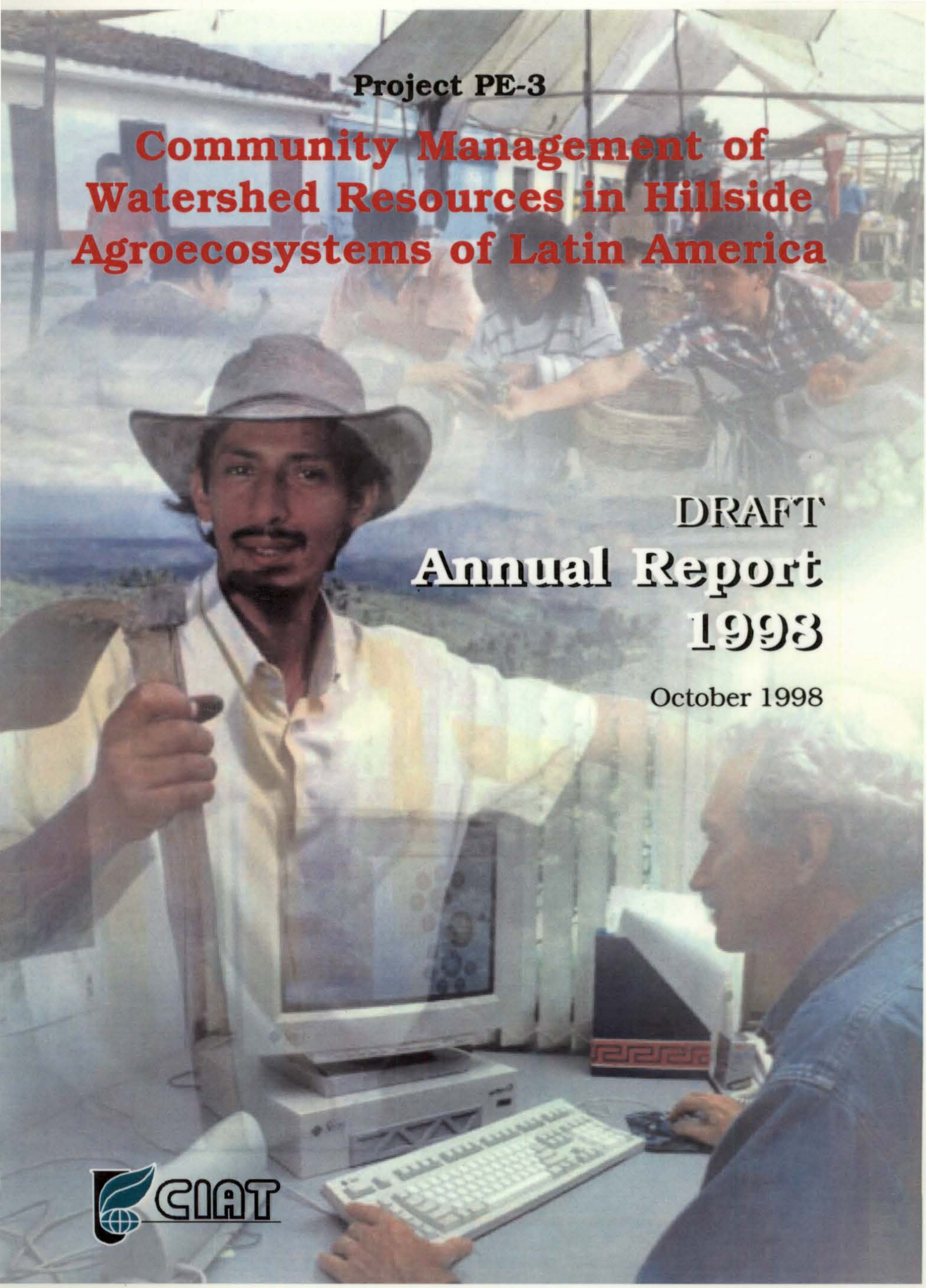
Project PE-3

Community Management of Watershed Resources in Hillside Agroecosystems of Latin America



DRAFT
Annual Report 1998

October 1998

CIAT

PROJECT PE-3

COMMUNITY MANAGEMENT OF WATERSHED RESOURCES IN HILLSIDE AGROECOSYSTEMS OF LATIN AMERICA

DRAFT

ANNUAL REPORT 1998

Centro Internacional de Agricultura Tropical (CIAT)
Cali, Colombia

October 1998

Project PE-3: Community Management of Watershed Resources in Hillside Agroecosystems of Latin America

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3.3 At least 15 development practitioners, NGOs, community leaders know how to interpret the results from using the DS tools to do land use planning

Output 4: Organizational models and principles have been developed that facilitate the use of the DS tools in participatory planning of watershed resource management

4.1 At least three local operational committees (CLODEST) formed at the project sites, meet at least twice a year for the purpose of participatory planning of watershed resources, management, and testing of the project's DS tools. One CLODEST in each of three sites by 1997,1998, and 1999.

4.2 Local operational Communities provide input to the annual Consultative Group meeting on the utility of the project's DS tools and interactive digital information system

Output 5: Stakeholders' experimentation with improved land management

5.1 Alternative policy land use scenarios developed with community participation have been evaluated in at least two project sites starting in 1999, using the project's DS tools

5.2 Stakeholders in at least two project sites are experimenting with and monitoring changes in land management that are more productive and environmentally sound as a result of scenario evaluation by the end of the project *Not reported on this year*

Meetings and Workshops

Publications

Donors

Collaborators

Personnel

Abbreviations

Acronyms

Project PE-3: Community Management of Watershed Resources in Hillside Agroecosystems of Latin America

Objectives: To develop generic biophysical and socioeconomic databases, decision-support tools, and social organizational models that interest groups can improve, institutionalize, and adapt for planning research and development activities for specific locations.

Outputs: Procedures for databases to target problems, priorities, and beneficiaries in watershed resource use management. Techniques for location-specific diagnosis, monitoring, and impact assessment of environmental problems and interventions. Interactive (computer-assisted) decision-support tools established for community-managed development of watershed resources.

Gains: Systemization of organizing, goal-setting, planning, gaining representation, and conflict resolution among communities seeking economic and social growth while protecting their environmental resource base. Technological and methodological advances in information technology for use by members of agricultural communities.

Milestones:

1998: Instructional materials for community-based resource planning organizations and use of environmental databases. Methods to incorporate indigenous biophysical and socioeconomic indicators in decision-support tools.

1999: Planning and policy workshops with stakeholders, incorporating simulation analysis for negotiating collective community action.

2000: Case studies of improved watershed resource planning and management by communities in Colombia, Honduras, and Nicaragua.

Users: Farming families and rural communities of the Andean and Central American hillsides. Project sites profit from increased community action aimed at sustaining the productivity of the resource base. As a result, off-site stakeholders benefit. National and international development organizations involved in priority setting and investments in development.

CGIAR system linkages: Protecting the Environment (60%); Crop Production Systems (25%); Strengthening NARS: Networks (10%); Livestock Production Systems (5%). Participate in the Tropical America Ecoregional Program. Linked to the System-wide Water Management and Mountain Initiatives.

CIAT project linkages: Inputs from soils (PE-2), Land Use (PE-4), and participatory methods (SN-3) projects. Collaboration with smallholder systems (PE-5) and agroindustries (SN-1) projects.

Project PE-3: Community Management of Watershed Resources in Hillside Agroecosystems of Latin America

Project Objective
To contribute to improved capacity for the implementation of community-led management of watershed resources in Latin America

Output 1

Interactive digital information systems for hillsides agroecosystems widely distributed

1.1 The GIS CD-ROM database of socio-economic and biophysical information for Honduras is in at least three distribution outlets by December 1998

1.2 The GIS CD-ROM database of socioeconomic and biophysical information for Nicaragua is in at least three distribution outlets by December 1999

Output 2

Decision support (DS) tools, including indicators, models for scenario building and participatory methods developed with the participation of stakeholders

2.1 The Consultative Group in 1998 has hands-on use of the decision support tools planned in the 1998 and 1999 work plans

2.2 Community-led initiatives, NGOs, universities, and NARS are using the DS tools in at least three sites in 1999

2.3 DS tools are published and widely distributed in Honduras and Nicaragua by the end of the project

Output 3

Trained people with skills to use the DS tools and interactive digital information system

3.1 At least 15 technical professionals, in Honduras and Nicaragua, are using the DS tools by the end of the Project

3.2 Training materials and course curricula on applying the DS tools to community-led watershed resource management are published by the end of the project

3.3 At least 15 development practitioners, NGOs, community leaders know how to interpret the results from using the DS tools to do land use planning

Output 4

Organizational models and principles have been developed that facilitate the use of the DS tools in participatory planning of watershed resource management

4.1 At least three local operational committees (CLODEST), formed in *the project sites, meet at* least twice a year for the purpose of participatory planning of watershed resources, management, and testing the project's DS tools. One CLODEST in each of three sites by 1997, 1998,

4.2 Local operational Communities provide *input* to the annual Consultative Group meeting on the utility of the project's DS tools and interactive digital information system

Output 5

Stakeholders' experimentation with improved land management

5.1 Alternative land use scenarios developed with community participation have been evaluated with the CLODEST in at least two project sites starting *in 1999, using the* project's DS tools

5.2 Annual reports of GIS coverages, indicators, adoption surveys, and *participatory impact* assessment reports at two points in time 1999 and 2000

PE-3 LOGFRAME[1]

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
GOAL	To contribute to improved capacity for the implementation of community-led management of watershed resources in Latin America	By Dec 1999 at least five local initiatives successfully implemented with local working groups in Honduras and Nicaragua	Local initiatives working	Interest and continuing collaboration of stakeholders
PURPOSE:	Decision support (DS) tools and methodologies for participatory planning of land use and watershed resource management are adopted by multiple stakeholders in the Latin American hillsides	By 31 Dec 1998, at least 80% of the instruments and methods planned in AOP 1998 are available to the Consultative Group members	Availability of instruments and methods planned in POA 1998; Annual report	Data are made available by partners and there is willingness to incorporate the DS tools in their decision-making process
		By 31 Dec 1999, at least 15 key entities of the region have at least three instruments and methods developed by the project	Availability of instruments and methods to key entities of region; Annual report	
OUTPUT 1	**Interactive digital information systems for hillsides agroecosystems widely distributed**	**1.1** The GIS CD-ROM database of socioeconomic and biophysical information for Honduras is in at least three distribution outlets by December 1998	1998 Annual Report	Partners are willing to distribute the CD-ROM
		1.2 The GIS CD-ROM database of socioeconomic and biophysical information for Nicaragua is in at least three distribution outlets by December 1999	1999 Annual Report	Data is made available to the project by partners

Continued

[1] For abbreviations and acronyms see page ..

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 2	**Decision support (DS) tools, including indicators, models for scenario building, and participatory methods developed with the participation of stakeholders**	**2.1** The Consultative Group in 1998 has hands-on use of the DS tools planned in the 1998 and 1999 work plans	Consultative Group Meeting November 10-11, 1998	Stakeholders are willing to participate in testing the DS tools
		2.2 Community-led initiatives, NGOs, universities, and NARS are using the DS tools in at least three sites in 1999	Manuals for use of DS tools are in circulation in draft version by Feb 1999, Executive Committee Meeting	
		2.3 DS tools are published and widely distributed in Honduras and Nicaragua by the end of the project	Follow-up meeting to evaluate tools in project sites Annual reports 1998, 1999; final report 2000	
OUTPUT 3	**Trained people with skills to use the DS tools and interactive digital information system**	**3.1** At least 15 technical professionals, in Honduras and Nicaragua, are using the DS tools by the end of the project	At least one university in Honduras or Nicaragua is incorporating the use of the DS tools into its curriculum by the end of the project	*University teachers are willing to* make innovation in the curriculum
		3.2 Training materials and course curricula on applying the DS tools to community-led watershed resource management are published by the end of the project	Proceedings and report on courses and workshops of the project 1998 and 1999, and its partners show participation in training Annual work plans and reports 1998 and 1999 Training materials are being distributed in Honduras and Nicaragua	There is a demand for professionals with these skills in the labor market
		3.3 At least 15 development practitioners, NGOs, community leaders know how to interpret the results from using the DS tools to do land use planning	Interviews with community leaders, development practitioners, and NGOs	

continued

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 4	**Organizational models and principles have been developed that facilitate the use of the DS tools in participatory planning of watershed resource management**	**4.1** At least three local operational committees (CLODEST), formed in the project sites, meet at least twice a year for the purpose of participatory planning of watershed resources, management, and testing the project's DS tools. One CLODEST in each of three sites by 1997, 1998, and 1999	Minutes and reports of the CLODEST	Local organizations are willing to meet in committees to do land use planning
		4.2 Local operational Communities provide input to the annual Consultative Group meeting on the utility of the project's DS tools and interactive digital information system	Proceedings of annual Consultative Group meetings	
OUTPUT 5	**Stakeholders experimentation with improved land management**	**5.1** Alternative land use scenarios developed with community participation have been evaluated with the CLODEST in at least two project sites starting in 1999, using the project's DS tools	User-friendly interactive DS tools for participatory scenario building and evaluation have been developed and tested with stakeholders	Policy disincentives to improved land management do not interfere with stakeholders willingness to experiment with new patterns of land use
		5.2 Annual reports of GIS coverages, indicators, adoption surveys, and participatory impact assessment reports at two points in time 1999 and 2000		

Major Highlights

Output 1: Interactive digital information systems for hillsides agroecosystems widely distributed

- Agricultural Atlases available on CD-ROM of over 90 spatial coverages and "grey" literature for socioeconomic and biophysical information for Honduras for use as a Decision Support tool
- Satellite and air photo imagery processed and supervised classification of land cover for the Honduran Departments of Atlantida, Yoro, and El Paraiso. This improved interpretation and value of official agricultural censuses and allows communities to visualize current and past land use and plan future land use.
- Created only digital database of latest agricultural and population censuses at resolution of household (4,255,105 records) for Honduras.
- Developed high resolution DTMs (digital terrain models) for four watershed study sites
- Land use trends determined by using remote sensing imagery were validated in the field
- Non-parametric statistical method developed to determine homologies with benchmark sites to determine how representative a watershed is and to make comparisons possible
- The CIAT Hillsides Central American Project accessible on website (www.intertel.hn/org/ciathill)

Output 2: Decision support (DS) tools, including indicators, models for scenario building and participatory methods developed with the participation of stakeholders

- Goal-driven, Group Decision Support System prototype methodology and software for community watershed management developed and introduced in Honduras workshop
- "Maqueta" or three-dimensional papier-mâché model made of Tascalapa watershed as community DSS tool
- Soil quality score card built using locally determined indicators of soil quality for participatory land evaluation
- Methodologies for the identification and ranking of soil indicators, and participatory mapping, analysis, and monitoring of natural resources (including GIS, photo-topographic analysis of land use changes, and use of 3D terrain model) are available in finalized or advanced form.
- Accessibility indicator map developed for Honduras to help decision makers assess transport infrastructure, access to market, and service provision
- The method for the participatory identification of market opportunities is also available.

- A study used the digital population census database developed by the project to create new exogenous indicators of "poverty" which are better measures of resident empowerment and ecosystem resilience than international and national institutional indicators currently in use.
- A study in Honduras has shown that of dozens of local well-being variables identified across a wide range of communities, fewer than a dozen can be used to structure a basic index. Parameterization of those variables still may require local survey data.
- Designed prototype ex ante impact analyses including rule-based scenarios of land-use change, deforestation-landslide risk for improving community management of water resources in hillside watersheds in collaboration with King's College, London
- A process-based, data-economic simulation model for testing effects of land and resource use decisions on watershed water-use is nearly complete as partial fulfillment of a PhD degree with U. of Florida.
- A model was developed for the interactive exploration of spatial point patterns across geographic scales. This is a useful DS tool for targeting problems, priority areas, and beneficiaries.
- Software has been developed (using spatial Honduran census databases developed by the Project) that can identify dominant spatial scales at which process that control landscape patterns and ecosystem function occur. (In partial fulfillment of a PhD degree with U. of Leeds, UK)
- In Colombia, the Project is field-testing, in collaboration with CONDESAN, unique technical assistance policies that create incentives for those in the "highest" well-being classification to create employment specifically for those falling in the "lowest" well-being classification. The Cauca case study is using blackberry production as the vehicle to create employment.
- Improved geographic poverty targeting to help decision-makers in prioritizing projects and assigning funds appropriately to help decrease poverty for Honduras
- The methodology to define levels of poverty in rural communities was applied in the micro-watershed of the Rio Calico
- Key elements identified in fostering and facilitating collective action for watershed management of pests, soil erosion, and deforestation
- Methodology to identify stakeholder groups and stimulate collective management of natural resources in micro-watersheds completed
- Participatory micro-watershed analyses underway; results are for use of key local decision-makers to help identify priority zones for action
- Data collected and being analyzed on the water quality in the Rio Cabuyal watershed to monitor the sustainability of this valuable resource

Output 3: Trained people with skills to use the DS tools and interactive digital information system

- During 1998, the Project entered into agreement with U. Nacional Agraria (Nicaragua) to train staff in the use of training materials developed by the Project.
- CD-ROM of national geographical information available for Honduras
- The CIAT Hillsides Central American Project accessible on website (www.intertel.hn/org/ciathill)

- 26 activities held with donor representatives, other projects, university scientists, and national organizations
- Active participation in workshops to train in the use of DS tools, and positive responses given on methodologies
- Nine methodological training guides for trainers produced
- Nine new training handbooks for diffusing/teaching the CIAL methodology in Central America produced
- Two major workshops organized to present and validate the above
- Policies are being evaluated with the collaboration of CONDESAN
- In 1998, the Project co-sponsored with PASOLAC (a technical assistance project funded by the SDC with headquarters in Managua, Nicaragua), the FAO Limpira Sur Project and CIDICO (a NGO) a workshop on "Legume Ground-Cover and Soil Conservation Methodologies".

