We obtained many of the citations from international land degradation projects such as the Desertification Information Network and the CIESIN's bibliographic database. The CIAT Information Unit has shown the importance of "gray" literature (research reports without a wide distribution) in Latin America and we have made efforts to include important bibliographic information for research reported outside of widely read journals.

The expert survey will rely on the opinions of agronomists, soil scientists, geographers, and other natural resource professionals. We developed a mailing list with over 900 addresses for experts throughout Latin America. We used the "Encuesta Geográfica de Organizaciones Latinoamericanas que Trabajan en Producción Agrícola y Conservación de Recursos Naturales" (Robison & Madrid 1992) as a foundation for the mailing list database. We built the database largely from directories of experts that individual scientific and technological agencies held in each country.

The governments of Mexico, Guatemala, Costa Rica, Bolivia, Chile, Brazil, Peru, and Colombia sent lists of potential experts that was added to the database. We obtained addresses from the CIAT mailing list, the Sustainable Hillside Agriculture in Central America Program (PASOLAC), the International Society of Soil Science (ISSS), the Soil and Water Conservation Society (SWCS), the Association of American Geographers (AAG), the Panamerican Institute of Geography and History (PAIGH), the Interamerican Institute for Cooperation in Agriculture (IICA), and the United Nations Environment Program (UNEP). We contacted many potential participants through the Internet by posting a call for participation to the discussion lists of the Environment in Latin America Network, the Conference of Latin American Geographers, the American Society of Agronomy, the World Conservation Monitoring Center, and TELESIG (a GIS and remote sensing in Latin America discussion group organized by a Bolivian non-government organization [NGO]). In November, we sent out a call for participation for our land degradation survey through regular mail and by electronic mail. As of the middle of March 1997, over 200 Latin American scientists have accepted our invitation to participate in the survey.

The LUP project team is developing the land degradation survey questionnaire using previous expert surveys as a guide. The survey has two parts. First, experts will be asked about the nature of land degradation problems in their geographic area of interest. Second, they are asked to indicate the geographic extension of degradation problems based on their field knowledge.

We will send survey participants a portion of our master base map and ask them to identify areas of human-accelerated land degradation. As part of the call for participation in the land degradation survey, natural resource specialists were sent a simple map where they indicated their geographic area of expertise. A GIS computer program was developed to automatically generate a questionnaire map of these areas of interest. The map questionnaire will be sent to the specialists where they will indicate geographic extent of soil degradation problems. The base data layer of the questionnaire map is a raster land cover map developed by the United States Geological Survey (USGS) from AVHRR satellite imagery. The CIAT LMU participated in verifying land cover classes for this map by providing USGS with some of our data from past research projects. They used our rice, cassava, and bean distribution maps for a general broad-scale verification. In previous research projects, the LMU produced satellite-derived land cover classifications for areas in Brazil, Guyana, and Costa Rica. The USGS group used these digital data for a more detailed verification.

The questionnaire map also includes roads, populated places, and other reference markers to allow participants to orient themselves. We have developed this secondary data from the Digital Chart of the World (DCW). We will not indicate land cover type but will give the respondents descriptions of different levels and types of land degradation. They will then indicate areas on the map that fit the descriptions.

In the latter half of 1997 we will begin to organize responses to the land degradation survey. We will develop a method for resolving conflicts between responses for the same geographic area. The project team is addressing various problems of analysis and presentation of results. GLASOD's world degradation map showed obvious difficulty in presenting different land degradation variables in the same map. Our advantage is that we will process all data in a GIS, which will give us greater flexibility in presenting the results. At the end of 1997 the first results of the Land Degradation in Latin America Project will become available. They will be the first step in our analysis of the continental-scale relationships between people, poverty, agriculture, environment, and degradation of natural resources.

Participating as moderator for an Internet discussion group on the topic of land degradation in Latin America is further developing our interest in the topic. The Bolivian Association for Remote Sensing of Environment (ABTEMA) in La Paz is facilitating the discussion. ABTEMA maintains an Internet server with discussion list software. The discussion group, called TELESIG, concerns all aspects of GIS and Remote Sensing in Latin America. Focus groups have been organized. The LUP (Glenn Hyman) moderates discussion on the use of GIS and Remote Sensing for the study of natural resource degradation. Participants share experiences, ideas on methodologies, data, and other resources for the study of land degradation. The discussion has been stimulating and will certainly aid our efforts to understand the relationships between land degradation, agriculture, and environment in Latin America, and to aid technology transfer in the R&D community.

In other Ecoregional Program-related efforts to reach out to our partners in the fields of agriculture, economy, and environment, LUP has initiated collaborative projects with colleagues in Ecuador and Peru. Dr. Carlos Larrea, of the Ecuadoran Ministry of Social Welfare, is working on poverty issues in Ecuador and throughout Latin America. He is concerned that his poverty studies do not include sufficient information on natural resources. We have agreed to share natural resource and geographic data in exchange for some of the demographic data they hold. In July, 1996 they provided us with third-level administrative data including rural and urban population, poverty indices, and income data. We linked this data to our ARCINFO maps and returned it to Dr. Larrea with a copy of public domain ARCVIEW 1.0 GIS software. Future work will include the incorporation of additional socioeconomic and natural resource data to the GIS database.

In another sub-project of the Ecoregional Program related to land management, the directors general of CIAT and the Institute of Statistics and Information (INEI) of Peru have signed an agreement to collaborate on mapping activities relevant to Peruvian agriculture and environment. CIAT shared its database of populated places, land cover, and elevation with the INEI. INEI is providing a broad range of tabular census data that will be linked to CIAT administrative boundary maps. We take great interest in this project because of our work in Pucallpa, Peru, where several scientists are taking a systems approach to understanding agricultural land use dynamics. The Pucallpa work is being carried out at the farm level. We will investigate the potential to extrapolate the Pucallpa results to the rest of country based on the GIS census data project with INEI.

Sub-Output. *Population Data for Natural Resource and Agricultural Development*

Knowledge of the geographic distribution of population is critical for efforts to link people, agriculture, and environment. On a world-wide basis Deichmann (1996) has recently carried out work for the developed countries and for Africa and Asia. In Latin America some detailed maps are available for individual countries such as Mexico. Continent-scale maps are rare and outdated. As part of the Ecoregional Project, we collected population data for Latin America. Population growth rates were used to correct the data to a common date. We are organizing the data at the third administrative level for each country – a scale appropriate to a continental-level data set. This data set will allow us to derive the most detailed continental-level population data set of Latin America yet developed. The population data has been linked to the digital maps shown in **Figure 1** to create our continental-level database. **Figure 3** shows preliminary dot distribution map of South America based on the data set. Due the variability in the types of data between different Latin American countries, we have uneven distributions of population characteristics such as the urban-rural, gender and age divisions of population. In collaboration with partners of the *UNEP/CGIAR Initiative on the Use of GIS in Agricultural Research*, we will address these problems and will convert the population data to a raster data set.

References

Robison, D. and Madrid, O. (1992) Encuesta Geográfica de Organizaciones Latinoamericanas que trabajan en Producción Agrícola y Conservación de Recursos Naturales. Working document No. 102. CIAT, Cali, Colombia. 34 p.

Deichmann, U. 1996. A review of spatial population database design and modeling techniques. National Center for Geographic Information and Analysis, University of California, Santa Barbara, CA. 58 p.

Sub-Output. *Economic Models - Joint Ecoregional Activities in collaboration with IFPRI*[1]

The IFPRI-CIAT activities funded by the ecoregional project have focused on four activities

- Improved *agroecological characterization* for research planning and evaluation.
- Compiling a consistent *spatial database* covering Latin America and the Caribbean (LAC) to support dynamic, technology-specific, agroecological characterization
- Enhancing *ecologic-economic evaluation methods* to accommodate research targeted to specific agroecosystems and agroecological zones (AEZs), and making initial attempts at analyzing the natural resource consequences (in addition to direct productivity impacts) of technological change
- *Dissemination of the improved methods* through participation in and presentations at sub-regional workshops on research evaluation convened with national agricultural research

[1] These activities were undertaken by the joint IFPRI-CIAT team working on regional research evaluation in an ecoregional context. The team was co-financed through CIAT's ecoregional and impact assessment project funding, and through IFPRI's regional and sub-regional research evaluation activities underwritten by the BID/IICA Project on *"Strengthening Research Evaluation and Priority Setting in Latin America and the Caribbean"* (IBP2).

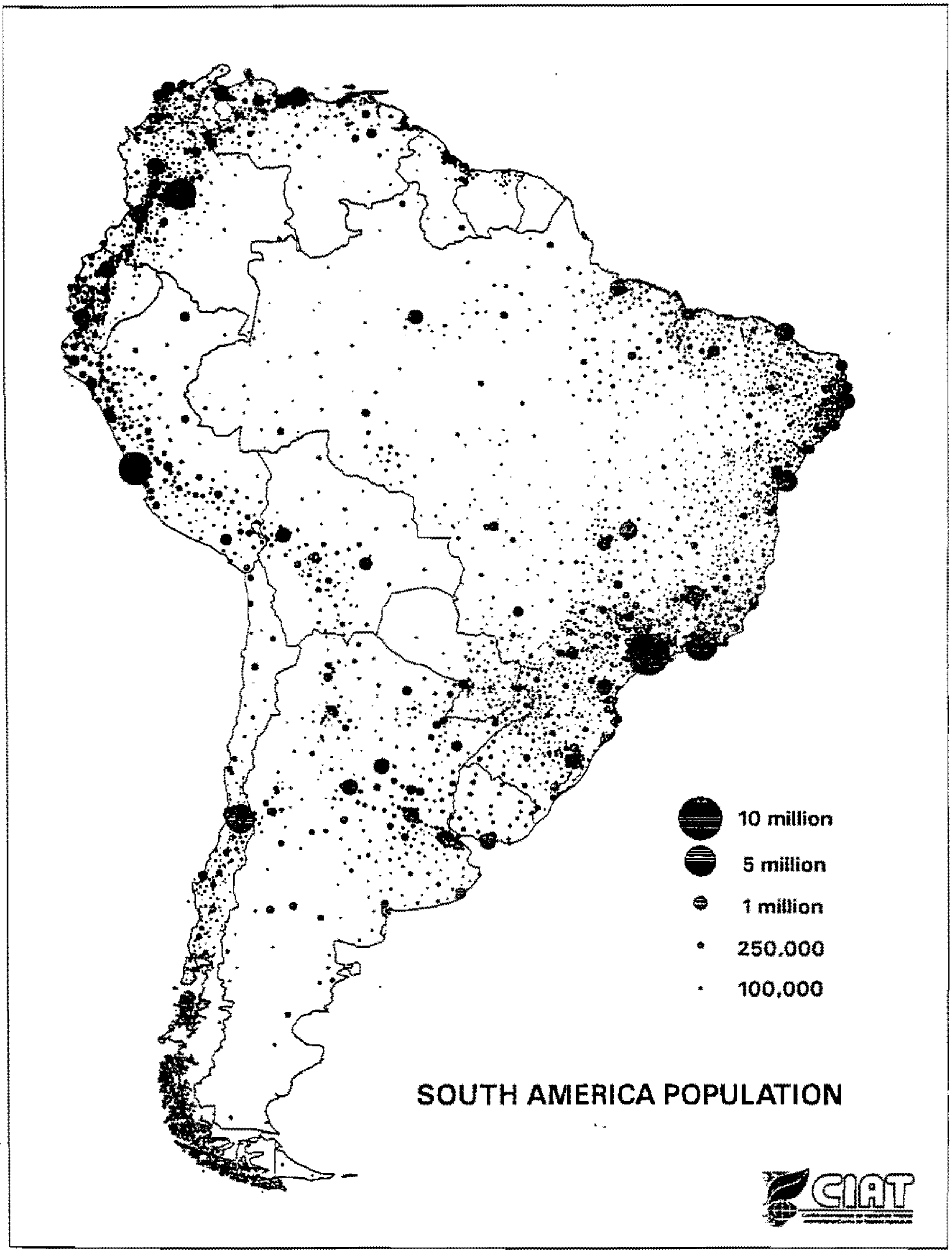


Figure 3. Population map of South America. The map is the first one made with our continental-level population database. Future maps will be much more detailed and in data formats for geographic modeling

agencies and universities, and organized and financed by the IBP2 project

Improved Agroecological Characterization

The IFPRI-CIAT team have been testing the practical implementation of more flexible approaches to agroecological zoning based on the definition of such zones for research evaluation purposes as:

> *A geographic area within which the impacts of new technology on productivity and natural resources are likely to be relatively homogeneous* (Pardey and Wood 1994).