Output 4 Organizational models and principles have been developed that facilitate the use of the DS tools in participatory planning of watershed resource management

- Stronger links made at local level through PPO workshops in Yorito, Honduras and in San Dionisio, Nicaragua
- 136 participants from NARS, NGOs, and local, international, and regional organizations in Central American Hillsides Project training and workshops, 1998
- The Project is a co-founder of National Networks for GIS in Honduras and Nicaragua and convenors of annual meetings.
- In 1998, the Project co-sponsored with PASOLAC a strategic meeting to coordinate research activities among various projects operating in Central America.
- The Project actively supports ICASA (the International Consortium for Agricultural Systems Applications.
- The Project actively supports the USAID-funded Soil Management CRSP as a member of the Technical Advisory Committee.

Introduction

This annual report is the sixth since the commencement at CIAT of research focusing on sustainable social and economic development for the Hillsides agro-eocsystems of Latin America. Throughout the past six years, the Project has navigated uncharted waters towards bold, perhaps even noble goals, in changing operational environments.

Strategic problems addressed by the Project have never changed. How to characterize responses to land management choices; responses that may not manifest themselves in the space/time frame of typical crop/soil experimental studies? How to methodologically manage research in socio-economic and boiphysical environments characterized by extreme heterogeneity in space and time? And managerially, how to organize requisite constituencies that transcend traditional CGIAR collaborative groups

In 1992, research activities were organized within four "outputs" and management activities were organized within a "program" framework. (CIAT Hillsides Annual Report for 1993).

By 1997 a metamorphosis resulted in a "project framework" with concomitantly narrowed outputs (CIAT Project PE-3 Annual Report for 1997). In 1998, the project had the benefit of an external management consultancy funded by one of its major donors, the Swiss Agency for Development Cooperation. (SDC). A major output was the rewriting of the project's Logical Framework. This was done to improve the transparency of linkages between sub-projects funded by SDC, the International Development Research Centre (IDRC), the Inter-American Development Bank (IDB), and the Ecoregional Trust Fund for Methodological Research.

Operationally, the Program/Project was quick to adopt a hierarchical, i.e., multiple-scale, systems approach. We believe there exist significant bodies of knowledge and skills at the individual field and farm scales and similarly at broad, silvo-agro-pastoral sector scales. The greatest current need, and we believe highest return, is for skills catalyzing collective actions that focus on interests of stakeholders at the "community landscape" scale. Because "community landscape" was not considered a sufficiently precise concept, the Project early on adopted the "community watershed" as a useful spatial structure around which to begin to catalyze collective action. We define community watersheds as complex, hierarchical, dynamic, and adaptive systems in which a multitude of natural processes and human activities take place.

The "environments" of community watersheds are primarily structured by large-scale physical and, to lesser degrees, economic processes and social infrastructure that are the domain of policy makers. Within these relatively large homogeneous structures, smaller scale processes take place which are of concern to individual farm families. A common meeting ground for communication, negotiation, planning and impact monitoring for technical assistance is the community watershed.

A major challenge for researchers addressing issues of "sustainability" of land use is to present evidence that so compellingly links decisions and consequences that stakeholders are willing to recalculate the price they are willing to pay to achieve their goals. One need not ponder for very long typical goals of food security, capital accumulation and healthy water to appreciate the challenge. However, the need to provide compelling evidence raises a second challenge for researchers which is the valuation of data. Researchers have an insatiable appetite for data. Borrowing from more profit-minded professions, the Project attempts to design methodologies that are governed by the principle of "optimum ignorance" which is merely a way of stating that decision-makers are not inclined to patiently wait for analysts to analyze.

The purpose of the Project places direct demands on ways in which sample research data are collected and interpreted. Typically the Project has focused on two types of studies. Sample surveys where researchers select (random) samples from well-defined statistical populations. Research results in good descriptions of population differences but explanation of cause-effect relations is problematic. The second type, controlled retrospective studies have researchers identifying a characteristic response and subsequently the *history* of the sampled unit is traced to detect explanatory variables. The Project is promoting a third type of study, controlled prospective studies, where researchers select study units for which various variables thought to be explanatory are measured. Study areas are then monitored to see if some particular event occurs. Like the retrospective studies, if all explanatory variables are measured, which is rare, conclusions can be drawn similar to traditional crop/soil experiments. Most of the research reported in the following pages focuses on development and testing of methodologies to process and sample data to carry out the types of studies characterized above.

In addition to traditional research activities, the Project is dedicated to increasing human capital through competency-based training. Seven major training themes have been identified. They incorporate skills to organize, communicate visions, inventory available resources, evaluate decisions using scenario-testing, prepare a plan , monitor progress and measure impacts. During 1998, nine training modules were prepared and tested in in-country workshops. In addition, in-country workshops were carried out addressing basic GIS skills. And our first in-country workshop was the testing ground for a new methodology, being developed in collaboration with the University of Georgia, for a goal-driven approach to decision-making for socially and environmentally sensitive development.

Finally, 1998 was a time of major changes in Project personnel. The Project started and ended the year with 4.2 FTE-IRS (full-time-equivalent, internationally-recruited-staff). However, statistics belie the fact that four "long-term" Project members left during 1998. Staff who will be missed beginning in 1999 include Dr. Hector Barreto, an agronomist who served as project coordinator and manager of the Honduras office since 1994, Dr. Ronnie Vernooy a rural sociologist who served as project coordinator and manager of the Nicaragua office since 1996, Dr. Helle Ravnborg a rural sociologist at CIAT headquarters since 1994 and leader of research on "well-being", and Dr. Bill Bell, GIS specialist at CIAT headquarters who was formally with the project since 1996.

Joining the Project in 1998 were Dr. J.I (Nacho) Sanz who returned to CIAT after taking part in a two-year exchange program with IDRC Canada. Dr. Sanz will be replacing Dr. Ron Knapp as Project manager based at CIAT headquarters. Dr. Knapp will return to full-time research. Dr. Miguel Ayarza, an agronomist, has taken over coordination of all Project activities in Honduras and Nicaragua. Ing. Agr. Jorge Alonso Beltran, an associate agronomist with over 10 years experience with CIAT and with the Project since its inception in 1992, will serve as the Project Liaison Officer for the Central America region and is based in Managua, Nicaragua. In addition, a GIS specialist, Ms. France Lemy, was recruited for the Project in January 1998 and is based in Tegucigalpa.

And what about the future? The "pathway" we are pursuing relies on developing and validating user-friendly information technologies that permit stakeholders to analyze land use goals and propose solutions that have traditionally been too complex for individual stakeholders and national technocrats. At least initially, project-trained personnel using "focus-group" procedures will conduct workshops on demand. Tutorials of procedures and required skills will be published as multi-media materials. Within the next year we will have developed software that will link stakeholders in "virtual" planning workshops. Within three years, we envision an army of trained, equipped, and experienced multi-national facilitators responding to demands for help from committees of multiple stakeholders that include government organizations (GOs), non-government organizations (NGOs) and community activists. We also believe that the Project offers unique opportunities for forging collaborative links between the private and development sectors. We are exploring ways in which public and private domain data and knowledge base development and maintenance can be profitably financed by the private sector for their own uses while remaining available to the public development sector. We hope you find the following report compelling evidence that we are on the right path.

Hillsides (PE-3) progress against milestones 1998

OUTPUT	MILESTONES for 1998	PROGRESS
Output 1 Interactive digital information systems for hillsides agroecosystems widely distributed	Strategic databases (GIS Honduras) available in Honduras in three distribution outlets by December	RENASIG (Honduras) and UNA (Nicaragua) will distribute the CD-ROM October 7-10, 1998
Output 2 Decision support (DS) tools, including indicators, models for scenario building, and participatory methods developed with the participation of stakeholders	DS tools developed and available for testing and evaluation by the Consultative Group in December 1998	Handbooks on DS tools available in published form in December 1998
Output 3 Trained people with skills to use the DS tools and interactive digital information system	At least 15 key professionals trained in testing the DS tools and strategic database (GIS Honduras)	Workshops and courses 1998
Output 4 Organizational models and principles have been developed that facilitate the use of the DS tools in participatory planning of watershed resource management	A multi-institutional agreement signed with stakeholders organized in at least three watersheds to test the DS tools in participatory land use planning	Consultative Group meeting Nov 10-11, 1998 for hands-on trials of DS tools **Local**: Yoro Clodest stakeholder analysis and PPO Formation of and PPO with the Asociacion de los CIALs in San Dionisio Meetings in San Dionisio leading to the formation of the Asociacion de Organizaciones Comunitarias "Campos Verdes" Validation workshops on methodological tools in Yorito and San Dionisio – three more planned in Danli, Ticuantepe, and Santa Teresa **Regional**: Consultative Group and Executive Committee have clear terms of reference Annual work plan of the project supplied in March 1998
Output 5 Stakeholder experimentation with improved land management	Soils and agronomy researchers recruited by September 1998	Recruitment completed; new staff have started work

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Output 1: Interactive digital information systems for hillside agroecosystems widely distributed

Activity 1.1 The GIS CD-ROM database of socioeconomic and biophysical information for Honduras is in at least three distribution outlets by December 1998

The CD-ROM

- CD-ROM available of socioeconomic and biophysical information for Honduras for use as a Decision Support tool

Objective

To create a detailed database using Geographic Information Systems (GIS), which is digitized from remote-sensed imagery and available maps from Honduran institutions.

Output

A CD-ROM with more than 90 maps and "grey literature" references for conservation technologies is available and will be released for sale by National collaborators in October 1998.

Activity 1.1.1 Revise, edit, consolidate, and georeference user-friendly databases

Highlight

- Satellite and air photo imagery processed and land cover classified for the Honduran Departments of Atlantida, Yoro, and El Paraiso. This allows communities to visualize current and past land use and plan future land use.

Objective

To georeference and map national demographic data at various scales of geographical aggregation.

Methods

Analyses of tradeoffs between database resolution – 30 m to 1 km – and precision (error) were carried out. This was done so that, in the future, institutions that adopt these technologies will be able to accurately budget similar activities.

Outputs

Satellite and air photo imagery have been processed and land cover classified for the Honduran Departments of Atlantida, Yoro, and El Paraiso at resolutions as detailed as 30-m square.

Activity 1.1.2 Develop agricultural Atlas for hillsides systems typologies

Highlight

- Agricultural Atlases available in CD-ROMs

Objective

To produce an agricultural Atlas for hillsides systems typologies to help in planning and decision making.

Methods

In both Honduras and Nicaragua considerable progress has been made. Agricultural Atlases are available in CD-ROM form. Red Nacional de Sistemas de Información Geografica (RENASIG) workshops will take place in October (Honduras) and November (Nicaragua).

Activity 1.1.3 A participatory approach to photographic analysis of tendencies in soil use in hillsides

Highlight

- Land use trends determined by using remote sensing imagery were validated in the field

Objective

The aims were to:

Isolate critical areas and differentiate classes of soil use in the hillsides
Determine causes and factors that condition tendencies in soil use
Make recommendations for promotion or correction of soil use in these hillsides

Methods

The methodology of this work consists of isolating zones that have suffered changes over time, comparing different mapping sheets. Later the work is validated in the field to determine causes and effects of the management of natural resources. The method was applied in an area of the

River Tascalapa, Honduras in two parts. First, using aerial photos of 1956, 1977, and 1993, we identified critical areas that had suffered changes in soil use. Second, we took observations of the landscape in these critical areas, carrying out a transect and taking data from key informants. Instructors led the fieldwork, guiding participants through the course, and taking into consideration their technical and local knowledge, while basing the work on the defined transect for the study zone overlaid on the aerial photos. At each observation point data were participatively taken and discussed, filling in record card that had previously been elaborated. Information was taken on rivers, streams, springs, settlements, and areas considered necessary to a more detailed analysis. Photos were taken at each observation point. Later, a plenary meeting took place where the field data were tabulated and interpreted. In the same way, the data were compared to aerial photographs to formulate recommendations in the better use of natural resources at each studied site.

Three sites in the Tascalapa River watershed were used for the validation. One site was defined as having changed forest cover in the community of Luquigue. Another site was defined as an environmental drainage zone for water production in the lower part of the watershed in the community of Jalapa. The last site was defined as having cultivation zones in the high part of the watershed in the community of Oropendolas.

Outputs

Critical areas in soil use were determined for the area. The classification of soil use was validated at field level and factors conditioning changes were identified. Recommendations were made to improve the management of natural resources.

Activity 1.1.4 Transport accessibility

Contributors: Andrew Nelson, Grégoire Leclerc, and Ron Knapp

Highlight

- Accessibility indicator map developed for Honduras to help decision makers assess transport infrastructure, access to market, and service provision

Objective

The project wishes to make methods available to decision makers whereby accessibility can be assessed for screening agroecosystems and evaluating scenarios that may facilitate or impede agroecosystem development. Our goal is to create a tool flexible enough to incorporate a wide range of perspectives and indicators.

Methods

A digital elevation model (250-m grid) for Honduras was completed. This was used to create an "accessibility indicator" map for Honduras. Some would argue that **transport accessibility** is the most important, short-term variable driving land-use change in lesser-developed countries. Figure 1 shows an example of many possibilities based on:

Existing transport maps,

"Most likely route" based on constraining terrain characteristics (mountains, forests, etc.),

Speed of transport estimates based on six road types and, where no roadways exist, travel times associated with land cover/use (from remote imagery analysis), and

Village and farm site location data collected from interview and global positioning system (GPS) readings.

Output

We now have a 250-m resolution grid map, where each grid has a value in hours for the time required to transverse the cell. This "ease-of-travel" map will help decision-makers at all levels on questions of accessibility and the provision of services etc.

The map is a variation on the theme "potential accessibility indicator". The map was created by combining data for roads and 3730 villages. Villages represent a set of sources and targets. From this basic network, least cost transport routes were calculated taking into consideration geographical factors impeding movement, like slope and land cover. Values calculated for each village were interpolated to a regular raster grid creating the map. It is important to keep in mind that this map represents only one of several possible stakeholder perspectives of the concept of accessibility.

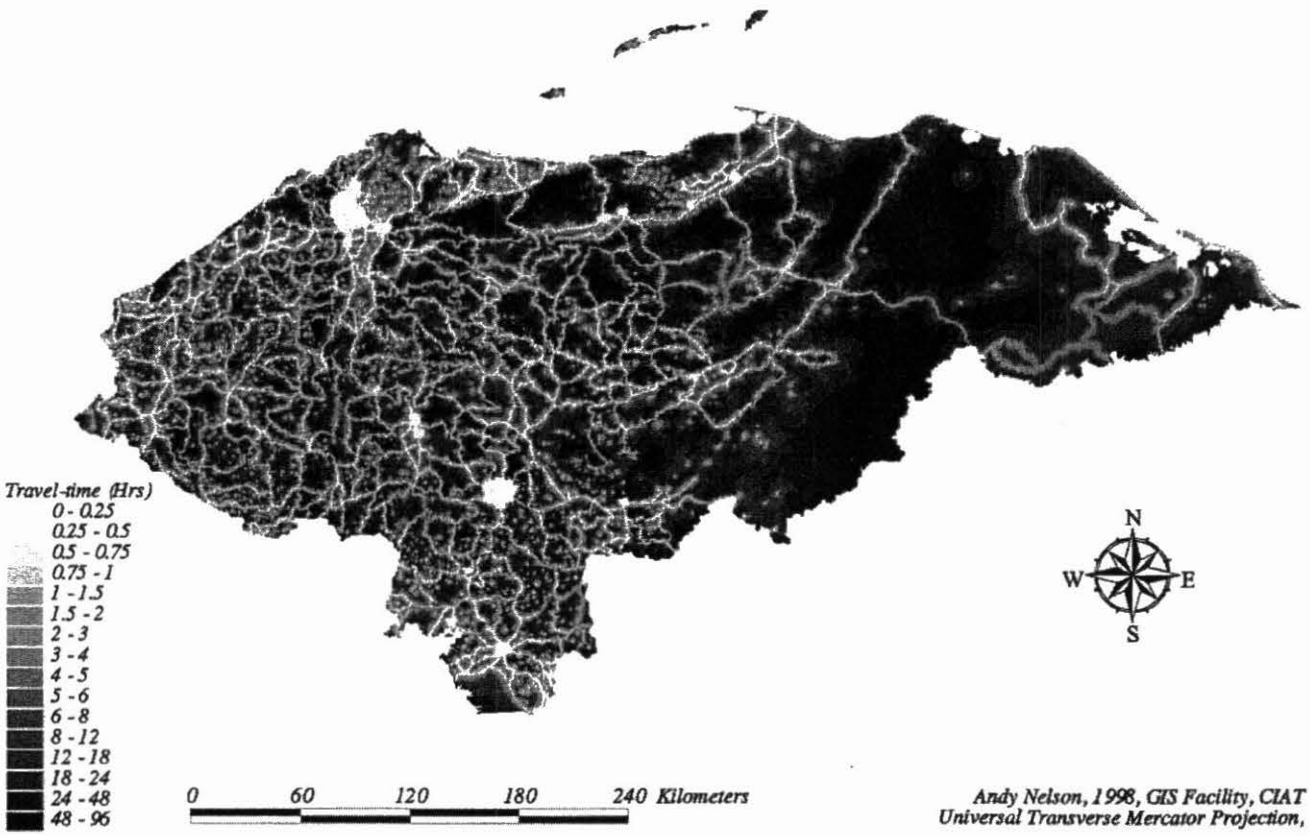

Figure 1. Transport accessibility map for Honduras from number of spatial coverages.

Activity 1.1.5 Spatial extrapolation methods developed for Honduras

Contributors: Grégoire Leclerc, Héctor Barreto, and Nathalie Beaulieu

Highlights

- Non-parametric statistical method developed to determine homologies with benchmark sites to determine how representative a watershed is and to make comparisons possible.
- The method allows us to consider any categorical data by means of an Euclidian distance of proportions and validated by a chi-square test.
- Watersheds of Honduras have been ranked according to homology to the Río Tascalapa hillsides pilot watershed using selected biophysical factors.

Objective

Our objective is to quantify homologies of selected areas (i.e., watersheds) with respect to a benchmark site. This is accomplished by inferring ecosystems from a variety of data sources and allows us to compare and contrast domains for technologies and methods developed in benchmark sites.

Method

Three watersheds were chosen to cover a wide range of conditions for Hillsides Project research. We wanted to see exactly how different these are to one another, then find out what each one has in similarities to other watersheds over the whole of Honduras. This would reveal how representative each of the chosen watersheds is of Honduran watersheds as a whole, what percentage each represents.

When analyzing the response of a system with respect to categorical variables (such as soil type, housing, etc.), we cannot apply the same methods as those applicable to continuous variables (such as temperature, rainfall, etc.). Therefore we needed to develop a non-parametric method that allows us to examine biophysical and socioeconomic data on the same scale.

A region can be characterized by the proportions of the various factors considered as important. For example, the percentage of the area occupied by particular land features, or the proportion of poor to non-poor. In this way the data become dimensionless, and can easily be integrated into a common factor.

The method comprises the following seven steps:

1. We prepared raster maps of the factors, reducing as much as possible the number of categories (i.e., three elevation classes, two soil types, and four climate types).

2. We extracted the number of pixels and proportions of each factor within the benchmark site (e.g., 30% is flat and 70% on steep slopes). This gives a distribution (of both sample size and %) for each factor for the benchmark site.

3. We prepared a map of the sites for which to evaluate the degree of homology with the benchmark site (each site has a unique ID). In the case of watersheds, we automatically generated a set of watersheds of about the same size as the benchmark watershed. We then extracted the proportions for each site (this gives a distribution of % for each factor and each site).

4. We computed the Euclidean distance between points whose coordinates are given by the proportion:

$$D(k, ref, x) = \sqrt{\frac{1}{2}\sum_{i=1}^{N}\left[x_i(k) - x_i(ref)\right]^2} \qquad (1)$$

Where k represents the site to compare to the reference site *ref*, x represents one factor, and N the number of classes within that factor. We thus obtain a distance in a given dimension (geology, or land use, etc.), that represents a difference between the two sites. The factor ½ normalizes the distances in such a way that the maximum distance is 1. Figure 2 gives a graphical representation of Equation 1.

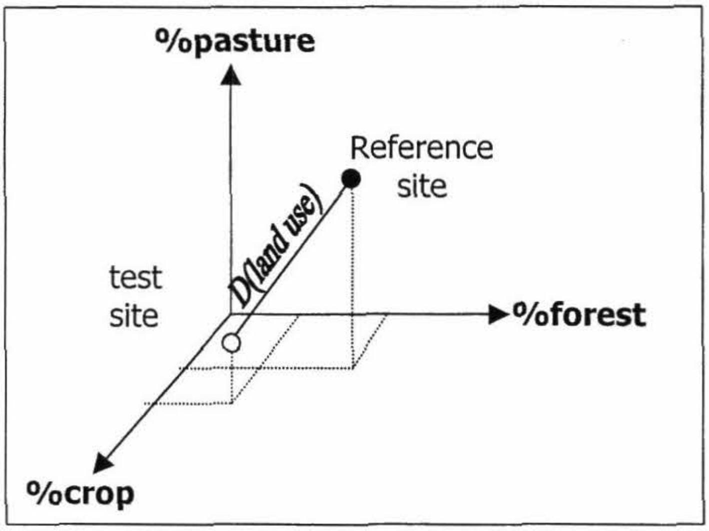

Figure 2. Graphical representation of Equation 1.

5. To combine several factors and get an overall similarity distance, we can use the distances obtained in (4) instead of raw proportions, as long as we can consider that the factors are orthogonal (independent) :

$$D(k,ref) = \sqrt{\frac{1}{2}\sum_{x=1}^{M}[W(x)D(k,x)]^2} \qquad (2)$$

Where *W(x)* is a weight to a particular factor *x*, and *M* is the number of factors. Again the factor ½ normalizes the distance to a maximum value of 1. Figure 3 shows Equation 2 graphically.

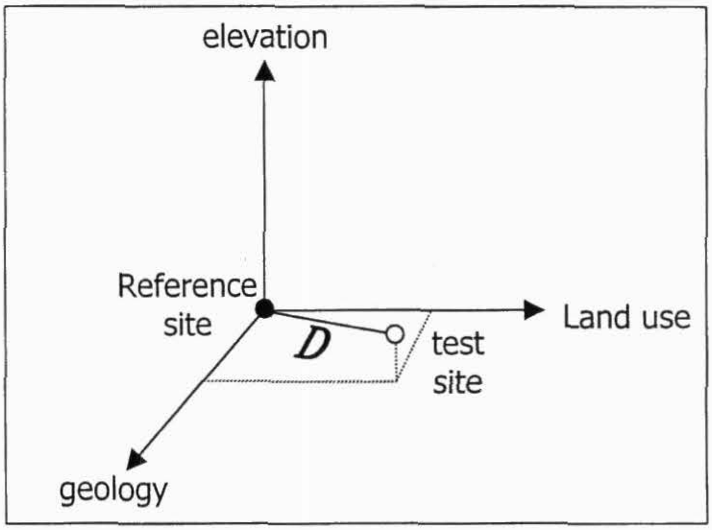

Figure 3. Graphical representation of Equation 2.

6. We assign the *D* to all watersheds for mapping.

7. We run a statistical test on the distributions to ensure the estimated D is reliable. A chi^2 test using the frequencies for each factor (taken separately or as a whole) allows us to estimate a threshold below which the distributions cannot be different. The chi^2 is computed as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E} \qquad (3)$$

Where the sum runs on all the classes within a given factor (or for all classes and factors together if needed). 0 is the number of watershed pixels occupied by a given class. For each watershed and class, the expected value *E* is obtained by multiplying the area (in pixel) of that watershed with the sum 0 for that class and the two watersheds, and dividing by the total area (in pixels) of the two watersheds. For the chi^2 test to be valid, the total numbers must exceed 20, *E*>5 (if only two classes) or no more than 20% of the *E* should be >5 (when more than 2 classes).

Four EASI+ programs are used for this analysis: PROPX.EAS extracts the number of pixels and proportions of classes for the benchmark watershed and writes it to a file. This file is used by PROPDIST.EAS and CHIPROP.EAS to produce a file with the distance (Equation 1) and a file of chi^2 (Equation 2) for all watersheds. CHIWRIT.EAS is used to map the results by writing them to an 8-bit image channel.

We applied the method to the Rio Tascalapa benchmark site in Honduras, starting with biophysical factors. We prepared raster maps with a pixel size of $0.826km^2$ of the following factors:

Elevation –United States Geological Survey (USGS) digital elevation model (DEM)
Reclassified to obtain agroecological zones

1. 0-500 m (lowland tropical)
2. 500-1000 m (lowland tropical)
3. 1000-1500 m (midaltitude tropical)
4. >1500 m (midaltitude to highland)

Geology
Reclassified with respect to parental material

1. Tv,Tpm,Tm, Tg,Ti,Ts: Igneous extrusive
2. Kti,Ki,Kag: Igneous intrusive
3. Kva, Ky, Sedimentary fine grain
4. Qal,Qtbb,Qv: sedimentary alluvial
5. Pzm,Jkhg,Pzi: metamorphic/sedimentary

Land Use –1995 Corporación para el Desarrollo Sostenible de la Región Ucayali (COHDEFOR) (1:500,000)

1. Broadleaf/mixed forest
2. Dense conifer forest
3. Pine savanna
4. Non forest
5. Water bodies

Relief (contrast, 5 x 5 moving window on DEM)
1. <0.25
2. 0.25-0.75
3. 0.75-1.5
4. >1.5

Watersheds have been determined using a set of automated procedures of PCI (DWCON, SEED, WTRSHED), with automatic seeding of 100 pixels. This produced a series of watersheds of roughly the size of the benchmark watersheds, which do not necessarily correspond to the latter. Table 1 shows the proportions found for the Honduras benchmark site.

Table 1. Proportions found for the Honduras benchmark site.

		Tascalapa River (n = 138)	Cuscateca River (n = 50)	Cuero River (n = 51)	Saco River (n = 15)
Elevation:	1	0.00	0.00	0.86	0.87
	2	0.75	0.82	0.14	0.13
	3	0.24	0.18	0.00	0.00
	4	0.01	0.00	0.00	0.00
Geology	1	0.00	0.92	0.00	0.00
	2	0.00	0.00	0.00	0.60
	3	0.96	0.00	0.00	0.00
	4	0.037	0.08	0.02	0.40
	5	0.00	0.00	0.98	0.00
Land use	1	0.16	0.16	0.16	0.00
	2	0.02	0.14	0.00	0.00
	3	0.11	0.04	0.00	0.00
	4	0.71	0.66	0.84	1.00
	5	0.00	0.00	0.00	0.00
Relief	1	0.06	0.14	0.00	0.00
	2	0.93	0.36	0.00	0.00
	3	0.01	0.50	0.00	0.07
	4	0.00	0.00	1.00	0.93

Based on these proportions, we can compare the benchmark sites to ensure they are contrasting enough. Table 2 shows the chi^2 obtained.

Table 2. Chi-squares and distances (D) obtained when contrasting benchmark sites[a].

Rivers	Tascalapa River		Cuscateca River		Cuero River		Saco River	
	Chi^2	D	Chi^2	D	Chi^2	D	Chi^2	D
Elevation (n = 4):								
Tascalapa	-	-						
Cuscateca	21.10	0.07	-	-				
Cuero	81.40	0.77	38.60	0.79	-	-		
Saco	72.60	0.77	28.70	0.79	9.80**	0.004	-	-
Geology (n = 5):								
Tascalapa	-	-						
Cuscateca	89.50	0.94	-	-				
Cuero	92.80	0.97	48.90	0.95	-	-		
Sacor*	71.00	0.84	27.70	0.81	31.30	0.860	-	-
Land use (n = 5):								
Tascalapa	-	-						
Cuscateca	25.10	0.10	-	-				
Cuero	23.00	0.13	5.20*	0.17	-	-		
Saco	50.50	0.25	11.90**	0.28	10.80**	0.160	-	-
Relief (n = 4):								
Río Tascalapa	-	-						
Río Cuscateca	53.00	0.54	-	-				
Río Cuero	94.50	0.97	50.50	0.84	-	-		
Río Saco	75.50	0.94	30.60	0.78	11.00**	0.070	-	-

a. * = Probability of 0.2 that chi^2 is due to chance,
** = Probability of 0.05 to 0.01 that chi^2 is due to chance.

We can therefore say that the benchmark watersheds are sufficiently contrasting, except with respect to:

- Elevation ranges – There is a 5% probability that the Saco and Cuero River watersheds are the same.

- Land use – There is a 20% probability that the Cuero and Cuscateca River watersheds are the same. This probability is 1% to 5% between Saco and Cuscateca on Cuero River watersheds.

- Relief – There is a 2% probability that the Saco and Cuero River watersheds are the same.

Figure 4 shows the distance to the Tascalapa River watershed for all watersheds, and Chi^2 corresponding to 80%, 95%, and 99% confidence levels, according to elevation, geology, relief, and land use (maps shown at the top). Below these are the histograms showing the distribution of distances for all watersheds. The arrows at the bottom depict the distance to the Tascalapa River of the three other benchmark watersheds.

From Figure 4, imagining the limits of broad extrapolation domains (i.e., dark, grey, and light areas) is straightforward. The weighted combination of factors allows us to consider either the importance of the factor or map precision.

Outputs

The method developed allows homologies with benchmark sites to be determined. It was applied to the benchmark sites in Honduras and the watersheds found sufficiently contrasting. The method, here applied to watersheds, is a tool that allows us to answer the questions "Where else can I apply the work that I am doing here?" and "How representative is our watershed of Honduran watersheds?"

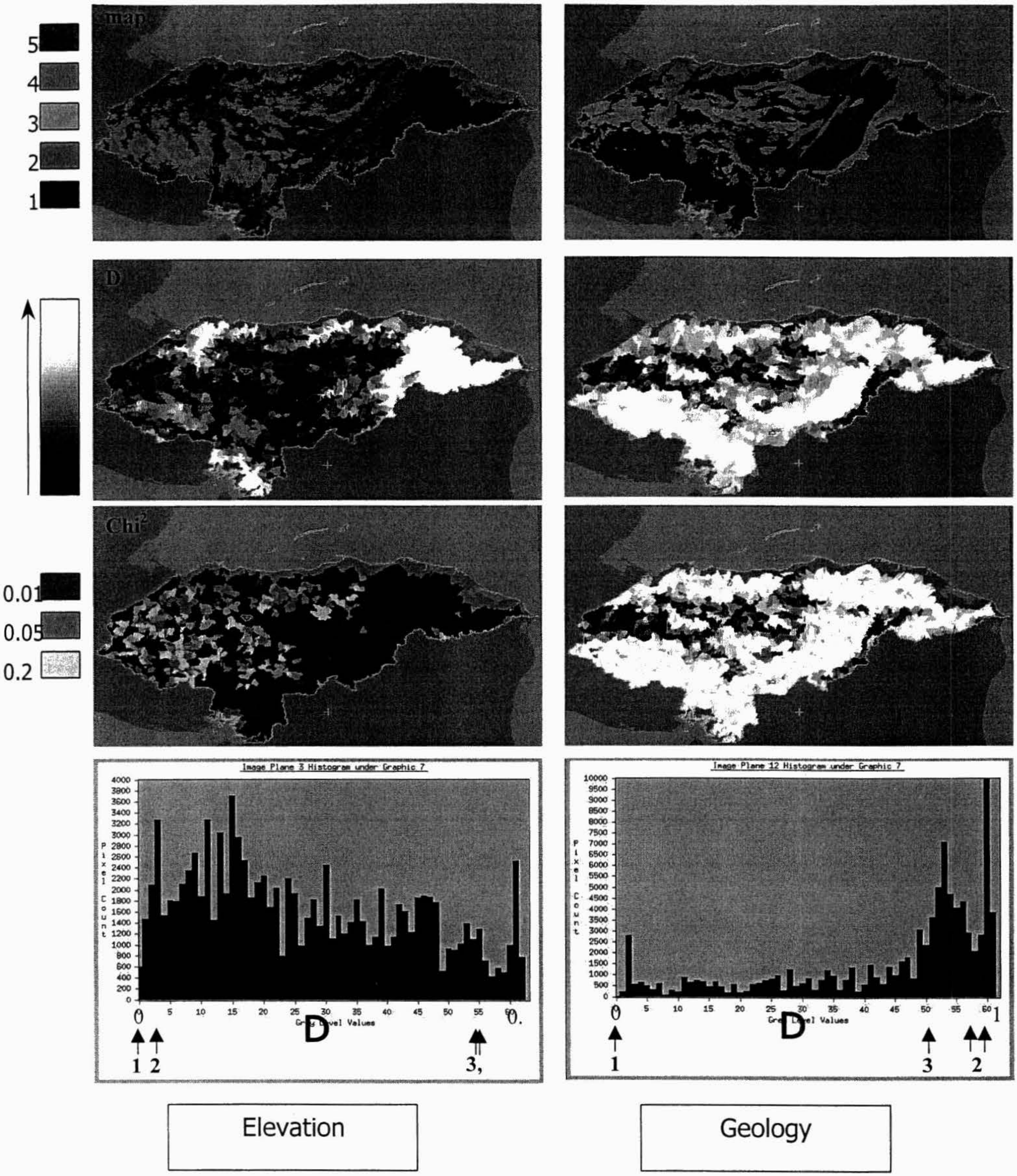

Figure 4. Maps showing distance to the Tascalapa watershed for all watersheds and chi^2 according to elevation, geology, relief, and land use; and histograms showing distribution of distances for all watersheds (1 – Tascalapa River, 2 – Cuscateca River, 3 – Cuero River, and 4 – Saco River).