This definition implies a flexible approach to defining zones, tailored to the specific technology being proposed or developed. Such zones could be broadly defined, e.g., as might be appropriate to a technology that reduces seed losses in storage, or may be quite specific, e.g., cultural practices for acid soils in well-watered tropical hillsides.

Increasing the precision by which the spatial consequences of new technology are assessed improves our ability to estimate the potential benefit of R&D, whether those technological impacts result from direct effects or by technology transfers (spillovers).

For example using a simple schema based only on mean annual rainfall and mean annual average temperature, INIAs of the Andean region were able to characterize the zones to which they were each targeting IPM research in rice, coffee, cocoa and potatoes. This resulted in a different schema being devised for each crop, as well as different schema being devised for the same crop in different countries (reflecting differences in agroecologies, research capacities, and research priorities between countries). **Figure 4** shows the schema for each country in the case of potatoes and, at the top of the diagram, the composite schema based on those. This simple procedure is very powerful in demonstrating the spatial overlap and potential complementarities of research across the countries. It is equally powerful when the schema is applied to an underlying GIS database to produce a *Potential R&D Impact* (technology-specific AEZ) *Map* of the Andean region. In **Figure 5** such a map depicts the spatial distribution of the AEZs in which one or more countries are currently targeting (or plan to target) research *and* shows those zones in all countries in which they occur. Thus, it becomes easy to see

- where, in country A, the research of country A is potentially applicable
- where country A's research could be applicable in country B, C, D, etc.
- where the research being carried out in countries B, C, D, etc., could be applied in country A.

A quantitative summary of this map, automatically generated by the GIS is summarized in **Table 2**. Such information provides a solid, initial basis for dialogue between countries

MANEJO INTEGRADO DE PLAGAS : PAPA

		Temperatura (°C)		
		6 - 9	9 - 18	18 - 22
Prec	500 - 1000	P	C.E.P.V	
	1000 - 2000		[illegible]	
	>2000		C	

COLOMBIA

		Temperatura (°C)		
		6 - 9	9 - 18	18 - 22
Prec	500 - 1000			
	1000 - 2000			
	> 2000			

ECUADOR

		Temperatura (°C)		
		6 - 9	9 - 18	18 - 22
Prec	500 - 1000			
	1000 - 2000			
	> 2000			

PERU

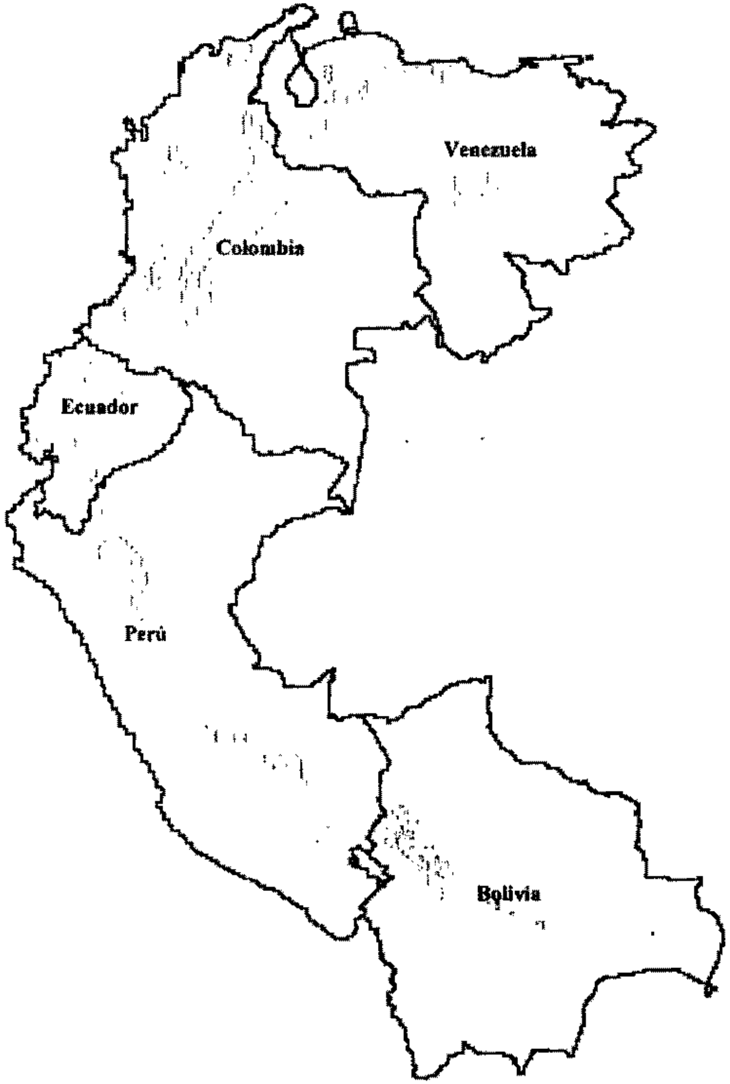
		Temperatura (°C)		
		6 - 9	9 - 18	18 - 22
Prec	500 - 1000			
	1000 - 2000			
	> 2000			

VENEZUELA

		Temperatura (°C)		
		6 - 9	9 - 18	18 - 22
Prec	500 - 1000			
	1000 - 2000			
	>2000			

Figure 4. National and Composite Andean Schema for Targeting Research on Potato IPM

PROCIANDINO : ZONAS AGROECOLOGICAS ESPECIFICAS
CON BASE EN LOS BLANCOS BIOFISICOS DE INVESTIGACION NACIONAL



MANEJO INTEGRADO DE PLAGAS : PAPA

		Temperatura (°C)		
		6 - 9	9 - 18	18 - 22
Prec	500 - 1000	P	C,E, P, V	
	1000 - 2000		C,E, V	V
	>2000		C	

Proyecto BID/IICA IBP2: Elaborado por el Equipo Técnico Regional IFPRI/CIAT con base en los criterios nacionales suministrados por el Grupo Técnico de Prioridades de PROCIANDINO

Figure 5. An Example of Technology-Specific AEZs - Potato IPM Research in the Andes

Table 2. *Distribution of Technology-Specific AEZs - Potato IPM (hectares)*

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bolivia	2233	6833	899	0	2746	97147	[illegible]
Colombia	26	907	8711	2870	6679	94698	[illegible]
Ecuador	454	2912	1730	754	1370	21136	[illegible]
Perú	6864	6626	4322	1309	3267	106134	[illegible]
Venezuela	0	560	1205	718	4428	84294	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(or any other research management divisions of space) on the potential for technology "trade" and the corresponding scope for initiatives on the joint funding or

There are additional significant advantages in the delineation of technology-specific AEZs relating to improvements in the aggregation of technical R&D parameters when they are juxtaposed with adoption, production, market, and policy data in the economic evaluation of R&D (Wood and Pardey 1997).

LAC Spatial Databases to Support Research Evaluation

Dynamic, technology-specific AEZs, as defined and demonstrated in the previous section, can only be implemented on the basis of a rich, and spatially consistent set of thematic GIS data. There is a broad range of variables that could demarcate the spatial limits of zones of homogeneous R&D impact, e.g., elevation, annual rainfall, maximum temperature in May, frost free days, soil pH etc. And for each variable, and its key
delimiting value ranges, we must generate a corresponding map. The final overlay (spatial intersection) of these maps will define our technology-specific AEZs[2]

To service these requirements a set of relevant data themes have been compiled in GIS format, drawn largely from CIAT-developed GIS materials. Most computer files in this collection comprise a rectangular grid of 1068 rows by 1008 columns (a total of 1,076,544 grid cells or pixels, of which 257,000 correspond to the land mass of LAC). At this scale each grid represents 5 arc-minutes of latitude and longitude, or approximately 9km x 9km ($81km^2$) at the equator. Each pixel location contains a single value of the thematic variable, e.g., 2134 (mm of rainfall), 310 (average temperature in tenths of a degree Celsius), or 15 where, in a separate legend 15 corresponds to the soil type Ferric Acrisol.

The themes compiled include:

Elevation (NASA/USGS)
Precipitation (12 months and 1 annual total - 13 images) (CIAT)
Maximum temperature (12 months and 1 annual average - 13 images) (CIAT)
Minimum temperature (12 months and 1 annual average - 13 images) (CIAT)
Average temperature (12 months and 1 annual average - 13 images) (CIAT)
Potential Evapotranspiration (12 months and 1 annual average - 13 images) (CIAT)
Dominant soil type (FAO)
Dominant topsoil and subsoil pH (FAO)
Soil degradation (wind and water) (UNEP, ISRIC, FAO)

[2] This description assumes a direct correspondence between existing mapped themes and the AEZ boundaries, but it is often necessary to construct new variables as part of this process, e.g., soil water availability, degree days, biomass indices, that require more complex pre-processing (Wood and Pardey, 1997)

Minimum temperature (12 months and 1 annual average - 13 images) (CIAT)
Average temperature (12 months and 1 annual average - 13 images) (CIAT)
Potential Evapotranspiration (12 months and 1 annual average - 13 images) (CIAT)
Dominant soil type (FAO)
Dominant topsoil and subsoil pH (FAO)
Soil degradation (wind and water) (UNEP, ISRIC, FAO)
Land use/cover (92-93, NASA/USGS)
Distribution of rice production (86-90, CIAT)
Distribution of bean production (86-90, CIAT)
Distribution of cassava production (86-90, CIAT)
Parks and Reserves (WCMC)
National and sub-national boundaries (CIAT)
Roads, Rivers, Cities (ESRI, CIAT)

Two samples of these images are shown in **Figure 6**. Now that this core GIS dataset has been compiled it will continue to be refined and extended in two ways.

- by improving the spatial resolution of the datasets. A new elevation dataset based on a NASA 30 arc second (1km x 1km) grid, and a compatible set of land use/land cover images (USGS) has recently become available. This represents an 80 fold increase in information content of elevation and land use data. However to bring the climatological data up to date it must be spatially re-interpolated over the new elevation grid using the underlying point climate station data. Furthermore, first approximations can be made at physiographic classifications including aggregate slope indices - interpretations that are not appropriate at the scale of the current data.

- by adding themes as needs dictate and as more evaluation exercises are carried out;

  - themes to define technology specific AEZs that depend on variables other than those currently available, e.g., relative humidity or frost free days. (i.e., new themes that help define *potential* technology impacts)

  - themes that contribute to defining the spatial determinants of adoption, e.g., market accessibility and rural infrastructure (i.e., themes that help identify the spatial distribution of *realized* technology impacts)

- themes that improve the delineation of current production areas. This has been an area of intense activity by CIAT within the ecoregional project (Hyman and Jones) (i.e., themes that provide the current basis for weighting the spatial incidence of potential and realized impacts for the purposes of the economic analysis).