Activity 1.2 **The GIS CD-ROM database of socioeconomic and biophysical information for Nicaragua is in at least three distribution outlets by December 1999**

Activity 1.2.1 **Measuring the impact of strengthening community management of resources: an ex ante analysis**

Contributor: Nancy Johnson (collaborative Project)

Highlights

- Designed an ex ante impact analysis for improving community management of water resources in hillside watersheds.
- Completed data collection for the analysis.

Objectives

The analysis is designed to estimate the impact of a PE-3 project and to test a new methodology for valuing investments in community resource management (Johnson 1998). The goal of the study is to estimate the magnitude and distribution of the economic losses associated with inefficient water management to see whether intervention is justified. Part of the goal of CIAT's research in this area is to identify methodologies and strategies that could be used by other people in other circumstances (especially local stakeholders) to analyze similar types of problems.

Methods

Data collection was completed for an ex ante analysis of the impact of strengthening community management of potable water. The site for the study is the CIAT research watershed in San Dionisio, Matagalpa, Nicaragua. The study is being carried out jointly with BP-1 (Assessment of Past and Expected Impact of Research).

The community identified potable water as one of its most pressing natural resource management (NRM) problems. According to residents, water scarcity, inefficient distribution systems, and contamination combine to significantly reduce welfare for many people. Local committees currently manage potable water so improving access to it would involve strengthening these organizations.

Various types of data were collected to compare and contrast the results under different estimation methods. The value of water will be measured in terms of 1) the opportunity cost of time spent bringing water from distant water sources, 2) the loss of income associated with water-borne diseases, and 3) residents own willingness to pay for better water supplies (contingent valuation).

Outputs

In addition to comparing the final estimates that result from different valuation methods, the different methods will be compared in terms of their appropriateness for use by local communities to analyze their own resource management problems.

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Output 2: Decision support (DS) tools, including indicators, models for scenario building and participatory methods developed with the participation of stakeholders

Activity 2.1 The Consultative Group in 1998 has hands-on use of the decision support tools planned in the 1998 and 1999 work plan

Activity 2.1.1 Testing effects of land and resource use decisions on watershed water-use using a process-based, data-economic simulation model

Contributors: J.C. Luijten and J.W.Jones (Ag. & Biol. Eng. Dept.University of Florida), E.B.Knapp

Highlights:

- A process-based, data-economic simulation model for testing effects of land and resource use decisions on watershed water-use is nearly complete as partial fulfillment of a PhD degree with U. of Florida.

Objective:

Adequate watershed management is required and appropriate decisions need to be taken to guide future development in directions that are desirable for local communities and to sustain the natural resource base. Decision-makers require good knowledge on the supply and demand of water resources over space and time with emphasis on spatial and temporal variability.

Methods:

A watershed sits within an hydrological, agroecological, economic, social, and cultural setting, the boundaries of which may go beyond those of the watershed itself. Several watershed components can be identified (see Figure 1). These components do not function as independent systems, but they exist in association with one another and interact with their environment, that is, everything external to the watershed.

A watershed ecosystem is generally considered to function around a dynamic equilibrium state or multiple stable states (see Holling, 1986). A multitude of interwoven natural processes and human activities take place within watersheds. These processes include climate, crop production, aquaculture, dairy farming, resource extraction, industrial activities, commercial activities, urban development, tourism, and population growth. Some of these processes have relatively low impacts on watersheds, whereas others permanently alter watershed components such as the landscape and natural resources. Decisions and policies can influence each of these factors. Watersheds have various important functions (Black, 1997). One such function is to provide communities and their members with basic human needs and to sustain the natural ecosystem and resource base. Kiker and Lynne (1997) pointed out that watershed functions benefit a broad range of people (and animals) whereas services from alterations in the landscape and resource extraction rates primarily benefit the individuals who make these alterations. Such individual actions may not necessarily be in the public interest, and conflicts can arise because of differences in valuation of resource units.

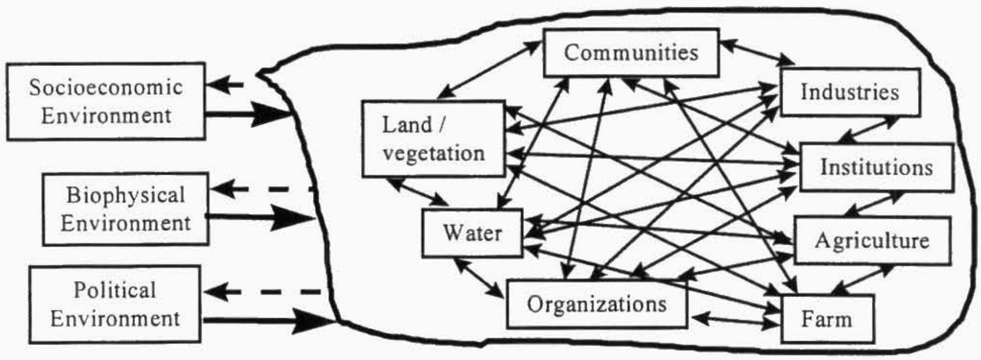


Figure 1: Conceptual Representation of a Watershed System.

Proper watershed management is needed to guide, monitor, and control changes in watersheds and to resolve and/or prevent resource use conflicts. Watershed management typically involves the regulation, allocation, and conservation of water and land resources (Hanna, 1995). Adequate watershed management is required and appropriate decisions must be taken to minimize conflicts and to guide future development in directions that are desirable for local communities and its people. Decision makers and managers need better information to manage watershed resources in ways that are equitable, efficient, and effective. Different scientific disciplines suggest different perspectives from which to view watersheds and to collect relevant information for decision-making (Kiker and Lynne, 1997). In general, however, all decision making process and management activities require profound knowledge on the supply and demand of water resources over space and time.

We are proposing an analytical approach which can provide such information, with particular emphasis on spatial and temporal variability in a watershed. It includes a methodology to estimate water supply and demand over space and time. The emphasis is on water resources, but land resources will be considered as well. This holistic approach is based on the following hypotheses:

1. Useful information can be provided by spatial water budgeting model, i.e. a model which accounts for all water gains, storages, uses, losses, and discharges over space and time.
2. While emphasizing spatial variability, it is sufficient to include only a basic rather than a detailed description of the processes of surface runoff, subsurface flow, infiltration, and percolation.
3. Modern Geographical Information Systems (GIS) provide a flexible environment for implementing a spatial model and facilitates flexible transfer of spatial data to and from the model.

Precipitation is generally the primary source of water within a watershed. Other sources are direct surface run-on and subsurface flow from neighboring watersheds, rivers, wells, and natural springs. Surface run-on is negligible if the extent of the watershed being analyzed coincides with the extent of the drainage basin as determined by topography. Likewise, subsurface flow can be ignored if phreatic boundaries (the hydrological boundaries as determined by subsurface rock formations and other impervious soil layers) coincide with the boundaries of the watershed. These assumptions are quite common in hydrological research (Black, 1996).

Precipitation water may runoff, evaporate, infiltrate or percolate. These processes are described in detail in hydrology books (such as Haan et al., 1982; Black, 1996). Lateral flow on the surface and subsurface lateral flow in deeper ground layers may (partly) flow into streams. If flow directions throughout the watershed are known, the flow volume at any point in a stream can be determined over time. Humans can affect this water amount directly (e.g. construction of dams, water reservoirs, and artificial stream channels) and indirectly (e.g. modifications in the land cover, land use, and tillage).

Water demand is the sum of water needs by different sectors (Table 1). A distinction can be made between *withdrawal use*, which means that water is withdrawn from its original source for a particular use, and *in-situ* use, in which case water does not need to be extracted for its use (Kulshreshta, 1992). Water can be extracted from streams, wells and springs. Only stream water extraction is further considered in this paper. The locations of extraction points, and the rate of extraction at those points, may change over space and time depending on the actual water needs at that time and the available supply of water. Many biophysical, social and economical factors can affect the spatial and temporal variability in water demand.

Table 1: General typology of water use (Source: Kulshreshta, 1992).

Sector	***Withdrawal use***	***In-situ use***
Domestic	Drinking, Cooking, Bathing	Recreation, Waste assimilation, Flushing of wastes
Agriculture	Irrigation, Livestock use, Fish farming	Waste assimilation, Flushing of wastes, Fisheries
Industry	Industrial processing, Commercial use, Thermal power generation	Hydro power generation Waste assimilation, Flushing of wastes
Nature	Support of wildlife	Natural Habitat, Wetlands, Flora & fauna
Other	Mining water use, Forest fire fighting	Transportation

SCENARIO ANALYSIS

The modern farmer, natural resource manager, and planner are less interested in receiving definite answers to questions than in having a presentation of a series of realistic alternative options from which he or she can make a selection (Bouma, 1997). Scenarios analysis is one way to provide such information, and has been used successfully in explorative land and water use studies (e.g. WRR, 1992; Stoorvogel et al., 1995; Veldkamp and Fresco, 1997). Scenarios are not forecasts but technical surveys based on a number of different political philosophies about the future. Scenarios aim at describing resource use and the state of the resource base as a result of expected or (hypothetical) changes in biophysical, socio-economic, and/or institutional conditions. They provide information for assessing strategic policy and management options to help decision makers by identifying the best options for future development. Scenarios may help identify under what conditions conflicts between water use and water demand can be expected, may help negotiate compromises to resolve water use conflicts, and may suggest the biophysical and socioeconomic boundary conditions for sustainable agricultural production and natural resource use. Table 2 lists a number of scenarios that are important with respect to water use in an agricultural hillside watershed.

Table 2: Examples of scenarios that may affect the supply, allocation, and use of water.

Policy Oriented Scenarios	***What-If Scenarios***
1. Equitable per capita water availability. 2. Minimize risk of temporal water shortages. 3. Minimal river flow requirements. 4. Maximize forest lands 5. Main self-sufficiency in food production 6. Environmental protection.	1.Climate variation 2. Increased irrigation water needs. 3. Construction of dams and water reservoirs 4. Future population growth 5. Hydro-power generation. 6. Increased industries.

A SPATIAL WATER BUDGET MODEL

Scenario analysis requires information on the supply and demand of water. This section explains the concepts of a spatial water budget model description that can provide such information. Spatial variability is represented by using a grid cell approach. This model is explained in three steps below: (1) the vertical water balance for a single soil element (a grid cell) over time based on land cover, soil, and climate characteristics; (2) flow of surface runoff and subsurface lateral flow throughout the watershed towards streams; and (3) an accounting of the flows into the streams and the withdrawal of water from the streams.

A SOIL ELEMENT WATER BALANCE

A simple soil profile is considered for a vertical water balance in a single soil element (Figure 2a). The root zone is the soil layer where evapotranspiration water loss is taken from. The depth of this layer is determined by maximal rooting depth. The lower boundary of the soil profile is an impervious layer, which is assumed to be parallel to the soil surface. Soils are assumed sufficiently deep so that the impervious layer is below rooting depth. Above the impervious layer is a saturated Deeper Soil Water layer. This water layer may seem like a groundwater aquifer. It should be noted, however, that real groundwater aquifers are generally more complicated. They may comprise one or more confined and/or unconfined aquifers at different depths, with spatially-varying thickness, and a complicated structure of the boundaries. Water can flow in horizontal direction out of a soil element as surface runoff (RO) or as lateral flow in the deeper soil water layer (LF).

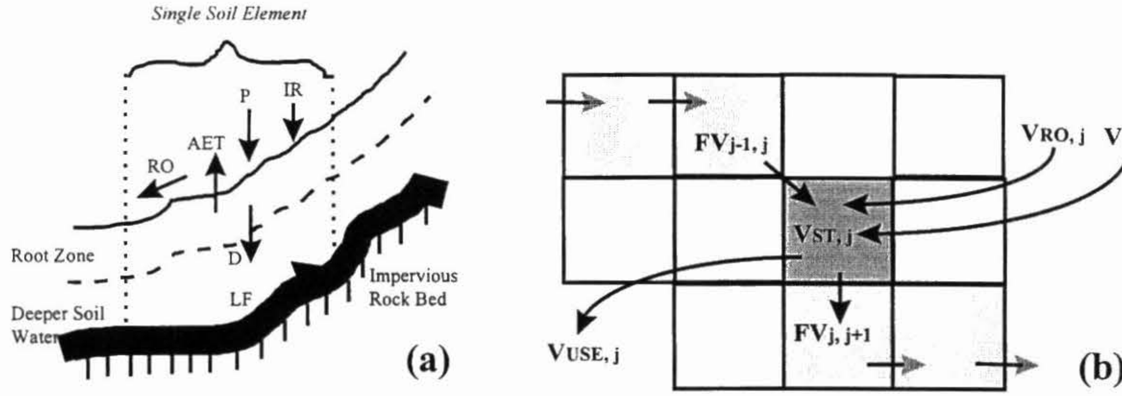


Figure 2: (a) Representation of the soil profile. Basic water flows associated with a single soil element (a grid cell) are indicated with arrows and are explained in Equations 1 and 2; (b) Grid cell based stream routing. The light gray cells form a stream network; the white cells are non-stream cells. All water flows associated with a single stream cell (the darker gray one) are indicated and explained in Equation 7.

For a soil element ***i*** (i.e. a grid cell), the changes in the water content in the root zone (ΔRZW_i) and in the deeper soil water (ΔDSW) during a time period Δt is given by Equations 1 and 2 respectively,

$$\Delta RZW_i / \Delta t = P_i + IR_i - AET_i - RO_i - D_i \quad (1)$$

$$\Delta DSW_i / \Delta t = D_i - LF_i \quad (2)$$

in which P_i is precipitation, IR_i is applied irrigation; AET_i is actual evapotranspiration; RO_i is surface runoff; D_i is water drainage from the root zone to the deeper soil water, and LF_i is the loss of deeper soil water due to lateral flow to streams. All values are in mm water depth per time unit. The typical time step is 1 day.

The components of Equations 1 and 2 are calculated on a grid cell basis because most physical watershed characteristics (such soil texture and water holding capacity, land cover, crop coefficients, rooting depth, depth to impervious layer, and elevation and precipitation) may vary throughout a watershed. Precipitation (P) and irrigation (IR) are assumed the only sources of water. Surface runoff is calculated using the SCS curve number method (USDA-SCS, 1972). Potential evapotranspiration (PET) is calculated using the equilibrium evaporation concept method of Ritchie (1972), which requires only data on temperature and short-wave radiation. Actual evapotranspiration (AET) is based on PET corrected for prevailing land cover and actual soil water conditions. Land cover type is expressed by a crop coefficient which is a function of the type of crop and its development stage (Doorenbos and Pruitt, 1977). The effect of actual soil moisture content is that AET is at the maximum rate (PET * crop coefficient) if the actual soil moisture content is between field capacity and some critical value, but decreases linearly from the maximum rate to zero for actual soil moisture content between the critical value and wilting point (Doorenbos et al., 1979). The critical soil moisture content depends on the physiological tolerance of crops to drought. Drainage (D) is equal to the precipitation surplus after runoff has occurred and the root zone has been filled to field capacity. Lateral flow (LF) is explained in detail in the next section. Note that elevation is not only important because it determines how water flows throughout the watershed, but it may also cause temperature and AET so vary.

LATERAL FLOW AND SURFACE RUNOFF

Surface runoff (RO) and lateral flow (LF) from each soil element ***i*** are assumed to flow to the nearest stream cell ***j*** along the flow path. Lateral flow in the root zone is assumed negligible. The RO and LF flow paths from each soil element to the nearest stream can be determined from a Digital Elevation Model (DEM). An empirical approach has been used to estimate how much water flow into stream cell ***j*** in each time period.

Surface runoff: It is assumed that all runoff water originating from any place in the watershed will ultimately reach a stream. Infiltration of runoff water during its flow path is not considered. The underlying assumptions for this are that (a) the size of the watershed does not have a significant effect on runoff volumes per unit area (Black, 1996), implying that grid cell estimates of the surface runoff are additive for the entire watershed, and (b) that any surface runoff will relatively quickly reach a major stream via a sufficiently dense network of gullies and temporary streams. For each soil element ***i***, the average velocity of surface flow, v_i (in m/d), can be calculated using the method in the AGNPS model (USDA-ARS, 1987):

$$v_i = 0.3 * 86400 * 10^{0.5 * Log10(LSi) - SCSi} \quad (3)$$

in which LS_i is the average land slope in percent; SCS_i is the Surface Condition Constant which describes the effects of land use and vegetation (USDA-ARS, 1987); factor 0.3 is the conversion factor from feet/s to m/s; and 86400 is the number of seconds in a day. Assume that there are ***k*** grid cells in the flow path from grid cell ***i*** to stream cell ***j***, then the total flow time, $ft_{i,j}$, of surface runoff from cell ***i*** to the stream cell ***j*** is given by:

$$ft_{i,j} = \sum_k \frac{\text{Effective flow length through grid cell}}{\text{Velocity in grid cell}} \quad (4)$$

Flow time ft_i is constant for each grid cell ***i*** if land cover and topography do not change. RO_i will reach stream cell ***j*** on the same day ***t*** if $ft_i <= 1$, on time t=1 if $1 < ft_i <= 2$, on time t=2 if $2 < ft_i <= 3$, etc.

Lateral flow: Physically-based modeling of lateral flow using a grid cell approach is rather complicated, even if lateral flow between two adjacent grid cells were assumed a simple Darcian flow, and only few groundwater models are truly distributed parameter based. Lateral flow can reach the surface at locations with positive pressure zone (i.e. flowing wells and natural springs) or at locations where the impervious layer is near the surface. The hydrology of such upward flows may be very complicated. We have used a simple empirical approach that considers the volume of lateral flow from each soil element ***i*** into a stream proportional to the volume of water stored in DSW_i (Eq. 5). This method is similar to the methods used in the ANSWERS (Beasley and Huggins, 1981) and SWBM (Boughton, 1995) models to describe groundwater depletion.

$$LF_i = d_i * DSW_i \quad (5a)$$

with

$$d_i = \frac{P}{P + \frac{(\text{length of flowpath})_i}{(\text{average slope})_i * K_i}} \quad (5b)$$

in which LF_i is the daily volume of lateral flow originating from "water store" DSW_i; d_i is the (depletion) fraction of DSW_i which flows into a stream cell ***j*** during each time step; K_i is the hydraulic conductivity of the soil along the flow path; and *P* is a watershed scale parameter. The best value for P be determined by analyzing long-term precipitation and hydrograph records. A smaller depletion fraction $\boldsymbol{d_i}$ (for increasing flow paths, flatter slopes, and/or increasing hydraulic conductivity) represents a "smoothing effect" of lateral flow. DEM-based flow routing is still used to determine the point ***j*** of the stream network (also a grid cell) in which lateral flow from soil element ***i*** drains, just like has been done for surface runoff.

WATER IN STREAMS AND RESERVOIRS

A stream network is a (branched) chain adjacent grid cells throughout the watershed. A stream network can be based on mapped streams or it can be delineated using a Digital Elevation Model. A grid cell is considered a stream cell if the accumulated area from which that cell receives flow is above some reasonable threshold value. Stream water originates from surface runoff and lateral flow.

Water in a stream is assumed to flow sufficiently fast so that water inputted into the stream at the most remote locations of the watershed (i.e. furthest away from the watershed outlet) will reach the watershed outlet within a day. This is a reasonable assumption for smaller hilly watersheds. Stream water may be prevented from flowing to watershed outlet for three reasons: (1) it is extracted from the stream for immediate use, (2) it is stored in the river because of a dam, or transported to an external reservoir or tank. We will not further distinguish between these three types of storage, and just consider a single storage. Each such storage has a specific capacity and can be at any point in the stream. Considering a stream as a chain of ***n*** grid cells with grid cell *n* being the watershed outlet, then the water volume that flows from stream cell ***j*** to stream cell ***j+1*** during a day is (see Figure 2b):

$$V_{j,j+1} = V_{j-1,j} + V_{\mathbf{RO},j} + V_{\mathbf{LF},j} - V_{\mathbf{USE},j} - \Delta V_{\mathbf{ST},j} \qquad (6)$$

$$\text{with} \quad 0 <= V_{\mathbf{ST},j} <= V_{\mathbf{STMAX},j}$$

in which $V_{j-1,j}$ is the water volume that flows from the neighboring upstream stream cell j-***1*** to stream cell ***j***; $V_{\mathbf{RO},j}$ is total surface runoff volume that flows into stream cell ***j***; $V_{\mathbf{RO},j}$ and $V_{\mathbf{LF},j}$ are the accumulated surface runoff volume and accumulated lateral flow volume that flow into stream cell *j* <u>from its contributing area</u> (the previous stream cell is not included in this area); $V_{\mathbf{USE},j}$ is the volume of water extracted from stream cell ***j*** for direct use; $V_{\mathbf{ST},j}$ is the change in volume of water stored in stream cell ***j***; and $V_{\mathbf{STMAX},j}$ is the maximum storage volume in stream cell ***j*** (in m^3). Note that $V_{0,1}$ is always zero and that $V_{n,n+1}$ is the daily flow volume at the watershed outlet. It is important to understand the key role of the water extraction term $V_{\mathbf{USE},j}$. Typically, the storage capacity $V_{\mathbf{STMAX}}$ will be zero for most stream cells, implying that all water that flows into such cells will flow into the next stream cell and further downstream. Likewise, water will typically be extracted from a limited number of locations of the stream, but the extraction rates may be different between these points and may change over time.

MODEL IMPLEMENTATION AND RESULTS

The Spatial Water Budget Model is programmed in Avenue (ESRI, 1996) and fully embedded in ArcView GIS 3.0 software with Spatial Analyst extension. This integrated modeling approach has various advantages, for example flexible input and output of large spatial data set, including remotely sensed data, easy geo-referencing, and flexible up- and down- scaling of data and model results. The model uses a daily time step and is suitable to estimate seasonal (weekly, monthly, annually) variation in the quantity of available water throughout a watershed. The model is not suitable to examine day-to-day variation and storm flow volumes.

The model has been applied to the 3,700 ha Cabuyal watershed in Colombia (CIAT, 1996). Although the model is not yet completed (the water demand part, determining the $V_{USE,j}$ in Equation 6, has still to be added) initial simulation results seems promising. Figure 3 gives an example of the type of spatial information the model can give. The flow volumes are the terms $V_{j,j+1}$ from Equation 6.

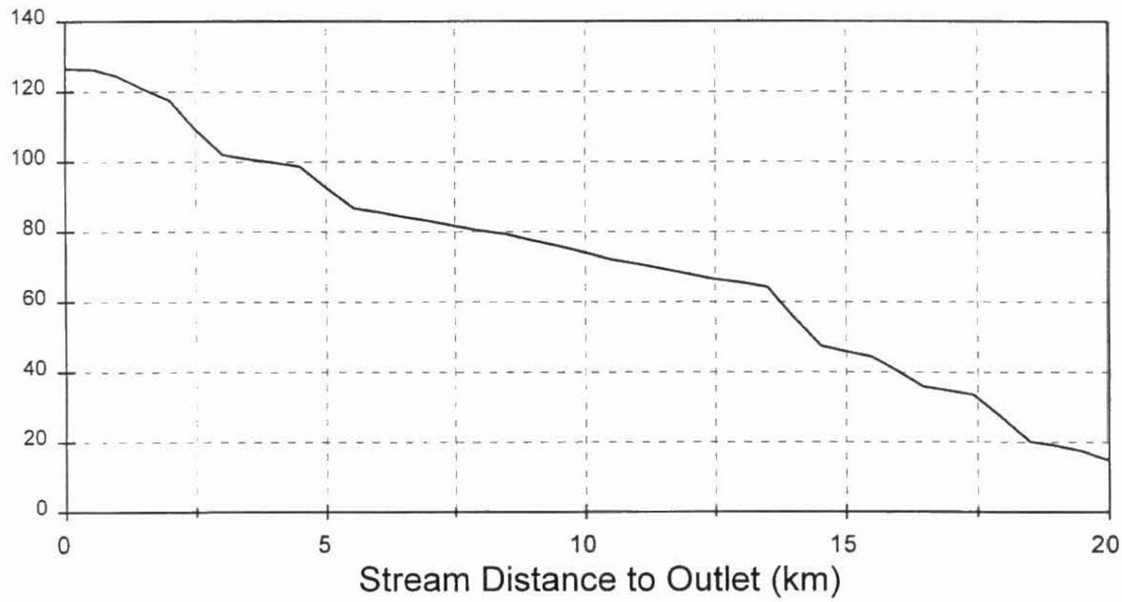


Figure 3: Simulated maximum flow volumes (in 10^3 m^3d^{-1}) at different locations in the Cabuyal river in Colombia during a typical day in the wet season, not accounting for any water extraction or water storage anywhere in the stream. Simulation is based on daily weather data from 1950 to 1955 were used. The entire length of the stream is a little over 20 km.

Activity 2.1.1 Framework and interfaces for community watershed management

Contributors: Grégoire Leclerc, Ron Knapp (CIAT), Brahm Verma, Shree Nath, Donald Nute, Greg Rosenberg (University of Georgia)

Highlights

- Workshop held on Concurrent Decision-Making Methodology (CDM)
- Beta version of Group Decision Support System (G/DSS) developed.

Objective

Decision-support tools are often associated with mechanistic models or goal optimization models. However, many land use decision requirements may be satisfactorily and economically addressed through a strategy of successive refinement of data on demand. We are engaged in a project aimed at developing a new methodology for making socially and environmentally sensitive decisions about development. Our vision calls for an "interactive group decision-support system (IGDSS) as a technological tool to facilitate the mutual understanding of perspectives held by different stakeholders.

Method

Since September 1997, CIAT has been working in collaboration with the decision support system (DSS) and Artificial Intelligence Centers at the University of Georgia (UGA). Years of experience in using the Participatory Planning by Objectives (PPO) methodology revealed that in certain circumstances it is inefficient. These inefficiencies become more problematic in circumstances where a diverse group of stakeholders attempt to address imprecisely defined core issues and desired future conditions. Rounds of discussion were held and a detailed analysis made of the results of the PPO in Yoro (Feb 3-6). A recent field trip to Honduras by two lead personnel of the project from UGA was also taken into account. It has become evident that any DSS developed for use in Honduras must meet a number of design specifications.

Our ultimate goal is to incorporate the new methodology into a *decision support system* (DSS), a software system that will help the users of the system make better decisions as they manage the development process. These decisions will have tremendous impact on everyone in the region where the development will take place. A basic assumption of this project it that the group of decision makers using the methodology and the DSS we develop will include individuals who understand and represent the interests of all the groups that wll be affected by the decisions made. Our work on this project to date has led us to some important initial conclusions about the needed methodology.

We propose that the methodology for making socially and environmentally sensitive decisions about development should be *goal-driven* rather than *problem-driven*. A *goal* is a situation which someone desires to bring about or to preserve so much that he is willing to allocate resources (time, effort, money, etc.) for that purpose. One identifies a *problem* when one recognizes some obstacle to achieving a goal. We believe that decision making in the context of managing a complex enterprise such as agricultural, industrial, or infrastructure development should begin by identifying goals rather than by listing problem.

Other key design criteria include:

- Support for collaboration among multiple stakeholders, often with conflicting perspectives;
- Support for a systematic procedure of decision making;
- The capability to access data (databases, GIS, etc.) and knowledge (models, expert rule bases, etc.) as appropriate; and
- A user-friendly and flexible computer interface.

We therefore designed a G/DSS, which can potentially satisfy the above criteria. GDSSs fall into the broader category of groupware that have emerged as powerful tools in the business world to fortify computer-supported collaborative work among groups of people. In the past, these tools have largely been restricted to providing support for electronic mail exchange, coordinating tasks among participants in local and/or remote locations, and scheduling face-to-face meetings. In other words, their primary role has been to serve as a means of improving communications among groups, as opposed to direct support for decision making.

Moreover, any DSS (as the name implies) is intended to support decision-makers and not replace them. This makes it imperative that any G/DSS lends itself well to a systematic decision-making procedure, in addition to providing communication capabilities among group members and access to data/knowledge. Such a procedure (called CDM) has been developed and is being refined at the CIAT and UGA DSS Centers. CDM consists of the following eight phases:

1. Identification and selection of goals
2. Identification of stakeholders
3. Problem analysis
4. Goal identification, evaluation, and specification
5. Generation of alternatives
6. Evaluation of solutions
7. Selection of the decision
8. Implementation and monitoring

To run evaluation models on spatial datasets we have been evaluating a commercial ArcView add-on called SmartPlaces. SmartPlaces, which is built around the Consortium for International Earth Science Information Network's (CIESIN's) Active Response GIS engine, offers a promising approach to spatial data handling in a group environment. SmartPlaces is build around a RADIX, which is a graphical representation of a hierarchical structure of multiple criteria. The GDSS allows us to design the RADIX suitable for a particular environment. Figure 5 shows a RADIX built on the results of the PPO in Yoro. We can immediately see the aspects of the community and their relative importance to the stakeholders. In this case, the community of

Yoro is largely biased toward socioeconomic problems. Evaluation models are run from the RADIX and depend on the definition of "pocket attributes" for the land units of interest.

The DSS team at UGA and various CIAT personnel presented the CDM methodology to a group of diverse stakeholders in a workshop on October 9-10 in Tegucigalpa, Honduras. An integral part of the workshop was the demonstration of a prototype G/DSS framework that lends itself well to the CDM methodology. This G/DSS prototype has been used to simulate discussions among a group of stakeholders assumed to be in a meeting room with a set of networked computers (clients) linked to a server.

The DSS team at UGA and various CIAT personnel presented the CDM methodology to a group of diverse stakeholders in a workshop on October 9-10 in Tegucigalpa, Honduras. Participants of the workshop were exposed to a detailed and systematic methodology of decision-making, and developed an improved understanding of the complementary roles of humans and computer technology in decision-making. The exercises were developed around the example problem of the Cabuyal River watershed (Colombia) to guard against any bias inevitable with the choosing of a Honduran site.

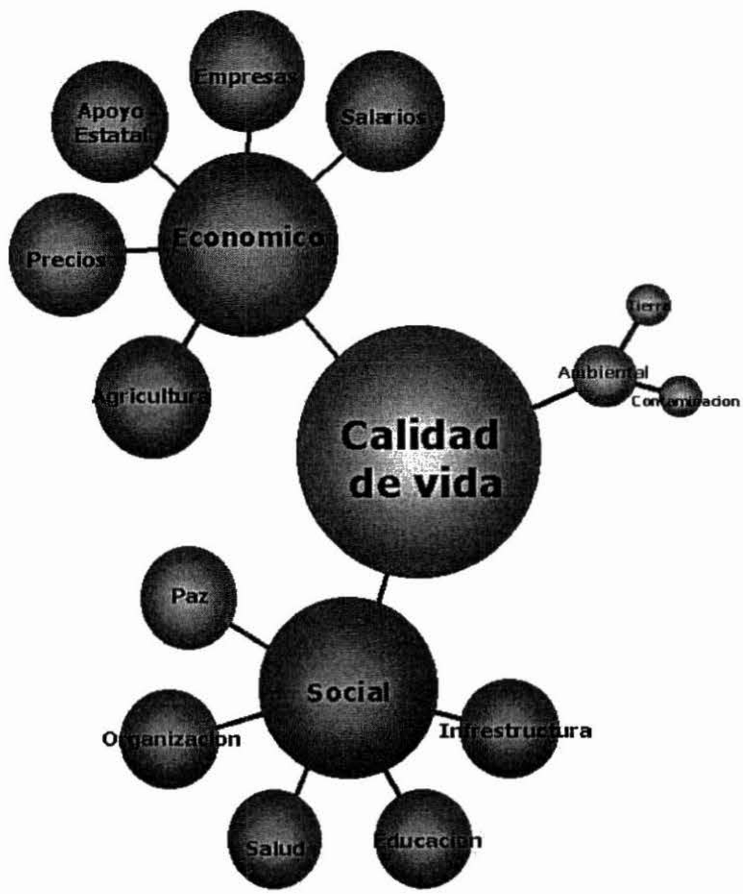


Figure 5. RADIX of objectives constructed based on the results of the February 1999 Participatory Planning by Objectives. The size of the spheres is proportional to the number of objectives identified. Under representation of environmental objectives is obvious.

Outputs

The tool is an effective way to match goals with resources and judge the use of research results. It offers guidelines, synthesis, and direct access to data and models at the same time considering the environmental and social consequences of such alternatives.

Preliminary versions of the following communication features are currently available in the G/DSS:

- Support for anonymous and non-anonymous discussions among stakeholders (i.e., discussion forum),
- Support for posing questions on any issue and eliciting votes/opinions,
- Support for electronic mail among stakeholders,
- Graphical tools for creating various types of process diagrams, and
- Security features to enable appropriate involvement of stakeholders at various phases of the decision-making procedure.

We are currently working on adding capabilities in the G/DSS for problem analysis and goal specification (i.e., Phases 3 and 4 in the CDM procedure, see above). Further, support for Phases 5 and 6 of the CDM procedure (i.e., generating and evaluating solutions) is provided to some extent in the form of model visualizations (RADIX) and GIS map outputs.

In parallel, with our collaborators we have developed several models that are being integrated in our GIS interfaces: a landslide risk model, a water balance model, an erosion model (universal soil loss equation [USLE]), and a crop model (DSSAT).

Activity 2.1.2 "Maqueta" of Tascalapa watershed

Highlight

- "Maqueta" or three-dimensional papier-mâché model made as DSS tool

Objective

To create a simple DSS tool to strengthen a sense of community among stakeholders.

Methods

In January 1998, a "maqueta" or three-dimensional geographical model of the Tascalapa (Yoro, Honduras) watershed was constructed. These "maquetas" are decision and planning tools that are used to strengthen a sense of community among stakeholders and were first developed for the Río Cabuyal watershed in Cauca, Colombia in collaboration with a local NGO.