Enhanced ecologic-economic evaluation methods

IFPRI has made a broad range of enhancements to their basic economic evaluation model *DREAM* (Alston, Norton and Pardey, 1995). Two major enhancements were related to improving the applicability of the framework in dealing with agroecological and natural resource issues:

Improvements in the technology spillover algorithm that accounts for technology targeted to one (spillout) AEZ being used in other (spillin) AEZs. The spillover algorithm supports the definition of differential impacts of the same technology when adopted in different zones, as well as differential time lags required to effect the transfer, e.g., to allow for possible local testing and adaptation of the technology. The spillover algorithm also permits a number of assumptions to be

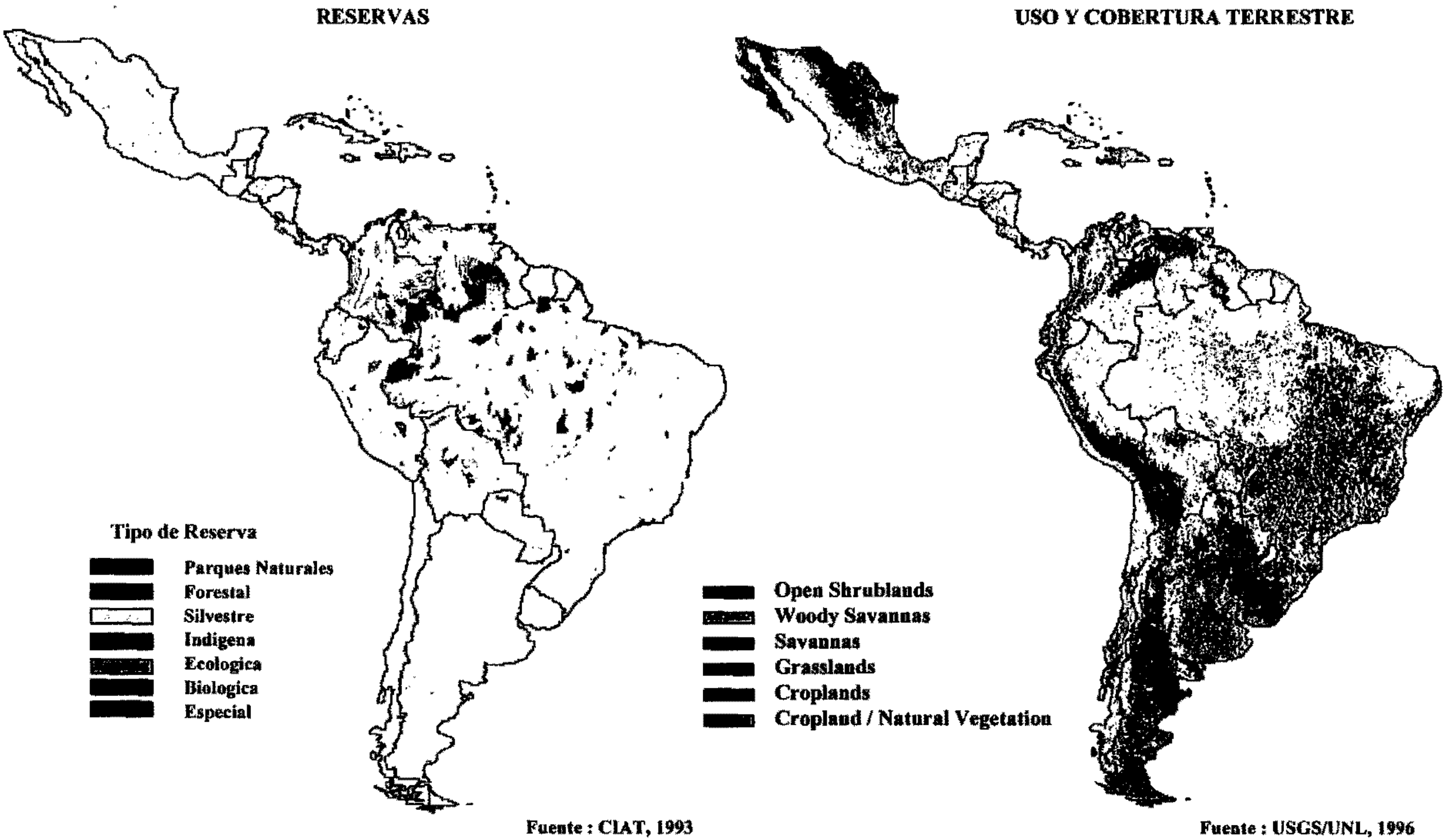


Figure 6. Selected Themes from the LAC GIS Database to Support Strategic Research Evaluation

made about the complementarity or substitutability of technologies. This feature supports the evaluation, amongst other things, of policy choices on "home grown" versus "imported" technology strategies.

- the introduction of an alternative representation of technology impact (in addition to the representation of a fixed reduction in the unit cost of production). This alternative representation allows the research impacts witnessed by an adopter of new technology to change over time. Once a technology, say, a new variety, is adopted the current algorithm assumes that the yield gain it brings is constant in every year its use continues. In this new impacts the positive (or negative) impacts of a new technology realized by an adopter can grow or contract over time. This enhanced *DREAM* approach has been used to assess the impact of direct seeding technology where the benefits of that technology arise from two sources;

    - using less machine passes and, hence, lowering unit production costs

    - the avoided loss of on-site productivity accruing from the reduction of soil erosion and, hence, from avoided soil loss. This benefit increases every year, relative to the counterfactual case.

    These effects were modeled simultaneously in *DREAM*. **Figure 7** summarizes the aggregate results of that test case based on field experience from Argentina and Uruguay.[3]

This feature could be used to represent a broad spectrum of abiotic natural resource related issues whose impact can be related to on-site productivity effects. Clearly, this is not capturing off-site effects but it has added an important type of technology impact to the range that the evaluation framework can address.

Further extensions of the framework to address potential natural resource impacts of R&D require more research, and CIAT and IFPRI have been seeking funds to carry out such research over the next two to three years, aiming to convert research findings into additional enhancements in the methodological framework.

Dissemination of Improved Methods

Thanks to participation in both the IFPRI-CIAT joint ecoregional activities and IICA-IFPRI LAC Research Evaluation and Priority Setting Strengthening Project (IBP2) there have been many opportunities to expose, review, and refine the new methods described in the previous sections. Indeed, within the IBP2 project, the approaches outlined above were adopted as the methodological vehicle on which to base the prototype sub-regional research evaluation and capacity building exercises. These were implemented by technical groups comprising research planners and analysts from INIAs, as well as some University representatives in Mesoamerica, the Andean region, and the Southern Cone. The Mesoamerica and Andean group's activities, in particular, had a strong agroecological component.[4] Since March 1996 the methods described

[3] As a precursor to the *DREAM* analysis it was necessary to convert soil loss into equivalent productivity loss and this was done using data from FAO (Shah, 1983).

[4] The AEZ example, and the direct seeding example shown above came out of the activities undertaken with these working groups.

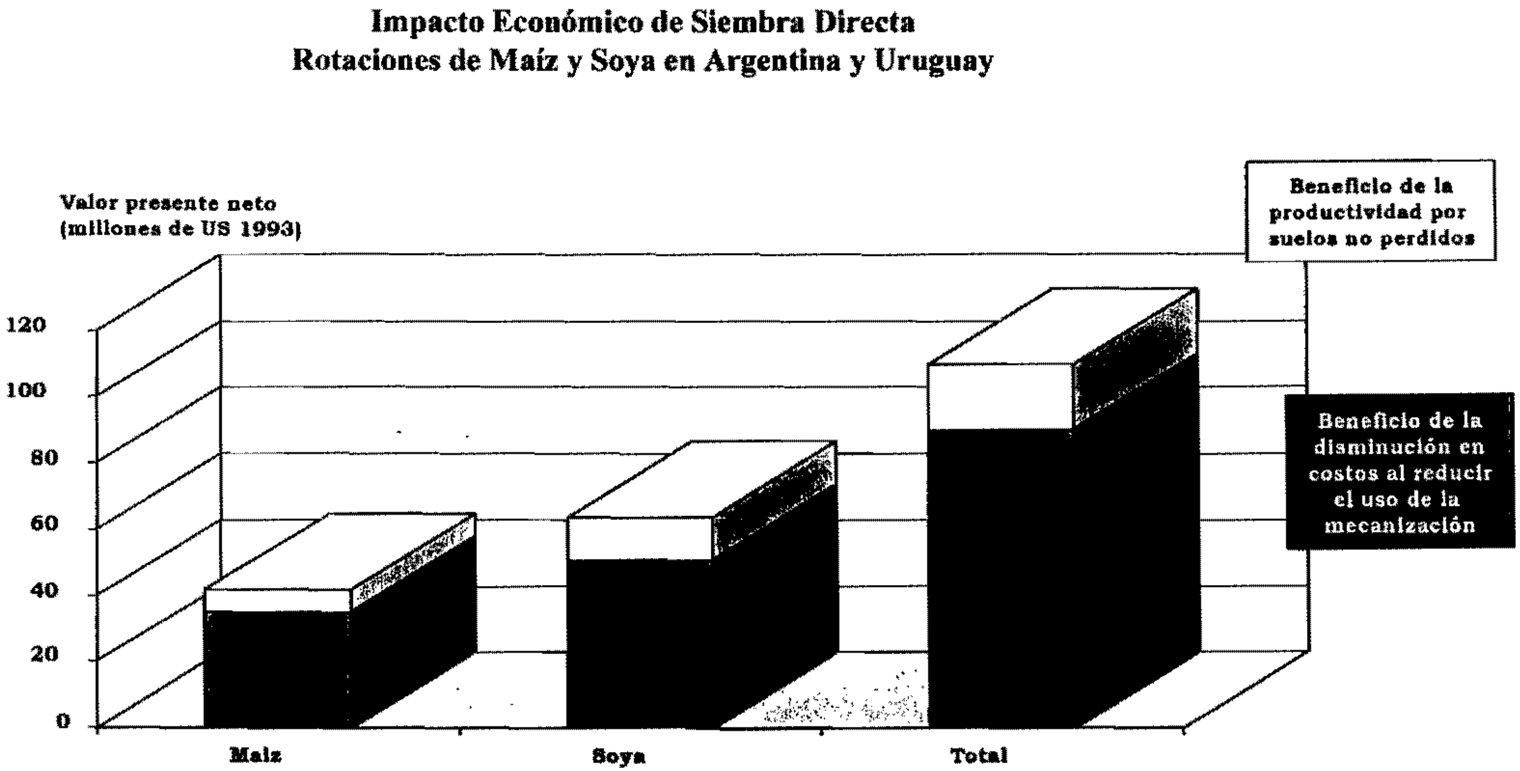


Figure 7. Example of the Combined Evaluation of Conventional Productivity and Natural Resource Related Impacts of New Technology Using DREAM

have been presented by members of the IFPRI-CIAT team in a large number of 2-3 day technical workshops, and 1 day seminars to senior research policy makers and planners. The Workshops and technical meetings (funded by the IBP2 project), were attended in; Bogota (2), Cali (3), San José, Santa Domingo, Mexico City, Caracas, Maracay, Quito, Montevideo (3), Brasilia (2).

The methods developed have also been reviewed and adopted by CIAT itself in several of it's on-going evaluation studies, e.g., on cassava germplasm targeted to different agroecological zones and markets. And, through CIAT's involvement in CONDESAN the methods are also being evaluated by that ecoregional initiative.

References

Alston, J., G.W. Norton, and P.G. Pardey. *Science Under Scarcity: Principles and Practice of Research Evaluation and Priority Setting.* Cornell University Press. Ithaca. 1995

Pardey, P.G., and S.R. Wood. Targeting Research by Agricultural Environments. Chapter 31 in *Agricultural Technology: Policy Issues for the International Community.* CAB International. Wallingford. 1994.

Wood, S.R. and P.G. Pardey. *Agroecological Aspects of Evaluating Agricultural R&D* Agricultural Systems (forthcoming).

Output 2. *Methodology for Watershed or 'Partial Area' Level Research*

***Specific objective*:** To develop more effective methods for identifying and prioritizing natural management research at the watershed level in the High Mountain, Central American Hillsides, Forest Margins, and Savanna agroecosystems.