Progress towards developing user-friendly access to a large biophysical and socioeconomic database is proceeding according to plan. Formal collaboration involving direct research by graduate students and post-doctoral researchers is underway with the Universities of Florida and Georgia in the United States; King's College, Leeds University, and the Royal Agricultural College in England; and Wageningen Knowledge Center in the Netherlands. This work relies on simulation modeling to support stakeholders' understanding of complex social and environmental relationships so that the best plans will result from the most productive analysis. The work relies heavily on completion of other, more basic work reported above.

Activity 2.1.3 Indicators of soil quality

Highlight

- Soil quality score card built using locally determined indicators of soil quality for participatory land evaluation

Objective

To develop indicators for local monitoring of the natural resource base.

Methods

1997 saw the publication of a "soil quality score card" (SQS) that was built "from the ground up" using locally determined indicators of soil quality. The SQS was developed in the Cuscateca watershed (Danli, Honduras) during three local workshops and with the assistance of a Swiss visiting professor of soil science. A key aspect of this work is the development of a glossary of local taxonomy. The philosophy behind this work is the same as with that local "well-being" indicators. Results were presented at the 1998 meetings of the PCCMCA.

Results of the work in Danli, Honduras were validated and extended in the San Dionisio watershed in the Department of Matagalpa, Nicaragua. Again, a series of three workshops were conducted with the collaboration of the Director and several students from the Escuela de Suelos y Agua at the Universidad Nacional Agraria, and also representatives of the Cooperative for American Remittances Everywhere (CARE)-Matagalpa.

Also during 1997, in San Dionisio, progress was made in extending the concept of local soil quality evaluation to defining procedures for participatory land evaluation. These procedures include:

i) A land use survey by transect and opinions of the actual state of resources like forest, pasture, crops, livestock, and water courses

ii) Opinions on the fitness and risks for identifying priority areas of the landscape requiring intervention, and

iii) Local mapping of survey results for communicating and planning.

This work was carried out in collaboration with *Campesino a Campesino* of San Dionisio, the Asociación Indígena of Matagalpa, CARE, and members of the Comité de Agua Potable del Municipio de San Dionisio. Results were presented at the 1998 meetings of the PCCMCA.

Outputs

Concepts of local soil quality evaluation were used to define procedures for participatory land evaluation. A soil quality score card was built for use locally. A glossary of local taxonomy was made.

Activity 2.1.4 Methodologies and workshops

Highlights

- Methodologies for the identification and ranking of soil indicators, and participatory mapping, analysis, and monitoring of natural resources (including GIS, photo-topographic analysis of land use changes, and use of 3D terrain model) are available in finalized or advanced form.
- The method for the participatory identification of market opportunities is also available.

Activity 2.1.6 Incorporate endogenous indicators related with poverty, based on local perceptions using knowledge and consolidation of spatial analysis (GIS)

Contributors: Tonny Oyana, Patrice Couillaud, ~~E.B.~~(Ron) Knapp, and Gregoire Leclerc

Highlights

- A study used the digital population census database developed by the project to create new exogenous indicators of "poverty" which are better measures of resident empowerment and ecosystem resilience than international and national institutional indicators currently in use.
- Improved geographic poverty targeting to help decision-makers in prioritizing projects and assigning funds appropriately to help decrease poverty for Honduras is now available.
- More detailed micro-level social analyses are covered than before.
- The study's major finding is that size and quantity of households and the basic services, non-land assets, education, and the educational attainment index are strongly correlated.

Objective

The objective was to understand the link between poverty and environmental degradation, using Honduras as a case study. The original data from the 1998 Honduran population census with 4,255,105 responses have been analyzed using a methodology based on indicators of "***unsatisfied basic needs***" (UBN). Similar approaches have been used in at least eleven Latin American countries. For our analysis, two compound indicators were designed from responses to a number of census questions ranging from housing material to education completed. The result is a geographic database at the resolution of 3,660 *aldeas* or villages. We are not proposing that indicators developed by the project are inherently superior to indicators proposed by the World Bank or Fundación Hondureno para Inversión Social (FHIS). We have developed our own UBN indicators because we believe they characterize more accurately than other available indicators two critical ecosystem properties: ***self-reliance and empowerment*** of local stakeholders.

Methods

The methodology used in this study draws from the traditional unsatisfied basic needs (UBN) philosophy and has been applied in at least 11 countries in Latin America (UNDP 1992, Boltvinik 1996).

The UBN method evaluates the status of each household in relation to specific groups of needs. Boltvinik (1996) notes that three critical factors are pertinent in conceptualizing UBN: selection of needs, the definition of minimum criteria for each need, and the poverty definition criteria. Based on these essential factors we characterized census data by selecting a group of subindices and micro multiple indicators at microlevel. In addition, these micro multiple indicators of human resources development were processed to ascertain the village human resource potential, gender proportions, and educational levels (Oyana 1997, UNDP 1996).

This study relied on secondary data sources that CIAT used for implementing a baseline poverty study in Honduras. In particular, results from the census that the Government of Honduras conducted in 1988 are used (SECPLAN 1991). The census data are provided in digital format and inputted in Oracle. The database contains about 4,255,105 individuals and 891,298 households. Note that a range of tools/functions has been applied using commercial packages such as Oracle, Microsoft Excel, ARC/INFO, and ARCVIEW to achieve the processing of data and subindices. Also, specific scripts in SQL, AML, and Avenue languages were written to automatically carry out some of the tedious command-driven tasks. Oyana et al 1998 give full details.

The methodology used involves scoring all the variables with different weightings at household level. By using the two derived composite indicators (NBI_3j and NBI_4j) six classes were defined according to the set poverty criterion (Table 3).

Table 3. Household poverty classes in Honduras.

Stratum number	Definition	Value	
		Minimum	Maximum
I	Extremely poor	0.7	1.0
II	Poor	0.4	0.7
III	Moderately poor	0.1	0.4
IV	Threshold of poverty	-0.1	0.1
V	Above threshold	-1.0	-0.1
VI	No data	-	-

The strata II and I include households with high poverty in terms of a lack of basic needs. Stratum I includes households whose basic needs have a non-satisfaction average of 85%, stratum II an average of 45%, and stratum III of 25%. For stratum IV the average corresponds to the norm defined, and for stratum V of 55% above the norm.

Using the individual and the derived indicators, villages and municipalities were classified taking into account the percentage of households with unsatisfied basic needs. The two derived composite indicators, NBI_3 and NBI_4, were further processed and measured the magnitude of poverty. At the administrative level, the intensity of poverty was measured by considering the values taken by NBI_3_j, NBI_4_j, and the number of persons living in each household affected in strata I and II according with the criteria:

$$MAGP\_3 = (\Sigma(m_j * NBI\_3_j)_{s=1} + \Sigma(m_j * NBI\_3_j))_{s=2} / Tot\_household$$
$$MAGP\_4 = (\Sigma(m_j * NBI\_4_j)_{s=1} + \Sigma(m_j * NBI\_4_j))_{s=2} / Tot\_household$$

Where m_j is the number of persons by household, NBI_3_j the value of NBI_3 for the household j, NBI_4_j the value of NBI_4 for the household, and s the stratum number.

These two indicators give the magnitude of poverty in terms of people, and households in relation to the threshold levels of households. In addition, the values of P_6, $MAGP\_3$ and $MAGP\_4$

were used for manipulating administrative units, which were then classified. To ascertain the level of human capital development in Honduras, micro multiple indicators were derived at village level.

By handling geographic information, efforts were made to ensure that spatial microdata were properly integrated with census data by matching the village codes in the ARC/INFO coverage and the census codes that were used in the census survey. By so doing, better spatially referenced micro datasets were created to allow a proper geographic analysis of poverty at that scale. The relationship between the village codes in Oracle and ARC/INFO coverages was also established. This was done to maintain data consistency and integrity between the village codes reported in the Polygon Attribute Table (PAT) and the census codes used to represent these villages. All redundant codes were weeded out in both cases and matched. In total, 3660 village points were georeferenced and a column created in Oracle, which becomes the unique identifier between ARC/INFO and Oracle.

Both data types were crosschecked systematically to enhance their quality before the final integration. The updated coverage contains another field type *(accuracyfin)* that shows users the degree of consistency between the original and the new coverage (Table 4). The 1974 and 1988 census data are compared to establish the spatial changes that have occurred over time.

Table 4. A summary of errors checked within the spatial data.

Consistency with the municipal code	Distance between two villages (m)	*Accuracyfin*	No of villages
Inconsistent (0)	0	Very bad (-1)	4
Inconsistent (0)	0 – 300	Bad (0)	10
Inconsistent (0)	> 300	Bad (0)	276
Consistent (1)	0	Medium (1)	25
Consistent (1)	0 – 300	Good (2)	32
Consistent (1)	> 300	Very good (3)	3313

At national level this method shows that of the total population, 55.11 % as measured by the derived composite indicator referred to as type 1 (P3_NBI_3) and 58.74 % of type 2 (P3_NBI_4) do not meet the defined satisfaction criteria (Table 5). The hardest hit Departments are Intibuca and Lempira, ranked with a value of 4.

To test the technique we had to work at municipal, Department, and national scales because the data and results available from other studies mainly reflect the status of poverty at these scales (Table 6).
Results are strongly correlated: FHIS 1993 and NBI_3 are 0.886, FHIS 1993 and NBI_4 are 0.782, SECPLAN 1992 and NBI_3 are 0.938, and SECPLAN 1992 and NBI_4 are 0.945.

Table 5. The magnitude of poverty across departments in Honduras.

Department	Derived composite indicators Type 1 (%)	Rank	Type 2 (%)	Rank	Poverty index 1 (points)	Rank	Poverty index 2 (points)	Rank
Atlantida	47.2	2	36.7	2	165.7	2	124.2	2
Colon	66.2	3	53.9	2	245.2	3	192.8	2
Comayagua	60.8	3	60.5	3	232.8	3	229.3	3
Copan	72.5	3	73.3	3	265.8	3	276.8	3
Cortes	32.1	1	24.9	1	104.5	1	79.1	1
Choluteca	72.7	3	58.3	2	279.0	3	217.7	3
El Paraiso	69.9	3	70.1	3	277.9	3	281.2	4
Francisco Morazan	36.7	2	29.7	1	129.5	2	102.1	1
Gracias A Dios	74.7	3	59.4	3	283.5	4	215.7	3
Intibuca	80.5	4	79.1	4	350.3	4	337.6	4
Islas De La Bahia	18.7	1	18.1	1	50.0	1	45.6	1
La Paz	69.9	3	69.0	3	295.9	4	289.1	4
Lempira	81.4	4	81.5	4	341.6	4	347.2	4
Ocotepeque	63.6	3	65.7	3	233.5	3	243.0	3
Olancho	70.2	3	69.6	4	296.6	4	293.0	4
Santa Barbara	69.6	3	71.3	3	251.8	3	261.7	3
Valle	74.2	3	72.6	3	294.3	4	280.8	4
Yoro	55.2	3	53.3	2	208.2	3	198.0	2
Average	58.7		55.1					

a. Type 1 = P3_NBI_3 and type 2 = P3_NBI_4.

This particular study is different from previous ones conducted in Honduras in that it:

Contains a more detailed, spatial microlevel analysis of the social and economic situation for 3660 villages, 291 municipalities, and 18 Departments, disaggregated at urban and rural level, and reflecting gender proportions,

Presents better micro multiple indicators,

Creates better, spatially referenced micro datasets with demographic characteristics disaggregated at age level to enable one to conduct population analysis at village level,

Tests some of the relationships between the household subindices and other micro multiple indicators,
Incorporates the spatial element at microlevel,

Establishes microlevel benchmarks and allows for a spatial comparison in different geographic regions, and

Uses a wide range of geotechnological tools and functions available commercially to process an enormous amount of data.

Note that census data alone are necessary but insufficient for an in-depth understanding of poverty. Other data sources such as survey data should be used to complement the approach.

This study gives three major recommendations from this microspatial characterization of poverty using the census data.

1. The hardest hit Departments, Lempira and Copan should be targeted. We recommend investing in basic skills and providing essential basic services to enhance the social and economic development of both Departments as a major intervention measure.

2. We recommend that a beneficiary assessment be conducted in the Departments of Francisco Morazan and Isla De la Bahia to identify the "hard-to-reach" female households.

3. Our results should be taken a step further in other studies.

Table 6. The percentage of poor (averaged) as assessed by this study and others.

Department	Other studies[a]		This study[b]	
	FHIS	SECPLAN	NBI_3	NBI_4
Atlantida	33	22	47	37
Colon	39	31	66	54
Comayagua	37	35	61	60
Copan	43	41	72	73
Cortes	22	13	32	25
Choluteca	48	41	73	58
El Paraiso	44	45	70	70
Francisco Morazan	27	21	37	30
Gracias a Dios	62	38	75	59
Intibuca	53	60	80	79
Islas de la Bahia	23	5	19	18
La Paz	45	48	70	69
Lempira	51	57	81	81
Ocotopeque	35	35	64	66
Olancho	46	46	70	70
Santa Barbara	38	36	70	71
Yoro	33	28	55	53
Valle	51	48	74	73

a. FHIS = Fondo Hondureño de Inversion Social, and SECPLAN = Secretaria de Planificación Coordinación y Presupuesto.

b. NBI_3 = type 1, and NBI_4 = type 2.

Outputs

Several indicators of poverty have been derived at household and village scales, and presented graphically. These scales allow for a comparison and a contrast of the level of poverty spatially among villages. Our methodology breaks new ground as a GIS and Database Management technique aimed at localizing census data and also as a means for effectively studying poverty. By defining a broad number of satisfiers and micro multiple indicators at microspatial level and then processing them for all the 3660 villages in a spatial context, the method goes a step beyond the three household satisfiers processed at municipal level by SECPLAN in 1992. It also covers more detailed microlevel social analyses than before (Thorpe 1993, p.74). The method was applied in the micro-watershed of the Rio Calico (see 2.2.1)

Activity 2.2 Community-led initiatives, NGOs, universities, and NARS are using the DS tools in at least three sites in 1999

Activity 2.2.1 Application of method of measuring poverty

Highlight

- The methodology was applied in the micro-watershed of the Rio Calico.

Objective

To use the participatory methodology of measuring poverty, which uses the perceptions of the actual families within a community.

Methods

This methodology differs from others in that it is participative. It was applied to the 17 rural communities that make up the micro-watershed of the Rio Calico. Eight steps were followed.

1. Communities were selected based on sampling and strategy factors of maximum variation.
2. Families were classified according to levels of well being within the rural community.
3. Families were grouped into different levels of well being.
4. The indicators were applied to the whole study zone.
5. Indicators of levels of well being were quantified and the index of level of well being was elaborated.
6. The index of level of well being was validated.
7. Categories of well being levels, based on the index, were defined.
8. An Outline of Poverty was elaborated for the study zone.

Varied use can be made of the information gathered. With this methodology, the informants of each community identified the different family groups that corresponded with each level of well being, and established the factors and causes that contributed to placing a family at a determined level. These were converted into real necessities of each of the groups.

Outputs

The analysis helped understand the situation of poverty and may facilitate decisions made by the central government, municipalities, and development projects aimed at alleviating poverty in this watershed.

Activity 2.2.2 Collective action in watershed management - a participatory action research project in the Andean hillsides

Contributor: Olaf Westermann, Helle Ravnborg

Highlights

- Through FPR methods the combination of lime and Lorsban has been identified as an effective means of control of leafcutter ants.
- Farmers have planted live barriers against soil erosion.
- Together with researchers, farmers have done trials aimed at identifying Cucaron (*Macrodactylus Ovaticollis* Bates)-resistant maize variants.
- Reforestation of natural springs has been initiated.

Objective

The objective of this work is to find ways to foster collective or concerted action among watershed users and other stakeholder groups in their day-to-day management of natural resources and thereby enable them to deal with problems that cannot be solved effectively by individuals acting alone. The research aims to identify key elements in fostering and facilitating collective action for watershed management.

Background

As part of its interdisciplinary research, CIAT's Hillsides and Farmers Participatory Research and Gender Analysis projects are working in two, small multi-ethnic watersheds (Los Zanjones and Guadalito) in the Andean hillsides of southern Colombia. So far, this work has dealt with problems related to water management and conservation, erosion control, and pest control (white grubs and leafcutter ants).

The project has been focused on the development of a methodology to identify stakeholder groups to accomplish collective management of natural resources in micro watersheds. Watersheds are biophysically delineated on the basis of topography and water flows. Watershed can have many sizes but we have defined our micro-watershed to be within 25-150 ha. The rationale for developing a stakeholder analysis methodology for micro-watersheds arose from a practical experience in other parts of the Rio Cabuyal Watershed. The decision made by the watershed users organization FEBESURCA (now ASORBESURCA) to stop the burning of forests around natural springs, was violated as a result of not all stakeholders being included in the decision-making process. ASORBESURCA recognized this situation and invited more stakeholders to participate in the analysis and exploration of possible alternatives. The incidence triggered our research on a methodology that recognizes all stakeholders and identifies contrasting perceptions through a sequence of individual interviews and meetings.
We are producing a set of handbooks on key issues, such as stimulating interest in collective watershed management and stakeholder identification aimed at NGOs and other agencies working in NRM.