The outputs will be used for:
- defining and solving productivity and sustainability problems within a specific watershed,
- transferring information across watersheds within an agroecosystem and
- analysis at a higher level of aggregation.

This research is closely linked to existing research consortia in the four agroecosystems and to research being conducted by other Systemwide Programs such as Alternatives to Slash and Burn, Livestock and Soil, Water and Nutrient Management. Research programs will often merge and thus coordination is used to ensure complementarity or collaboration.

A. High Andes Agroecosystem

Highlights

- Comprehensive study of use of images for land degradation commenced
- Criteria for the hydraulic characteristics of soils and water usage by crops have been established.

Activities to date:

Sub-Output. *Assessment of the problems of soil degradation among small farmers using new methods of geographical analysis.*

Firstly, a comparison is being made between using traditional satellite images and radar images for obtaining precise data at a reasonable cost. The study is focussed on the Rio Angel watershed in Ecuador. Ecociencias, Ecuador, is undertaking the study with satellite images and CIAT with radar images. Radar images obtained from Japan were not suitable and at present we are looking at the use of images obtained from Canada. It is anticipated that this comparison will be finished by the end of 1997.

Secondly, a study is being made of land degradation in two contrasting watersheds, one in Rio La Encanada, Peru, and the other in Rio Doña Juana, Colombia, both of which are reference sites for CONDESAN. In the latter it is easy to identify farms because cadastral information is available. However, this is not available for mountain areas in Peru. Hence we have resorted to contracting persons to directly digitize this information. Information is also being digitized for soils, geology, vegetative cover and slope. **Figure 4a and 4b** shows farms in the two areas. The highest amount of land degradation occurs in the smaller farms. In Colombia, there are public funds which might be used to improve resource management in the small farms as degradation there has off-site effects. The mechanism to bring about improved resource management on smaller farms in Peru is not clear.

Sub-Output. *Simulation models of the dynamics of water and land use*

The high 'Paramo' areas are considered an important source of water for irrigation of agricultural land in the high Andes. However, there have been few studies of the impact of land use on water infiltration and retention. Such studies and also acquisition of field and farm level data that may effect parameters of soil erosion, nutrient loss and soil moisture retention are prerequisites to developing farm optimization models.

The studies are being conducted within the framework of the CONDESAN consortium (Consorcio para el Desarrollo Sostenible de la Ecorregion Andina), subproject 'Carchi' (Consorcio Carchi – Ecoregión Rio El Angel).

The El Angel watershed is a watershed of 300 km^2 in the northern Andes of Ecuador. The altitude varies between 1500 and 4150 masl. The lower section is dry and often degraded, in the middle section there is irrigated agriculture which uses water from the upper section, followed by a pasture/potato belt, and natural paramo vegetation in the most upper section.

Activities to date:

(a) A study of the conversion of natural ecosystems to agricultural lands: impact on water balances in a high Andean watershed.

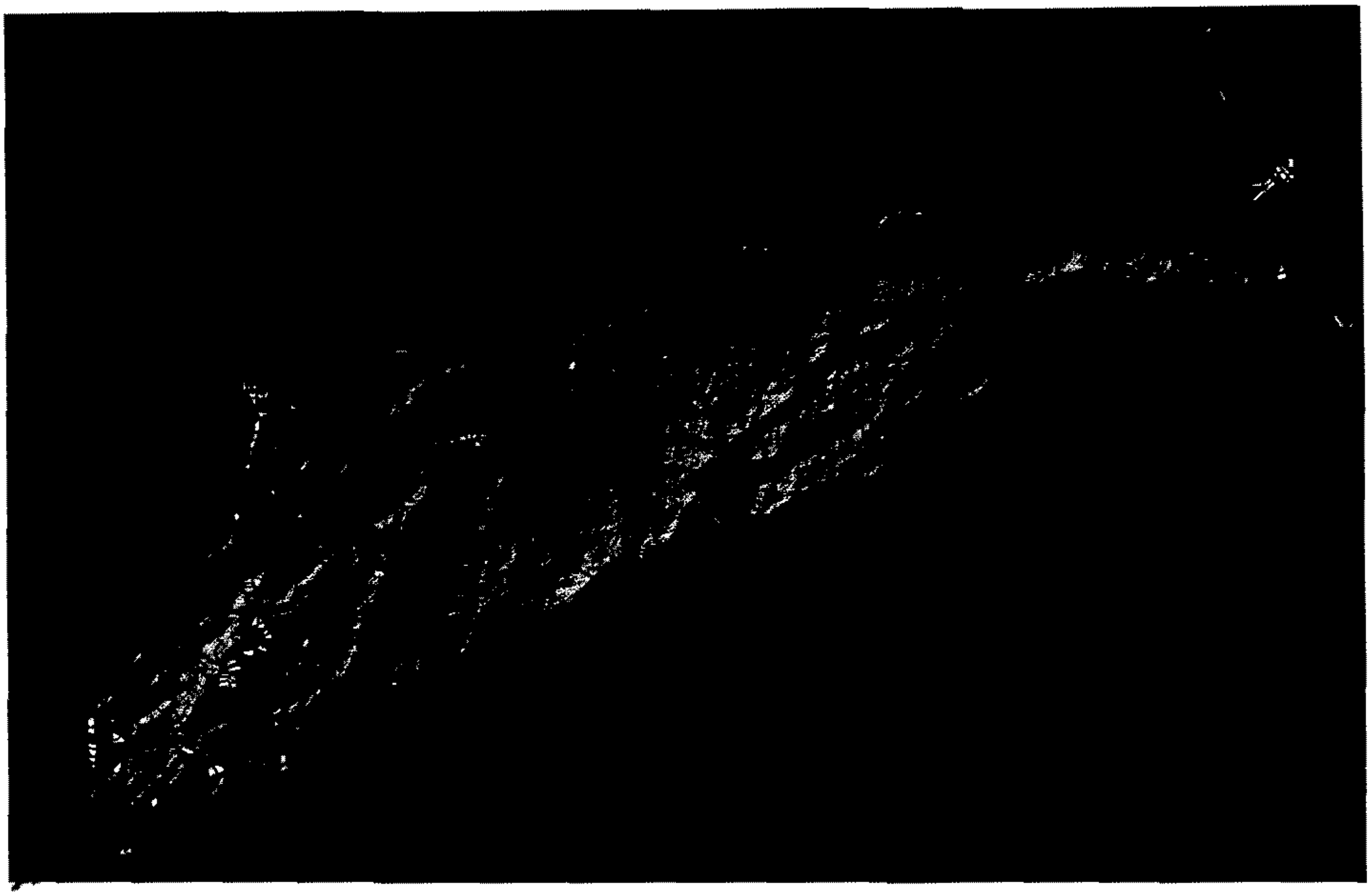


Figure 4a. Farms in Rio Dona Juana study area, Colombia (yellow < 5 ha)

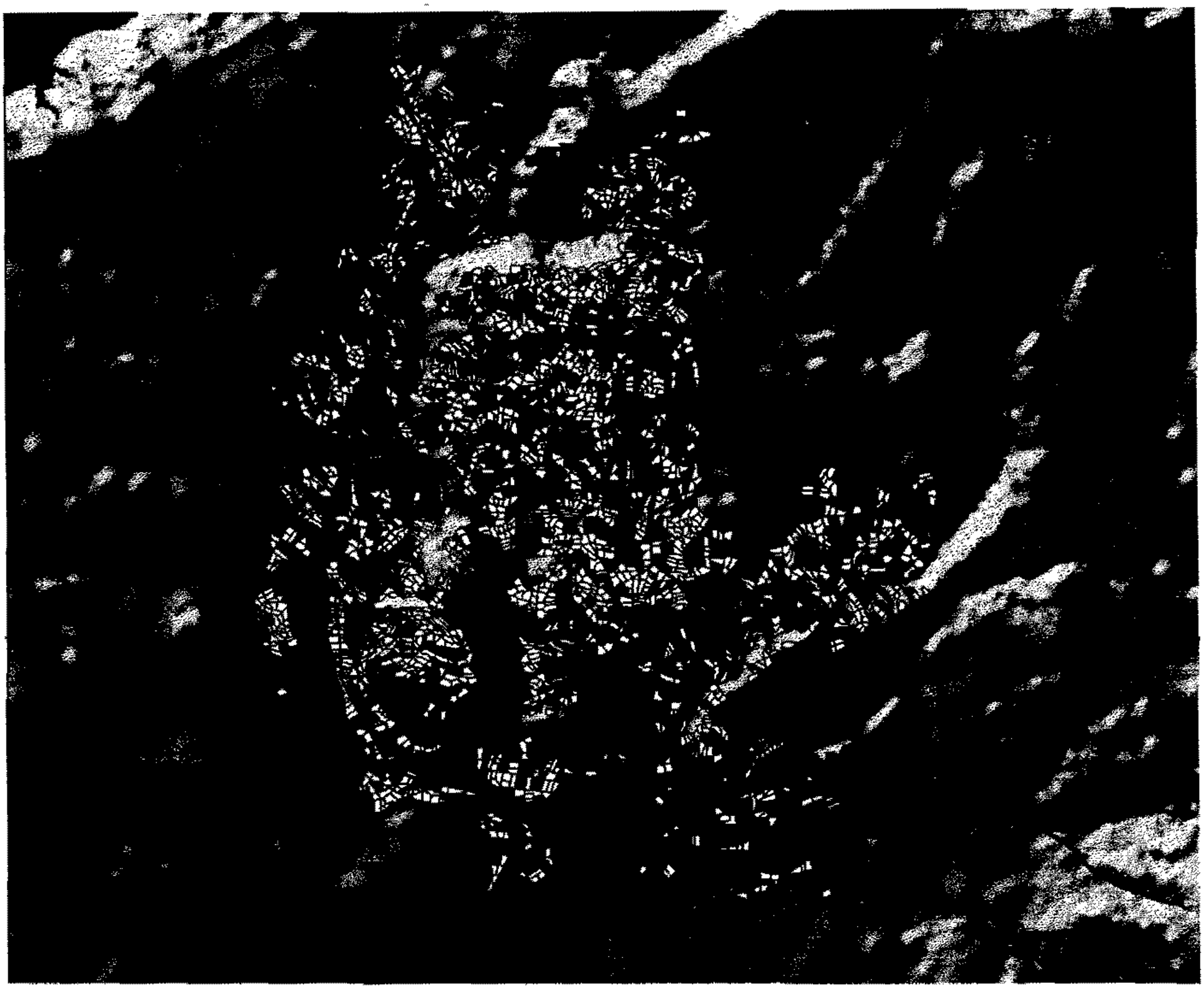


Figure 4b. Farms in Rio La Encanada study area, Peru. (yellow < 1ha, cyan > 1ha)

Background

In the watershed of the Rio El Angel water is a critical resource, being abundant in the upper zone and scarce in the lower zone. The climate within the region changes from dry (in the irrigated crop area, around 2500 masl) to very humid (in the nature reserve, above 3500 masl), over a distance of a few kilometers. Annual precipitation in the higher parts is more than twice the value in the lower parts, and evapo-transpiration is much lower due to lower temperatures, higher atmospheric humidity and abundant cloudiness (**Figure 8**). There is very limited knowledge on the actual quantity of water available. The agricultural frontier is advancing to greater altitudes where potato fields and managed pastures are replacing the natural *páramo* vegetation (a unique high Andean grassland with some very characteristic non-grass species). Given the ecological features of this natural vegetation and the physical properties of the soils, the destruction of this ecosystem would probably be irreversible. *Páramos* are often compared to sponges, retaining large amounts of water which are assumed to be released gradually, thus maintaining high base flows in the rivers. However this hydrological behavior is poorly analyzed and the impact of changes in land use is uncertain.

Our objective is to provide a better insight in these matters by the implementation of a hydrological model describing the water balances and discharge dynamics. We are aiming at using an existing hydrological model, but its applicability has to be tested and modifications may be necessary. A prerequisite for any hydrological model is good data on climate, soils and vegetation/land use. In El Angel, as in most tropical watersheds, the available information is very incomplete. To obtain the data that are considered essential for hydrological modeling, we initiated the activities outlined below. Our observations were concentrated around 3500 masl where natural and changed ecosystems coexist. **Table 3** provides a list of the land use types sampled. The typical management of farmland is to grow two crops of potato which is followed by a fallow (mostly 'natural grassland', sometimes sown grassland) which lasts three or more years. Older fallow is often invaded by shrubs and trees.

Table 3. Sampling sites.

Sites	Vegetation	Altitude (m)
Paramo	typical paramo, Graminae + Espeletia	3575
	typical paramo, Graminae + Espeletia	3705
	wetland, 'floating vegetation'	3700
Potato fields	potato, recently planted	3480
	potato, close to harvest	3500
Pastures	fallow, age 3 months	3450
	age 2 years	3510
	age >3 years	3450
	shrub-invaded abandoned pasture	3540
Forest	cloud forest	3390

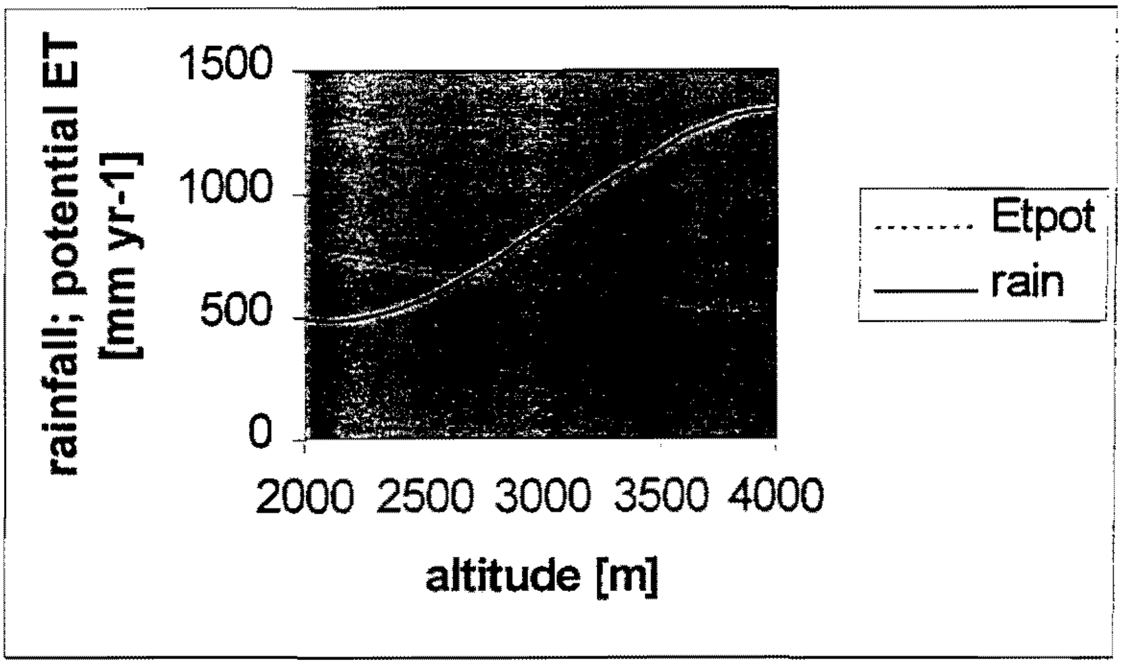


Figure 8. Rainfall and potential evapotranspiration as a function of altitude in the watershed of Rio El Angel, Northern Ecuador. The rainfall line was taken from an ORSTOM study (Pourrut, 1994). Potential evapotranspiration was calculated according to Thornthwaite's formula, using temperature data from the CIAT climate database and own data for altitudes above 3000 m (soil temperature at 0.5 m depth).

The original distribution limit between *páramo* and cloud forest (which must have covered much of the current potato zone, but is now absent except for some extremely small fragments) is unknown. The *páramo* ecosystem at higher altitudes does not seem to be very different from that at 3500 m. However, in depressions a wetland ecosystem develops with completely different hydrological characteristics.

Climate

There are two meteorological stations in the watershed, located in the same climatic zone. Even in a larger area around the watershed there exist no data for higher altitudes. As climatic gradients in the area are quite steep, simple extrapolation of climatic factors is unacceptable, particularly for precipitation. An additional unknown is the possible contribution of fog precipitation (the deposition of small droplets on plant and soil surfaces), which in some but not all ecologically similar areas has been shown to be a significant hydrological input. It was decided to install rain and fog gauges along two transects: one altitudinal (3000-3700 m) and one west-east at the altitude of the agricultural frontier (3500 m). Measurements will be taken for a period of six months (including a dry and a rainy period) and will enable interpolations for rainfall and an assessment of the significance of fog precipitation.

Soil

Soil maps of the region (ORSTOM) show that all soils in the upper parts of the watershed are volcanic-ash derived. The hydraulic properties of these soils are largely unknown, and less so the changes that occur under different land use. In general they are known to have very high organic matter content, very low bulk density, and high water retention capacity. Rather surprisingly, infiltration observed in the field was slow, except in recently prepared potato fields (ploughed surface only) and natural forest (throughout the profile). The generally low hydraulic conductivity is being confirmed by laboratory determinations (**Figure 9**). Rooting is dense and reaches great depth (>1.5 m) even in grassland ecosystems.

The first results of this study indicate that the infiltration of rainwater into potato fields is higher than into a *páramo* ecosystem. Therefore, conversion of the natural vegetation may reduce surface runoff (fast discharge), which in general should be considered a positive effect. In terms of water yield of the watershed (to be used for irrigation down slope), potato crops may contribute less water because increased infiltration means better availability of water, and a fast-growing crop can be assumed to transpire more. Another very interesting aspect is the contrasting properties of forest soil compared to the other soils. This means that the complete clearance of forest in the past has probably had an enormous effect on the region's hydrology. In addition to this, the aspect of fog precipitation, which would be much higher in forest than in other vegetation, it is worth exploring not only the effects of shifts in the proportion between *páramo* and managed lands but also between forest and managed lands. The modeling exercise will allow comparison between some contrasting land use scenarios.

Vegetation

Current land use is being mapped for the watershed by the foundation Ecociencia (Quito) using a SPOT satellite image. The topography is also being digitized by this institution. Additional data on land use practices, rotations, water use are being collected.

Site-specific vegetation characteristics were described. The (natural or managed) plant cover influences the water balance through processes like interception and evaporation of rainfall and

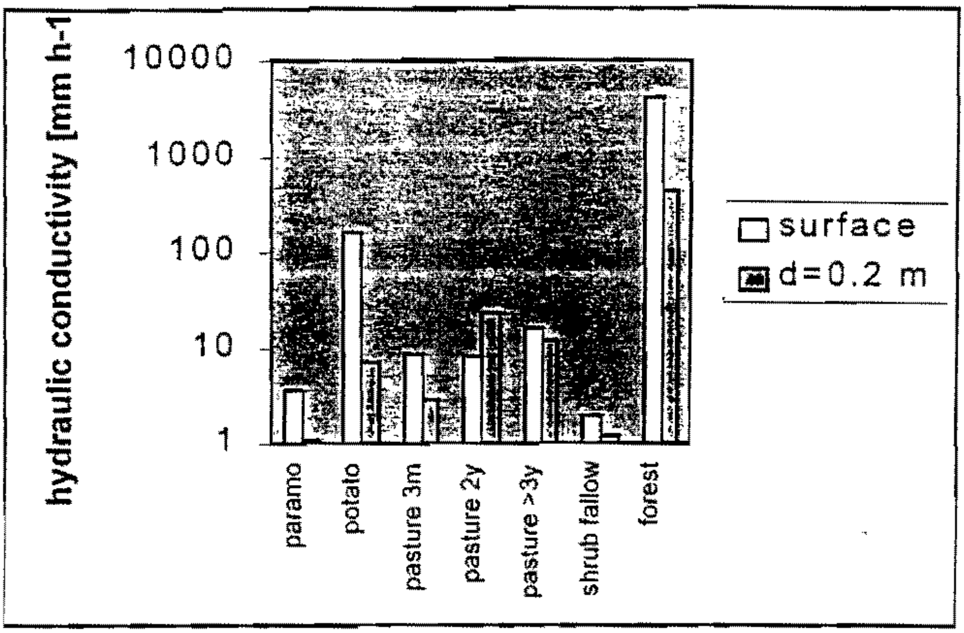


Figure 9. Saturated hydraulic conductivity of soils under different land uses at depths of 0 and 0.2 m, as estimated in the field using infiltration experiments

fog, soil water extraction and transpiration. Other more indirect effects are changes in radiation properties, soil surface cover, and effects on soil structure. Most if not all of the water loss of an ecosystem occurs through the foliage by transpiration and evaporation of intercepted water. We performed field sampling in different land use systems which will allow the estimation of leaf area indices. Moreover we described rooting patterns and measured vegetation albedo. The measurement of stomatal conductance, necessary for the estimation of transpiration, proved impossible because of weather conditions and the technical problems of measuring on the very narrow or hairy leaves of most dominant species. However, acceptable estimates can probably be derived from the literature.

(b) Survey of farms

Data has been obtained of the characteristics of farms in the different zones. Examples of the type of data obtained are shown in **Tables 4 and 5**.

Table 4. Characteristics of production systems in the Intermediate Zone

Group	Farmers (No.)	Area (ha)	Yield		Income (usd/yr)
			Potatoes (t/ha)	Milk (l/d/cow)	
1	31	3.2	12	4.5	1174
2	26	6.3	15	5.8	3085
3	4	12.0	20	8.0	6295

Table 5. Characteristics of production systems in five villages in the Low Zone

Sub-district	Farmers (No.)	Area (ha)	Availability of water (mm)			Bean production (kg/ha)		
			dry	normal	wet	dry	normal	wet
Grandeza	46	1.8	129	176	199	680	960	1250
Nacional	22	1.7	234	234	234	910	910	910
La Cocha	18	2.6	86	153	175	620	900	1130
La Providencia	30	2.1	130	195	256	700	933	1110

This information will allow us to model various options for the poorest farmers in the study area. One of these is the production of crops in relation to moisture availability, the extra water in dry seasons being supplied by irrigation with the cost of irrigation water being taken in account.

The type of data shown in **Table 4** will be broken down further to take account such things as the number of farmers with cows, the milk production potential of the cows and off-farm income. One can then examine the possibility of inputs needed to increase the productivity of the smaller farmers to that of the relatively larger farmers.

B. Central America Hillsides Agroecosystem

Highlights

- Complete geo-referenced data sets have been obtained for the reference site in the municipalities of Yoro and Sulaco, Honduras
- Spatial methodology has been developed to analyze this data set
- A decision guide for green cover use in Central America has been developed.
- Use of models to determine farmer perceptions of sustainability demonstrated

Activities to date:

Sub-Output. *Methods to characterize production systems dynamics*

Extensive data sets have been obtained of the climate, soils, slope, land use, population and crop productivity for a watershed that is located in the municipalities of Yoro and Sulaco, Department of Yoro, Honduras. This has allowed maps to be produced of land use and productivity in relation to population across the watershed. This information is being summarized in a report that can be used by the various organizations involved in technology development and by the community watershed organization (CLODEST) that has been established. An example is given here of the use to which these types of data sets might be used.

The first thought that occurs to people when 'Hillsides' and 'resource degradation' are mentioned in the same breath is soil erosion. Unfortunately, soil erosion is also one of the most studied and yet least quantifiable processes of resource degradation, leaving decision makers with almost no practical support for land use planning. To rectify this dilemma, we have adopted a strategy of 'successive refinement' of information for decision support.