Control of leafcutter ants

Methods

Through farmer participatory research (FPR) methods, the combination of lime and Lorsban has been identified as an effective means of control of leafcutter ants (Ravnborg, forthcoming).

The experiment took place in the micro-watershed, Los Zanjones, situated in La Laguna in the Andean hillsides in southwestern Colombia. Los Zanjones comprises 44 ha, subdivided among 14 individual owners, giving an average plot size of 3.1 ha. An anthill inventory, conducted with the owners in 1997, identified 39 anthills or nests. Figure 6 shows the extension of the 14 plots, overlaid by the location of the 39 nests. On the basis of farmers' experience from some anthills in the area, the average radius of action of the leafcutter ants, that is, the distance from the nest that the ants move to forage was estimated at 80 m. A circle with a radius corresponding to 80 m has therefore been drawn around each nest in Figure 6 to indicate their areas of influence.

Four possible alternative control methods and a control (no treatment) were selected for farmer experimentation in La Laguna for control of existing anthills:

- Agricultural lime, pumped into the anthill,
- Lime mixed with Lorsban, pumped into the anthill,
- Gasoline, poured into the anthill and set on fire to produce an explosion, and
- Washing powder poured into and around the entrances/exits of the anthill.

Fgure 6. Map of anthills, their radius of action, and farm boundaries, Los Zanjones, La Laguna, Colombia.

Table 7 shows the results from the ant control treatment in Los Zanjones.

Table 7. Results from the ant control treatments in Los Zanjones, La Laguna, Colombia.

Treatment	Anthill number	Holes at first application/ monitoring visit (no)	Holes at last application/ monitoring visit (no)	Total applications (no)	Reduction in number of holes (%)
Washing powder	1	44	7	7	84
	2	135	20	9	85
	3	25	43	9	(-72)
Lime	4	109	1	10	99
	5	257	18	9	93
	6	22	26	9	(-18)
Lime + Lorsban	7	70	3	7	96
	8	25	0	3	100
	9	13	0	4	100
Gasoline	10	8	0	2	100
	11	35	0	2	100
	12	102	0	3	100
Control (no treatment)	13	30	6	n.a.	80
	14	8	6	n.a.	25
	15	17	9	n.a.	47

Use of live barriers for control of soil erosion

Methods

Live barriers of rice, sugarcane, and pasture have been sown in the micro-watershed, Los Zanjones. In total, 382 m of pasture, 318 m of rice, and 971 m of sugarcane has been sown. Farmers opted for planting the live barriers to improve soil fertility, i.e., to reduce erosion and promote the build up of organic matter/humidity.

Asked about what would be their indicators for evaluating whether the barriers were serving their purpose, farmers mentioned the following possibilities:

- That the plants in between the rows would grow better;
- On the other hand, if the soil looks 'bright', it is getting tired;
- That there will not be any gullies; and
- That the soil would be flat.

Identifying Cucaron (*Macrodactylus Ovaticollis* Bates) resistant maize variants

Methods

To determine if the phenology of maize could serve as a basis for management of pests, comparisons of 10 genotypes of maize were made. Eight lines of *maize blanco* and two local variants were tested. Data were collected in relation to the time of flowering, ripening, adaptation to the environment, and the damage done by *M. Ovaticollis*. The flowering of five lines with *maize blanco* and the local variants coincided with the maximum presence of *M. ovaticollis*. As a result, nearly 50% of these maize variants were damaged. Conversely, three of the lines evaluated (SEW-HG A, SEW-HG B, and SEW-HG A and B) flowered before the peak of *M. ovaticollis*; and only 8.6% of these maize variants were damaged. The conclusion is that the use of early maize variants could serve to control the damage done by *M. ovaticollis*.

Reforestation of natural springs

Methods

Some problems of NRM cannot be solved on the farm or plot level but have to involve some sort of collective or concerted management of natural resources at the level of landscapes. This is especially true for NRM in watersheds where water, soil, and nutrient flows are evident (from the top to the bottom of the watershed) and in relation to pests, which easily cross boundaries.

Although it is evident that farmers cannot solve some problems individually, organization around collective action is difficult. Transaction costs may be too high, especially in watersheds selected by the size and number of families and not selected by type and importance of NRM problems. Further, concerted action may demand organizational skills the farmers, and researchers, do not have. Finally, inherent conflicts, which have nothing to do with the actual management of the natural resources, may hinder communication and collaboration among the farmers. This may be especially true when working with natural and not socially defined groups of natural resource users.

Stakeholders are defined by interest. Interests are often associated with social relations like ethnicity, gender, age, and culture, or defined politically or administratively, like municipalities, regions et cetera. Working with the collective management of natural resources we find it relevant to define stakeholders by their interdependency in use and management of natural resources. As such, watersheds (and other landscapes) become the boundaries of our work and the stakeholders defined and their interdependency of the natural resources within this biophysical boundary. These stakeholders may belong to different socially and politically defined units, but all have an interest or "stake" in the same natural resources. Stakeholders defined by the use of natural resources will not have social relations or norms that can motivate or force the actions of the individual farmers.

Activity 2.2.3 Identifying stakeholder groups and stimulating collective management of natural resources in micro-watersheds

Contributor: Olaf Westermann and Helle Ravnborg

Highlights

- The methodology to identify stakeholder groups and to stimulate collective management of natural resources in micro-watersheds was completed.
- The methodology applied serves to identify maximum variation in perceptions and contrasting opinions on use, problems, and conflict over NRM.
- The methodology serves to stimulate some degree of collective management of natural resources among watershed users, because it opens a public space for analysis and negotiation of NRM problems.

Objective

A basic assumption for our project is that to achieve a real impact of collective management of natural resources all stakeholders have to be identified and invited to become involved in decision-making processes and negotiation. Thus, stakeholder identification becomes both a normative goal and a precondition to the activities and impacts of collective management of natural resources.

Methods

Collective management of natural resources implies a broad range of activities of which stakeholder identification is one. Thus the development of the stakeholder methodology is only a step forward towards a more comprehensive understanding of which actions and structures motivate and facilitate collective management of natural resources. Table 8 shows the methodology developed. Among the issues the methodology does not deal with successfully are how to:

- Involve all interest groups in collective activities,
- Create a forum for negotiation where all stakeholder groups (when identified) can and will participate,
- Resolve conflicts, and
- Organize farmer groups to design collective activities.

Table 8. Step-by-step stakeholder analysis.

Activities and Objectives	Criteria and Methodology
Selection of work area: ✓ Facilitate direct communication ✓ Affirm that the opportunity exists for face-to-face meetings of stakeholders	• Naturally adjacent areas • Between 25-150 ha • Between 20-40 families • Clarify other selection criteria
First meeting: ✓ Present the project proposal ✓ Stimulate the appreciation of the importance of collective action in natural resource management (NRM) ✓ Estimate the possible existence of NRM ✓ problems in the micro-watershed	• Presentation of personnel • Clarify expectations and introduce topic • Collective analysis of fictitious drawing • First estimate of possible NRM problems • Clarify project's contribution • Survey of stakeholders' interest in participating in project • Proposals for future actions (second meeting and individual interviews • Thanks and farewell
Individual interviews ✓ Listen to all existing points of view ✓ Deeper analysis of problems and conflicts related to RRNN	• Interview randomly selected family (local leader, well-known family etc) • Analyze central ideas, perceptions, and preoccupations related to NRM in the micro-watershed to elaborate ~~a fi~~rst interpretation • Interview families with different perspectives, indicated by the first family. Present the structure based on the first family interview • Analyze central ideas, perceptions, and preoccupations related to NRM to make the second structure • Interview families with different perceptions, indicated by the second family. Present the structure based on previous interviews. • Finish interviews when families are renominated and no further variation occurs.

Continued.

Table 8. *continued.*

Activities and Objectives	Criteria and Methodology
First interpretation on uses and conflicts ✓ Understand use of natural resources ✓ Analyze NRM problems ✓ Assess conflicts in relation to natural resources ✓ Identify stakeholders	• What uses are made of natural resources? • What are the problems in putting them into effect? • What conflicts or disagreements have occurred in the watershed? • Who are the stakeholders – what factors define them?
Second meeting ✓ Voice existing conflicts on natural resources – without compromising those interviewed ✓ Initiate dialogue and discussion on the adequate use of natural resources	• Clarify expectations • Present the interpretation made • Discuss and modify the interpretation in plenary session • Discuss and modify the interpretation in stakeholder groups • Unify the above modified interpretations • Propose future actions • Final survey on stakeholders' interests in the micro-watershed in the project • Agreements and next steps • Thanks and farewell

Activity 2.2.4 Participatory micro-watershed analyses

Contributors: Ronnie Vernooy and Jacqueline A Ashby

Highlight

- Participatory micro-watershed analyses underway

Objective

The aim is to present the results of these analyses to key local decision-makers such as the mayor of San Dionisio, state agencies and NGOs operating in the watershed, and to the recently created Association of Community Organizations (considered a key stakeholder "in the making").

Method

We are carrying out a series of participatory micro-watershed analysis with the involvement of small groups of local key informants in each of the 13 micro-watersheds (farmers and/or local technicians, promoters or assistant mayors who know the area well). These analyses include land use (agroecological zones), the state of forests, water resources, crops, wildlife, domesticated animals, pastures, and soils. The analyses identify limitations and opportunities for agricultural production/NRM in the area. Based on the findings of these analyses, a set of natural resource indicators will be developed, which could be used for monitoring purposes and for comparing the state of natural resources in different micro-watersheds.

Output

The results will allow decision-makers to identify priority zones for action (because natural resources are already in bad shape or may decline to critical shape soon) or offer opportunities for alternatives.

Activity 2.2.5 Utilization of physical, chemical, and biological indicators to monitor water quality

Contributor: Catherine Mathuriau

Highlight

- Data collected and being analyzed on the water quality in the Rio Cabuyal watershed to monitor the sustainability of this valuable resource

Objective

The aim of this work is to diagnose the quality of water of the Cabuyal River through a physical, biological, and chemical analysis and develop a methodology to monitor the water quality of this watershed.

Methods

In 1997 work began on a PhD thesis directed by the French institute Centro de Ecología de los Sistemas Acuáticos Continentales (CESAC). The work was in collaboration with CIAT-Hillsides, the Consorcio Interinstitucional para una Agricultura Sostenible en Laderas (CIPASLA), the Corporación autónoma regional de Valle del Cauca (CVC), ASIAVA, and the Universidad del Valle to diagnose the quality of water in the Rio Cabuyal watershed.

The Cabuyal River watershed presents three types of potential contamination:

1. Fertilizers and pesticides used in cultivation
2. Cyanide as a byproduct of cassava processing in local agroindustries
3. Discharge of residual waters from rural and urban habitations in the area

To quantify the effect of these discharges on the water quality four sites were selected along the Cabuyal River watershed. At each site we took one sample of water. Collection was made during wet and dry periods over 1 year and a half to observe changes in contamination over a 1-

year period. We also hope to obtain better information on the biodiversity of species of macroinvertebrates existing in the zone and their role in the ecology of watersheds.

At present, we are analyzing samples in the laboratory and the results will be available by mid 1999.

Output

The off-site effect of water quality has to be taken into account when evaluating the resource management of the watershed. This study improves our knowledge and will help the community make correct decisions in resource management.

Activity 2.3 DS tools are published and widely distributed in Honduras and Nicaragua by the end of the project

2.3.1 Multiscale characterization of Honduran agroeconomic systems

Contributors: Andrew Nelson, E.B. Knapp, Grégoire Leclerc, and Stan Openshaw (University of Leeds)

Highlights

- Software has been developed (using spatial Honduran census databases developed by the Project) that can identify dominant spatial scales at which process that control landscape patterns and ecosystem function occur. (In partial fulfillment of a PhD degree with U. of Leeds, UK)
- A model was developed for the interactive exploration of spatial point patterns across geographic scales. This is a useful DS tool for targeting problems, priority areas, and beneficiaries.

Objective

The objective of this research is to prove that landscapes have critical thresholds at which processes (viz. "pressure, state, response indicators") show quantitative change and that heterogeneity, so prevalent in Hillsides ecosystems, is functional, not random. What this means to decision-analysts and stakeholders is that scales at which landscape data are organized for analysis must be chosen thoughtfully or inferences and planning are almost certain to be erroneous and incalculably costly.

Methods

Our methodology includes a powerful database query engine, provides a reliable data generalization process, is capable of building data across scale, compares cross scale with fixed scale data, classifies and intelligently represents data based on their use and purpose, and provide analytical and visual comparisons of similar representations. It also has the added factors of simplicity and future expansion.

We consider this method is viable both as an analytical tool to examine "better" ways to analyze and represent data, and as a final GIS tool for providing users with information that best represents their data for the specific purpose at hand.

We have created a subset of variables from the Honduran 1988 Population Census for the three departments of Atlantida, Yoro, and El Paraiso. There are 660 (18%) villages in these three departments out of 3729 recorded in the 1988 census.

This cross scale analysis can be broken down into seven distinct stages. Wherever possible the focus is on a data-driven analysis rather than a model-driven approach. Where we have adopted analytical techniques, we have aimed to make them as flexible and as data-dependent as possible. The methodology follows five steps.

Step 1: Selection and generalization of a variable from the database
We first select a variable from the interview level database through the SQL+ database query interface. The variable is then extracted or built for all sites in the test area. The generalization process is:

> Select/create the variable through the SQL interface,
> Determine all possible responses to the query,
> Build a table of the number or occurrences of every response for every point, and
> Calculate the total number of responses and represent the data proportionally.

Table 9 gives an example, where we see the data reduction involved between the input data (over 5000 responses to two separate questions) and output information.

Table 9. Typical output from a query[a] for four villages.

Village code	Responses	Method of water supply (%)			
		By pipe	By pump	Shared pipe	River
180901	1566	51.2	38.3	9.4	0.0
180902	814	41.4	39.6	10.2	1.0
181001	1845	50.3	35.5	12.2	0.0
181002	642	48.4	40.0	10.1	1.5

a. Query on method of water supply for households of more than eight people.

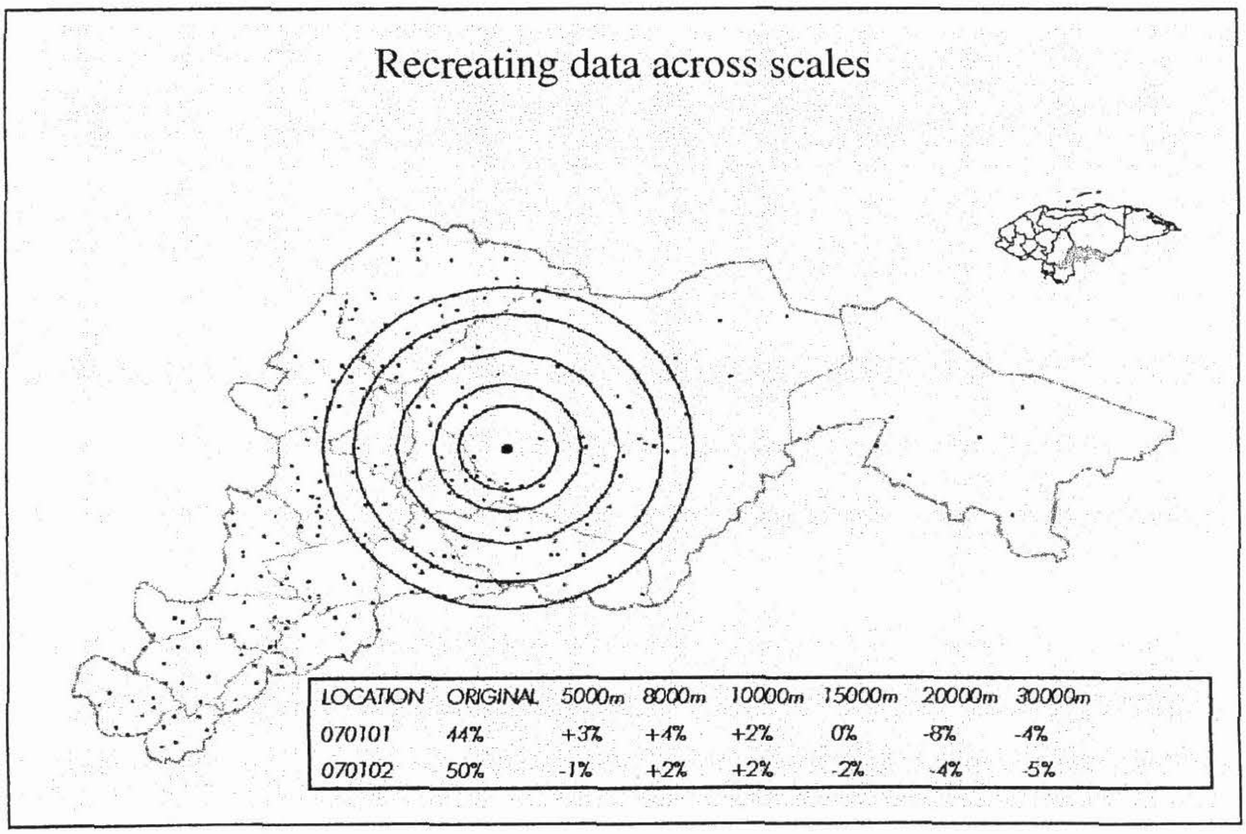
The advantage of storing data at their fundamental level and generalizing in an ad-hoc fashion is clear; we have a dramatic reduction in data volume, but not data quality, for minimal overhead in computation.