Within a limited geographical landscape like a community watershed with spatially narrow mean rainfall patterns, slope and ground cover are dominant indicators of soil erosion risk. The power of combining remote sensing (RS) and geographical information analysis (GIS) offers decision makers cost effective decision support.

Figure 10 is an example of a three dimensional representation of the Yoro-Sulaco watershed study site in Honduras. An intermediate step in preparing this image is a computer representation of a 'wire-mesh' grid map with watercourses and contour lines (**Figures 11 and 12**) called a digital elevation model (DEM). With the creation of the DEM, the slope and up-slope drainage area for each grid can be determined. It is not difficult then to create a map of the potential overland water flow accumulation (**Figure 13**).

Such representations are simplified, synoptic knowledge of potential erosion risk. If, for whatever reasons, more refined estimates are required, ground cover characteristics determined from remote image analysis can be superimposed over the DEM resulting in composite knowledge of topographic and ground cover. More accurate estimations follow from this 'second level' of data synthesis (figure not shown due to lack of differentiation of black and white images).

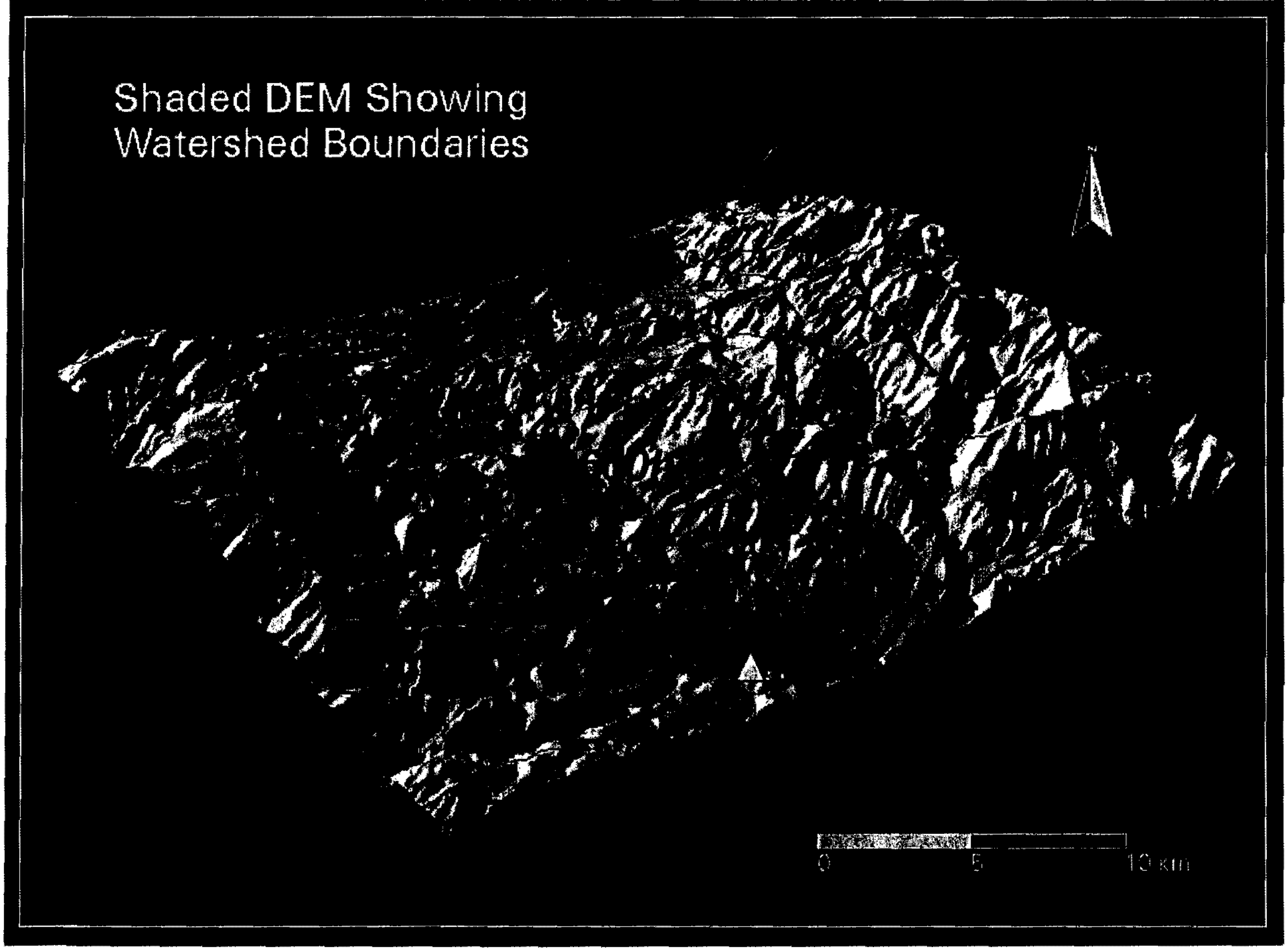


Figure 10. Shaded Digital Elevation Model showing watershed boundaries for the Yoro-Sulaco watershed study site in Honduras

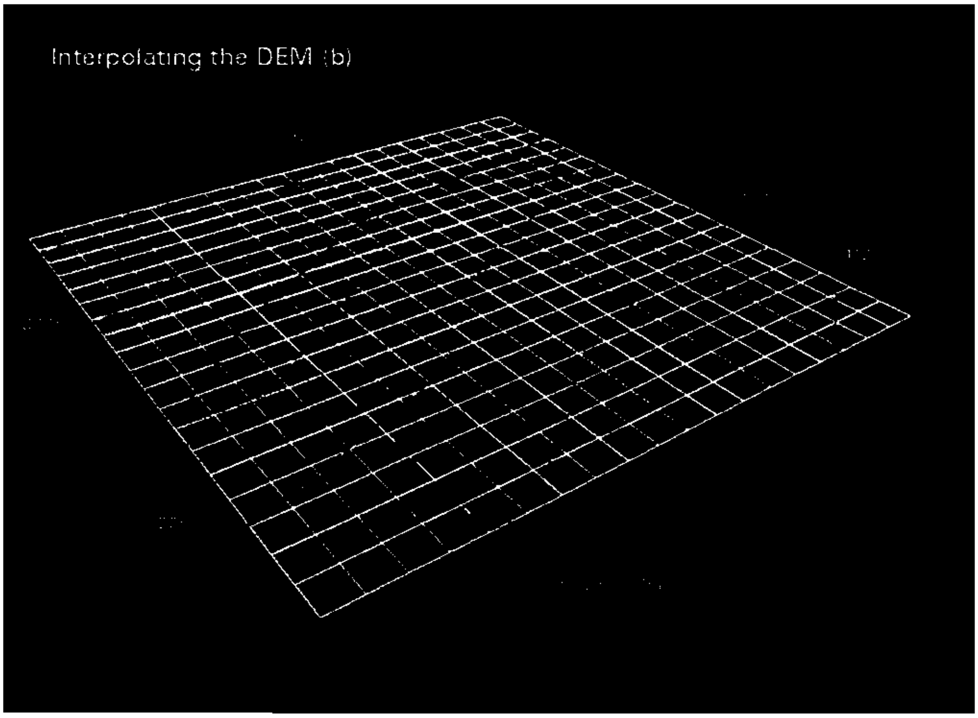


Figure 11. Grid for interpolating the Digital Elevation Model

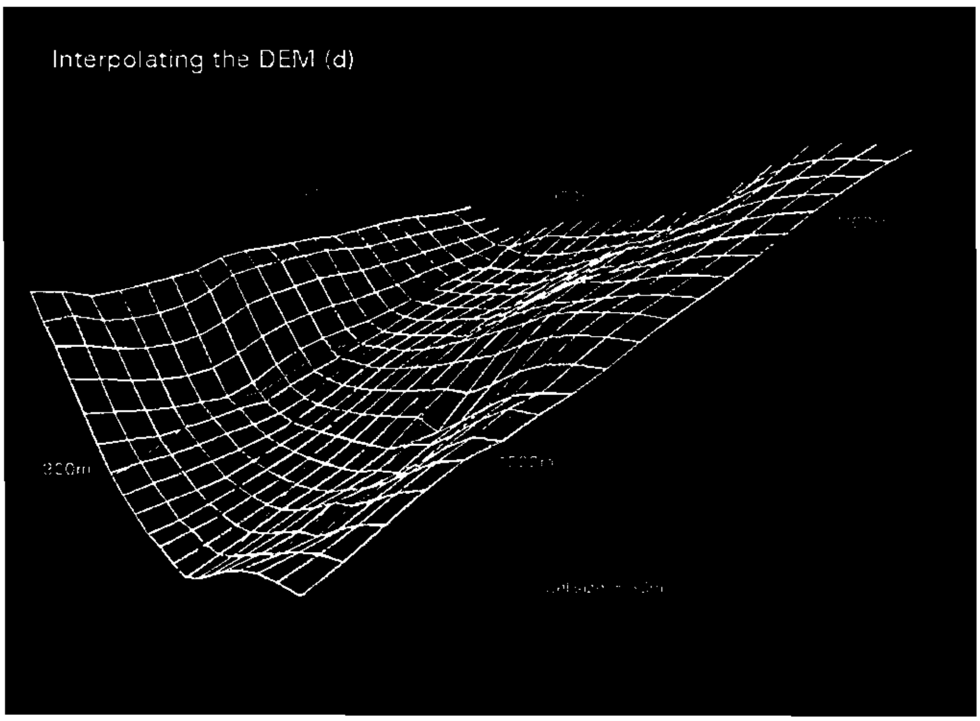


Figure 12. Second step in interpolation of the Digit Elevation Model

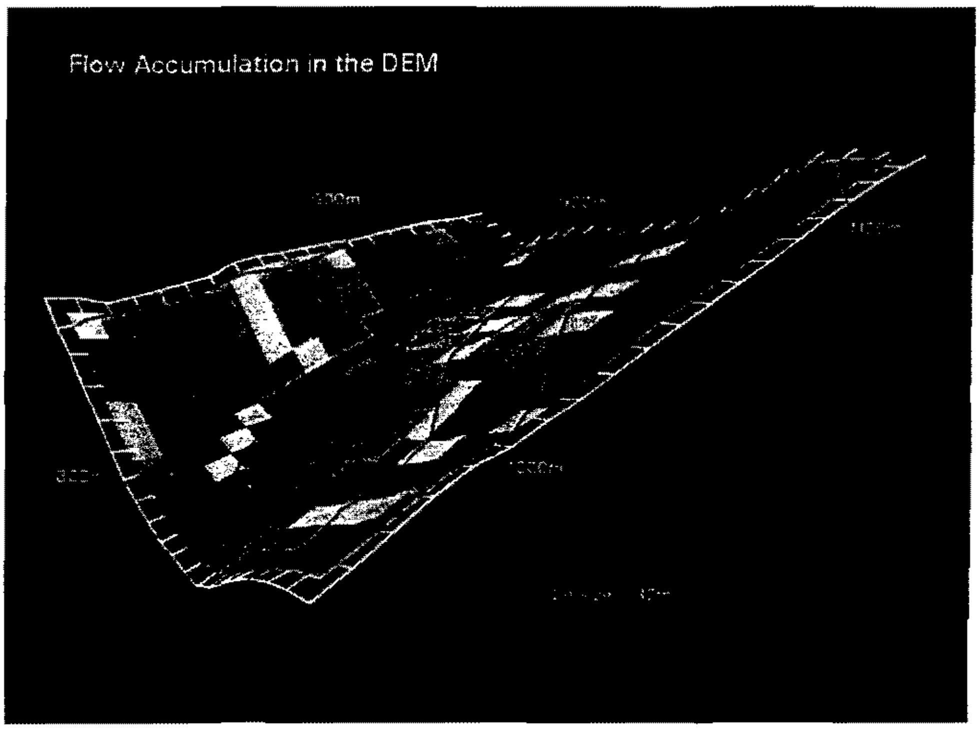


Figure 13. Flow accumulation in the Digital Accumulation Model

If, after this second level of data refinement, contentious issues of erosion risk assessment still remain, a logical third level of synthesis is to include erodability parameters. However, this requires rather costly soil sampling and analysis and would logically be carried out in high risk areas (grids) identified by the above analysis.

Work in progress is taking the analysis of erosion risk several steps further by incorporating process level models to test the outcome of selected land use management scenarios. Results will be reported in future documents.

Sub-Output. *Chronosequence methodology for economic appraisal of long term costs and benefits of resource conservation.*

Activities to date:

Applicability of green manure crops.

Production trials have been conducted to measure the amount of mulch production in relation to time of adoption and altitude in Honduras.

Variability of biomass of the green manure, mucuna, is not related to time of adoption by farmers. It is rather a function of rainfall and length of growing season. A minimum of 3000 kg/ha must be produced to have cover the ground sufficiently to prevent erosion and make a significant contribution of nitrogen to the following crop. A decision support model is being developed to enable farmers to assess what green manure crop to plant in different areas in relation to rainfall and altitude.

Determinants of sustainability in hillside farm in relation to soil loss.

This study applied system simulation to characterize determinants of sustainability of a hillside farm in the watershed of the upper Cauca river, southwest Colombia. A farm model linked to process-level crop models was used to simulate a set of farm scenarios. Sustainability, expressed as the probability of continuation of farming activities, was estimated for each scenario based on replicated simulation with stochastic weather and price inputs. Hypotheses about determinants of sustainability were tested by sensitivity analysis. Results identify cropping system, area under cultivation, consumption requirements and crop prices as important determinants of sustainability. The study highlights impacts of price variability and spatial diversification on farm risk. Results suggest ways to enhance sustainability of the farm.

The methodology was useful for integrating the diverse biophysical and economic factors that affect farm sustainability. For example, **Table 6** shows the results of an attempt to estimate the effects of different soil loss scenarios. Even acknowledging that there are approximations in the simulation, what is notable is the large quantity of soil loss that this farm family could "sustain" before it effected the livelihood of the farmer, at which point, presumably, decisions to rectify the situation would be considered. From the perspective of social cost, however, the analysis clearly raises the issue of potential degradation of watershed watercourses, a common-pool resource. In other words, the analysis identified "at risk conditions" for an environmental problem long before individual families would take notice from effects on private costs.

Table 6. Soil loss and predicted 15 year sustainability of erosion scenarios and G-test statistic for difference from erosion @ 0 Mg ha –1 yr-1 scenario.

Scenario	Annual soil loss (cm soil lost)	Total soil loss (cm soil lost)	G-test
erosion @ 0 Mg ha^{-1} yr^{-1}			
erosion @ 25 Mg ha^{-1} yr^{-1}	0.00	0.00	n.a.
erosion @ 50 Mg ha^{-1} yr^{-1}	0.56	8.33	1.0 n.s.
erosion @ 100 Mg ha^{-1} yr^{-1}	1.11	16.67	3.5 n.s.
erosion @ 150 Mg ha^{-1} yr^{-1}	2.22	33.33	29.5 **
	3.33	50.00	56.2**

C. Forest Margins Agroecosystem

Sub-Output *Identification of demands, opportunities and political priorities of the public and private sector in selected sites of the Brazilian and Peruvian Amazon.*

Highlights

- Digitized maps produced of land use change in Acre and Rondonia in Brazil and Pucallpa in Peru
- Study of effect of comparative land use in the Brazilian Amazon completed
- Opportunities for assisting resource poor farmers have been targeted

Activities to date:

Comparative land use strategies of amazonian colonists in Brazil

Settlers in two Brazilian Amazon colonies, Pedro Peixoto in Acre and Theobroma in Rondonia, were interviewed about land use practices. Settlers practice slash-and-burn agriculture on relatively large, forested parcels to produce rice, maize, and beans. Deforestation rates average some 2.0 ha per year per family in Pedro Peixoto and 3.0 ha per year per family in Theobroma. Lands are then converted to pasture as settlers develop herds for beef and milk production. Settlers in the older Theobroma colony also produce coffee; while colonists in Pedro Peixoto still harvest Brazil nuts from the forest. Cluster analysis was used to differentiate land use strategies. Four strategies in each community included from subsistence production on medium to large, mostly forested holdings in Pedro Peixoto to milk and cattle production on large, deforested holdings in Theobroma. It appears that land use strategies are converging into two types –a smaller, mixed agriculture system for most colonists and for a few, cattle ranching. Unfortunately, both strategies imply continued deforestation. Maintaining or enhancing settler well being after forest lands have been cleared will depend on successful slash-and-burn using fallow rotations for small farmers and on sustainability of pastures for the ranchers.

Land use strategies in Pucallpa, Peru

A reference area for the forest margins was selected in Pucallpa, Peru, by researchers representing Peru's Instituto Nacional de Investigacion Agraria (INIA), the Centro Internacional de Agricultura Tropical (CIAT), and the International Center for Research in Agroforestry (ICRAF).

Pucallpa is located on the Ucayali River, a section of the upper Amazon. The natural vegetation is tropical forest. The reference site is located along an east-west gradient, to the north of the highway leading from Pucallpa to the foothills of the Andes. Rainfall ranges from 1800 to 3000 mm. Although the Huanuco-Tingo Maria-Pucallpa highway was constructed in the 1940s, settlement only became substantial in the 1970s with improvements to the highway **Figure 14**. A multi-disciplinary team of researchers from INIA, CIAT and ICRAF interviewed 151 settlers in Pucallpa in mid-1996. Interviews dealt with patterns of land use and resource management.

Respondents were stratified according to broad differences determined by preliminary informal surveys. Settlers included: a) farmers practicing slash-and-burn agriculture in upper forested areas, b) slash-and-burn farmers living along rivers, c) small cattle ranchers with lands located largely along the road connecting Pucallpa to Lima, and d) a sub-set of forest slash-and-burn farmers who established oil palm as a cash crop (**Table 7**).

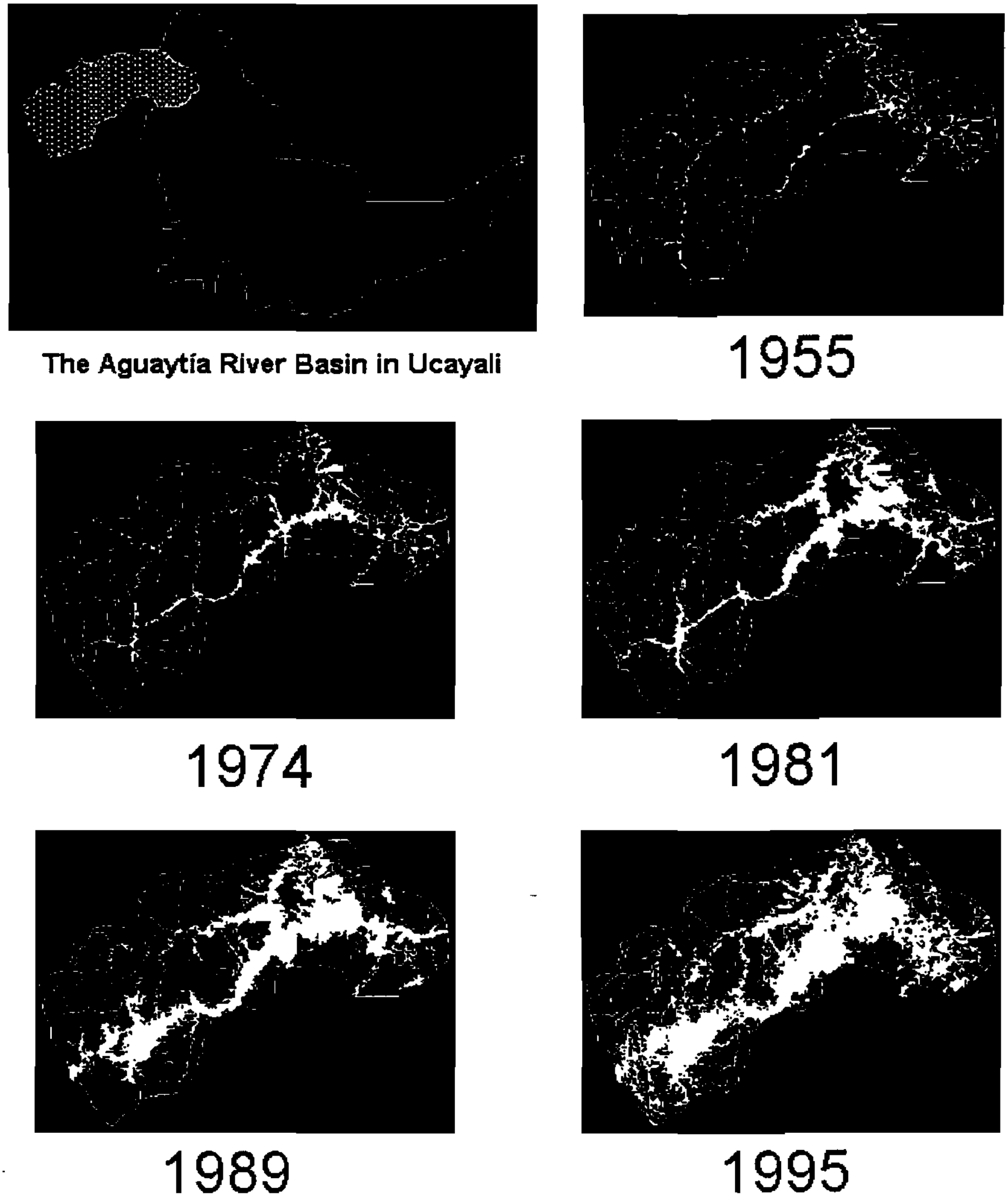
Table 7. Land use (% of area) by main agricultural system, Pucallpa, Peru. 1994-5 & 1995-96

	Slash-and-Burn													
	Forest		Riverine		Total		Cattle		Oil Palm		TOTAL			
	95	96	95	96	95	96	95	96	95	96	95	96	Change	Resp (%)
Forest	30	27	48	46	40	38	20	20	52	51	35	33	-5	67
Cleared	70	73	52	54	60	62	80	80	48	49	65	67	+2	100
Pasture	16	16	12	12	13	14	54	54	2	4	24	25	+0.5	44
Fellow	43	39	25	26	33	31	22	21	25	24	29	28	-5	82
Annual crops	3	8	8	6	6	7	1	2	7	4	5	6	+15	80
Perennials	8	10	7	7	8	10	3	3	14	17	7	8	+14	84
Total area (ha)	1443		1846		3289		1538		422		5249			
Sample size	44		71		115		23		13		151			
Farm size (ha)	33		26		29		67		32		35			

Analysis of the LandSat TM image largely confirmed farmers' accounts: the image covered 109,100 ha of which 17,300 ha corresponded to colonists' parcels and 7,400 ha were held by large haciendas. Analysis indicated that 70% of the colonists' parcels were deforested in 1993 (comparing closely to the reported 67% in 1996 once a correction based on parcel sizes was made regarding the depth from the road of farmers' fields).

Information was obtained on clearing of forest in the different agricultural systems, the frequency of clearing and the choice of location of land cleared (**Table 8**). Information was also obtained on the changes in cropping pattern and on crop yields.

Overall, Pucallpa farmers relied on rice as a major crop for both sale and consumption. Research to help solve upland rice disease problems and the problems of soil nutrient depletion and increases of weeds would benefit many farmers in the area. Pucallpa farmers had a high proportion of their lands in fallow or secondary re-growth. Working with farmers on improved fallows using trees and legumes would appear to be reasonable.



Source: CIAT-U. of Guelph Project on an Integrated Conceptual Framework for Tropical Agroecosystem Research
Prepared by: Ernesto F. Ráez-Luna
Data: IIAP - Instituto de Investigaciones de la Amazonía Peruana, 1996.

Figure 14. Land use change in Pucallpa, Peru, since 1956

Table 8. Percent of respondents (n=83) reporting criteria for choice of location of forest field to clear and crop by main agricultural system, Pucallpa, Peru

Area	Slash-and-Burn Forest	Slash-and-Burn Riverine	Slash-and-Burn Total	Cattle	Oil Palm	TOTAL
Fertile soil	9	5	7	12	17	8
No flooding	41	39	40	12	42	38
Close to road/house	29	28	29	26	33	29
Flatter areas	21	28	24	50	8	25

Conclusions: towards an appropriate research agenda for increasing income

Upper-area farmers who had earned incomes from coca production (from sales and/or from wages for weeding and harvesting) were seeking new alternatives. Charcoal production, given use of selected suitable forest species such as *Dipterix odorata*—cannot be expected to be sustainable. Efforts to develop and promote new crops (such as camu camu *Myciaria dubia*) and agroindustries (eg palm oil) would appear to be reasonable; and research is needed to carefully determine *ex ante* demand for new alternatives. Farmers have had experience with the promotion of supposedly income-generating crops such as citrus and achiote, which unfortunately were market failures.

Riverine slash-and-burn farmers were most concerned about diseases affecting their banana plantations and upland rice. Research to address the problem would be appropriate and needed.

Research in Pucallpa has long targeted the cattle ranchers in the introduction and testing of forage and feeding systems. These settlers, however, may have little interest in more productive forage systems as long as current pasture resources are more than sufficient given the area's reduced herd size. On the other hand, targeted work to increase systems productivity and sustainability with the few ranchers maintaining high numbers of animals per area may be appropriate.

References:

Fujisaka, S., O. Madrid and L. Hurtad. 1996. Land use strategies of Amazon colonists (*in press*).

Fujisaka, S. 1997. Land use strategies in Pucallpa, Peru. Paper prepared for the ASB meetings on characterization. (*in press*).

D. Savannas Agroecosystem

Sub-Output. *Soil processes studied in long-term production system experiments*

Improved-grass pasture and crop production systems have expanded rapidly in the savannas but soil degradation has become a major problem. In order to understand and reverse this process, nutrient dynamics and soil physical characteristics are being studied under different crop-pasture-green manure sequences, in long term trials, to develop indicators for land use sustainability. Process models are being modified for the tropical conditions of the savannas. Some form of crop-pasture rotation appears imperative to maintain desirable soil physical and soil biological characteristics.

Research in this area is closely linked to the Systemwide Soils, Water and Nutrient Management Program. The Ecoregional Program presently does not provide funds for research in the savannas except for the sorghum improvement program (see later section). The research has been fully reported elsewhere (Annual Report 1996 – Soil Process research in CIAT).

Output 3. *Technology Component: Sustainable Sorghum cultivars for acid soil savannas*

The savannas of Bolivia, Brazil, Colombia and Venezuela, Colombia are the most important areas for future expansion of crop production in tropical Latin America. The development of crop germplasm with the ability to produce an economic return under savanna conditions will contribute significantly to the diversification of production systems in the savannas. The savannas are characterized by having soils of high acidity and Al saturation. While research is being carried out to improve acid soil tolerance of rice, maize and sorghum, limited research has been focussed on sorghum. ICRISAT in collaboration with CIAT and CORPOICA, Colombia, agreed to establish and strengthen a program on the genetic enhancement of sorghum in the region with funds supplied by BID under the Ecoregional Program.

Specific objectives:

- Assemble and multiply sources of acid soil tolerance, foliar disease resistance, and agronomic eliteness, and evaluate these sorghums (and pearl millets) across a number of environments relevant to the acid soil savannas of Latin America.

- Develop high yielding seed parents, open-pollinated varieties, and restorer lines in a range of plant heights, maturities, tillering ability, and grain types, having tolerance to acid soils and low phosphorous availability combined with resistance to foliar diseases (principally anthracnose and grey leaf spot).

- Evaluate breeding products in a systems context for the acid soil savannas, for grain, forage and sustainability.

- Develop an effective network for the evaluation of progenies, sharing of information, data and materials, and enhancement of knowledge on sorghum improvement for the region by organizing workshops, training courses, degree programs, etc., for scientist in the region.

Highlight

- Superior lines for a breeding program to develop acid tolerant germplasm for the savannas have been identified and an improvement program initiated.

Activities to date:

Some 1200 sorghum lines were first evaluated at CIAT for various agronomic traits including resistance to foliar diseases. A set of lines was selected (**Table 9**) for evaluation at three sites in Colombia. These are at the experimental station of CIAT at Santander de Quilichao, and at the CORPOICA experimental stations at La Libertad, Villavicencio, and Carimagua.

Table 9. Summary of selected sorghum lines after evaluation in the introductory nursery at CIAT-Palmira.

Type of material	No. selected
High yielding R lines	143
Pest resistant R lines	49
Disease resistant R lines	83
High yielding B lines	33
Pest resistant B lines	65
Disease resistant B lines	40
Forage B lines	92
A2 cytoplasm and staygreen	31

The selected sorghum lines were evaluated in a completely randomized block design with 3 replications at 3 different sites: Quilichao (CIAT), La Libertad (CORPOICA) and Carimagua (CIAT/CORPOICA).

The soils in those three sites are characterized by different levels of Al saturation. In Quilichao, Al-saturation (55%) is relatively lower than at the other two sites; however, it has the highest concentration of Mn (114 ppm). La Libertad presented an intermediate level of Al saturation (66%), lower concentrations of Mn (4.3 ppm), and represents the growing conditions in the Piedmont region of Colombia. Carimagua, showed the highest saturation (75-80%) and represents the growing conditions of native savannas.

Fields were highly variable at Quilichao and La Libertad. In Quilichao the incidence of leaf diseases was very high, and enabled us to select the materials both for leaf disease resistance and Al tolerance. The other two locations did not present high levels of leaf disease incidence, due to the relatively lower air humidity in second half of the year in the eastern plains of Colombia in 1996. Since the rains ceased in the middle of December, and the materials matured in a rain-free situation, the grains were free from molds. Several lines were lodged in Carimagua as a consequence of strong winds in the months of November and December.

Carimagua was the best site for discriminating among genotypes with respect to grain production and other relevant traits. Grain production along with stay-green scores were considered as selection criteria to chose those materials with tolerance to high Al concentrations in La Libertad and Carimagua. The average grain production for the selected material in Carimagua ranged between 2.5 and 5.0 t ha^{-1}. Results for the different evaluated traits showed significant variability due to genotypes and genotype x environment interaction (G x E). The selected sorghum materials (24 R-lines; 32 B-lines and 5 forage-lines) form the test materials for the Regional Network Testing in Latin America.

During second half of 1996, two populations were planted for mass selection: a high tillering/brown mid-rib population (ICSP HT), and a large grain population tolerant to acid soils (ICSP LG). The bulks formed from mixing the mass selected male-sterile and male-fertile heads within each population were combined to form the new cycle population. During the following cycle, acid soil tolerant germplasm will be introduced into both the populations.

In addition, we also evaluated pearl millets at Quilichao, introduced from India (21 R-lines, 11 A/B line pairs and 30 populations), and a total of 2 R-lines, 4 A/B pairs and 13 populations were selected.

The selected populations and R-lines will be evaluated during first semester 1997 for forage production, along with the selected forage sorghum lines.

Further we introduced the seed of A-lines corresponding to the 83 selected B-lines, and 7 high yielding restorer lines; and a maintainer population (ICSP B) from ICRISAT Asia Center and 103 R-lines from ICRISAT Western and Central Africa Center. These materials will be evaluated and multiplied at Cali during summer 1996.

In the area of training, two scientists, Mr. Jaime Humberto Bernal, CORPOICA, Colombia, and Mr. Pedro Jose Garcia, FONAIAP, Venezuela, spent five months at ICRISAT, getting familiarized with sorghum nursery management, evaluation and selection procedures.

Output 4. *Strengthened NARS Capacity*

Specific objective: Involve NARS partners in the development of data bases, methods, models and information systems.

This will be achieved through:
- International workshops
- Training on an individual basis
- Evaluation of the utility and adaptation of methods and models by NARS scientists
- Provision of bibliographic and information services

Activities to date:

Training in methodology... A workshop was held in Nicaragua of national scientists involved in GIS studies in Central America to coordinate these activities.

Individual training. Several scientists from have spent short periods of assignment with the Land Management and GIS units.

Ecoregional Research – an evolving program

CIAT and its partners are involved in a more comprehensive research program of ecoregional research in Latin America than those areas specifically approved for funding by TAC under the initial TLAP proposal. In particular, this applies to germplasm improvement, to in-depth studies on soil nutrient and macrofauna dynamics, and to integration of germplasm improvement and natural resource management through system-based farmer participatory technology development.

Increasingly, the overall natural resource management effort in Latin America is being focused on the Central American Hillsides, the Forest Margins in Peru and the Savannas in Colombia, and in particular, the main reference sites, while that of CONDESAN led by CIP is strengthening its reference sites in four Andean countries. This work on the reference areas and agroecosystems is linked through GIS referenced data bases being developed for the whole continent. There is also a collaborative regional program on policy research with IFPRI.

The main reference sites for the Ecoregional Program are:

- Forest margins	Pucallpa, Peru
- Hillsides	Central America – La Ceiba, Yoro, Danli (Honduras), Matagalpa (Nicaragua)
- Savannas	Llanos, Colombia and
- High Andes	Cajamarca (Peru) (through the CONDESAN initiative led by CIP)

There are also associated sites for each agroecosystem, viz. Forest Margins (Yurimaguas, Iquitos in Peru; Acre, Rondonia in Brazil); Hillsides (Cauca in Colombia); Savannas (Uberlandia in Brazil) and CONDESAN has other principal sites in Bolivia, Colombia, Ecuador and Peru.

A comprehensive program is being developed at each of main reference sites in the areas of:

a. Consultation or development of a framework for guiding decisions on R & D interventions
b. Socio-economic characterization and analysis of land use dynamics
c. Germplasm evaluation
d. FPR technology development and investigation of land use alternatives
e. Soil, water and nutrient management dynamics under different forms of land use
f. Investigation of new agro-enterprise alternatives
g. Assessment of economic and environmental impact
h. Policy analysis

Role of CIAT

CIAT acts as a facilitator to catalyze efforts of IARC's in the priority agroecosystems working within a framework for regional priorities set by the different countries in the region as a whole and by national organizations for the reference sites. The key to synergy is through the development and acceptance of a common vision, definition of objectives and collaboration in the activities needed to achieve this vision.

Within CIAT, the mechanism for coordinating the Ecoregional Program operates at two levels, regional consultation and information sharing and agroecosystem problem solution. The Director, Regional Cooperation, maintains close liaison at the national levels of government providing information on the Program and obtaining feedback on government priorities. The Director, Resource Management, is responsible for translation of this feedback into setting of priorities and coordination of activities within the Center and between organizations at each reference site.

Conclusion

The advent of an Ecoregional Program for Tropical Latin America has been constructive in several aspects.

Firstly, it has ensured that there has been wide consultation with our CGIAR and national partners in Latin America on priority setting for research in natural management issues and defining the comparative advantage of the international centers.

Secondly, as a platform for research activities, it has made it easier for different organizations to work together in a complementary manner.

Thirdly, through focussing attention on reference (or benchmark sites), it has brought about a stronger cohesion and integration of activities within organizations.

General reference

CIAT. March 1996. An Ecoregional Approach to Enhancing Agricultural Research in Tropical America. 23 pp. CIAT, Cali, Colombia.