Step 2: Create fixed scale representations
A standard dataset is created at the village, watershed, and municipality levels.

Step 3: Recreate the variable at a range of scales
The next stage is to rebuild the point dataset at a range of scales in a way that accounts for the "local" distribution of data locations and data values. Local is used in the sense that each scale has its own definition of a "locality" defined, for example, by a circle around each point. Figure 7 illustrates the concept of locality and aggregation of data.

The size of the circle defines the scale at which we are examining the dataset.The aggregation algorithm is:

1. Select a point P, and record its value.
2. Place a circle over the point.
3. Count the points that fall in the circle, average their value, and append the value to P.
4. Increase the circle size, and repeat step 3.
5. When all circle sizes have been examined, move to the next point, Q, and repeat steps 2-4.
6. When all points have been examined, map results.



LOCATION	ORIGINAL	5000m	8000m	10000m	15000m	20000m	30000m
070101	44%	+3%	+4%	+2%	0%	-8%	-4%
070102	50%	-1%	+2%	+2%	-2%	-4%	-5%

Figure 7. Illustration of the concept of point-centered aggregation.

In Figure 8 the aggregation process is clearly essentially an averaging out process where outliers and extreme results are removed at higher levels of aggregation. However it is also obvious that these aggregation effects are neither homogenous across space nor predictable.

The best way to visualize the data is by interpolating each scale into a surface and animating this process. Because the data are not spatially homogenous, Universal Kriging was used to interpolate the surface. Snapshots of four scales are shown in Figures 9 and 10.

The animation across scale gives an intuitive feel for the spatial distribution of data and the changes that occur, which are sometimes dramatic and unpredictable and yet in other locations are very gentle.

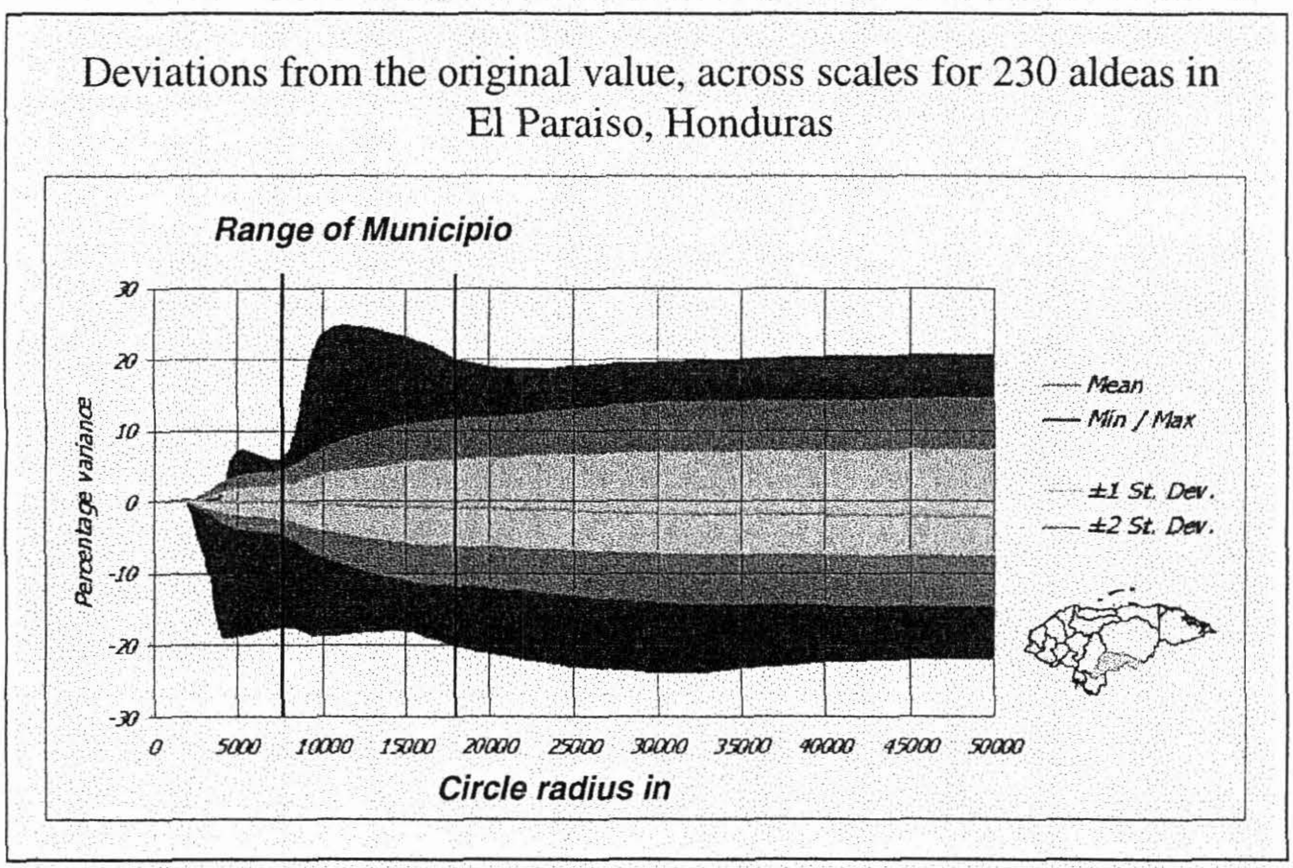


Figure 8. The change in a variable across scale shown by highlighting the averaging out process that occurs through aggregation

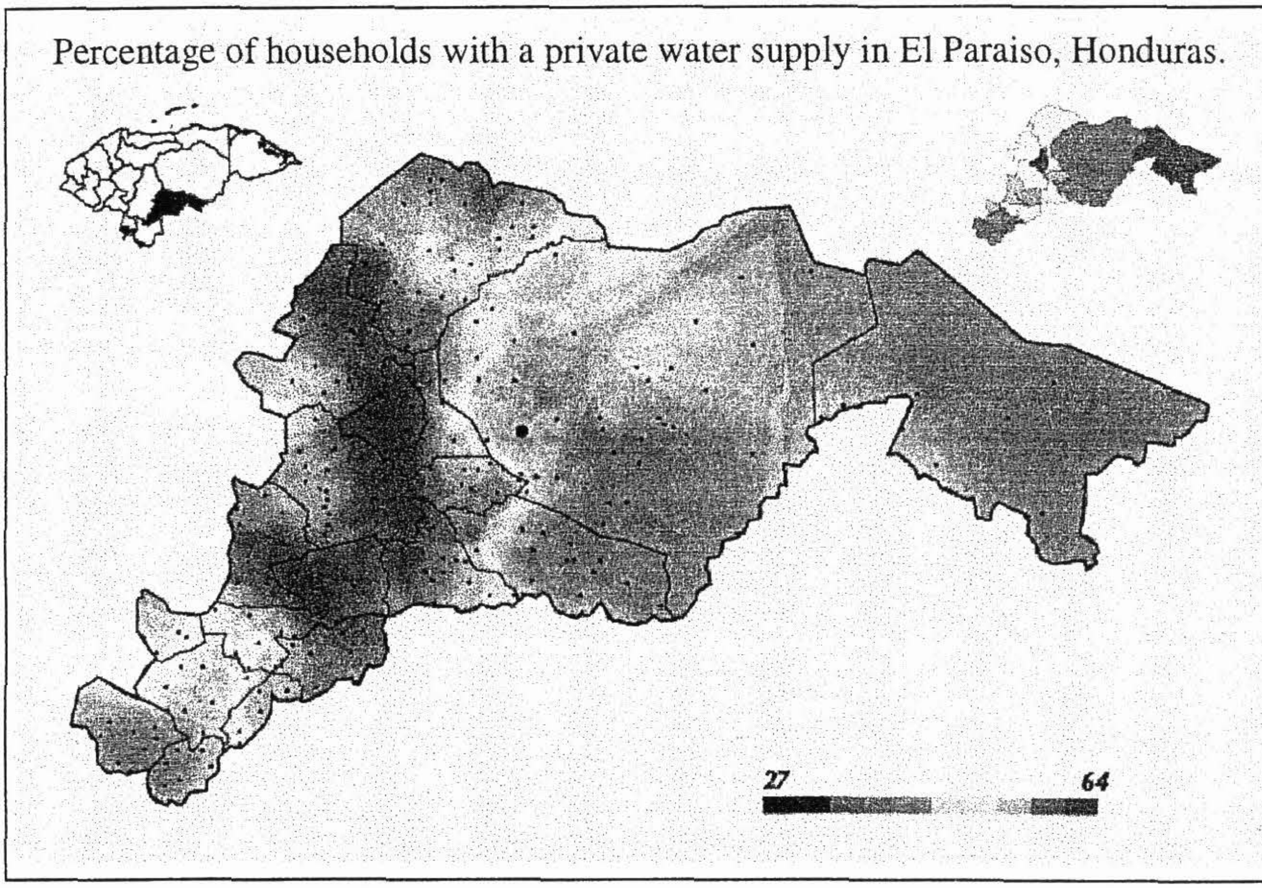


Figure 9. A Kriged surface of the original village (point) data. The small image (top left) shows the location of El Paraiso in Honduras, and the small image (top right) is a typical chorpleth representation of the data at municipality level.

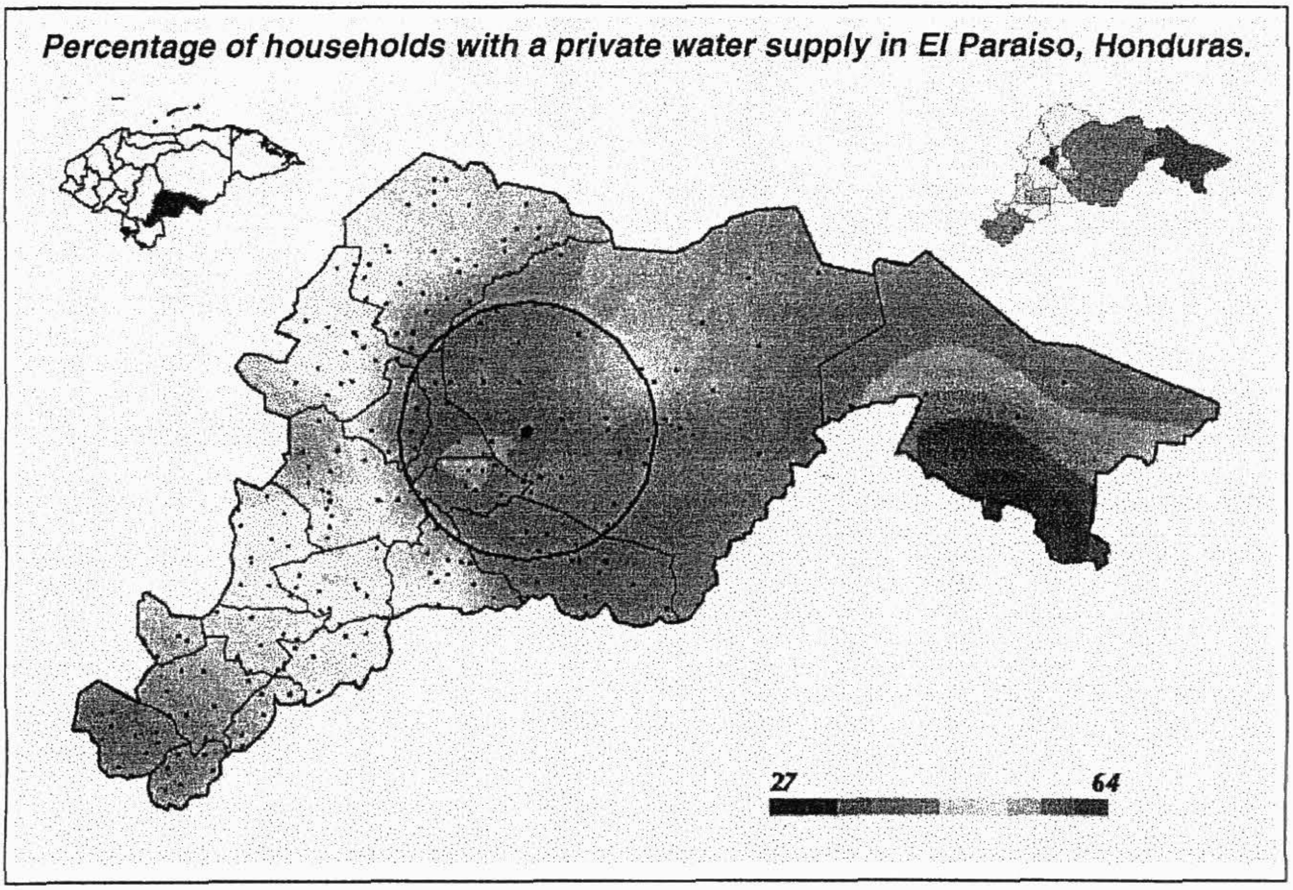


Figure 10. A Kriged surface of the data aggregated with a circle radius of 20,000 meters. This circle size gives an area equivalent to the average Honduran municipality area. The municipality map is shown (top right) as comparison. Clearly the municipality map does not give a fair representation of household water supply.

It is easy to relate the artificial scale (circle size) to real geographical entities, such as villages, municipalities, watersheds, sub-watersheds, etc. This is achieved through a rule base analysis of the site under study. We can set predetermined "scales" such as:

Village rules:

Half the distance between the two closest villages = smallest "village" radius
Half the distance between the two remotest villages = largest "village" radius
Half the average distance between all villages = average "village" radius

Municipality rules:

Smallest municipality area = smallest "municipality" radius
Largest municipality area = largest "municipality" radius
Average municipality area = average "municipality" radius

This rulabase can be repeated for watersheds, land ownership, and other available boundary information.

This rule-based method was developed to allow any limits to be imposed on the analysis. These limits can be based on simple analytical rules as in the example above, or they can incorporate any amount of local knowledge that would help to better define the geographic scale (such as accessibility or terrain). The lack of knowledge does not impede the methodology; rather the propensity of information improves it. By packaging any local knowledge into this "preamble" stage, we uniquely define our study site without over complicating the analysis.

Step 4: Spatial analysis across scale of point, and areal and surface data.
There is no single model or framework for exploring spatial data across scale. Instead we have developed some spatial analysis tools and adapted several others to create a generic framework that users can follow to explore their datasets and generate hypotheses. Table 10 gives a list of all the techniques being used. Those in italics are either completely self-written or have been adapted from previous work. However, taken as a whole, the framework itself is a completely new methodology.

Table 10. Spatial analysis tools that will be incorporated into the framework.

Analyses		
Point data	Areal pattern	Surface data
Point centered aggregation	*Zone design*	*Smart interpolation*
Geographical analysis machine	Spatial lag plots	*Pycnophylactic interpolation*
Geographical explanation machine		*Dasymetric interpolation*
Moran scatterplots and local indicators of spatial association		Geographically weighted regression

In the final stage (Step 5) we make analytical and visual comparisons of similar representation for hypotheses generation.

Outputs

We have developed a toolkit for exploratory spatial data analysis (Figure 11). It performs several advanced analysis functions but presents the results in an intuitive and highly visual format that is easy to understand. Both researchers and GIS users could use this as a means to:

Reduce the complexity of their datasets, by 'data-mining' huge databases for important information,

Better utilize their datasets by selecting the most suitable scale for further analysis' and

Increase their knowledge and understanding of spatial processes and scale effects.

Scale effects and data complexity are the norm in spatial datasets. The next step is to explore the interaction in the data of changing scales and processes, and explore the effect of the extent to which various assumptions underlying certain statistics are affected by different levels of aggregation. There is a long way to go before aggregation effects can be fully understood (or purged), but this research purports to be a first step in that process.

Figure 11. The user interface for aggregating and visualizing agroeconomic census data.

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Output 3: Trained people with skills to use the DS tools and interactive digital information system

Activity 3.1 At least 15 technical professionals, in Honduras and Nicaragua, are using the DS tools by the end of the project

Contributors: Hillsides team but particularly France Lamy, Elizabeth Barona, G. Leclerc

Highlights

- CD-ROM of national geographical information available for Honduras
- The CIAT Hillsides Central American Project accessible on website
- 26 activities held with donor representatives, other projects, university scientists, and national organizations

Objective

To make all available data easily accessible to interested users.

Methods

A CD-ROM of national geographical information is now available for Honduras. Since September 1997, up-to-date information and results from the CIAT Hillsides Central American Project can be accessed on our Internet website at www.intertel.hn/org/ciathill.

During the year, over 26 activities were held with representatives of donors (IDB, IDRC, and SDC), other projects (PASOLAC, Food and Agriculture Organization [FAO], IICA-Holland, CARE), scientists from universities (including EAP, CURLA, and UNA), and several national organizations including IHCAFE, DICTA, and INTA.

Outputs

Data are available for interested users and help in prioritizing research and decision making.

Activity 3.2 **Training materials and course curricula on applying the DS tools to community-led watershed resource management are published by the end of the project**

Activity 3.2.1 **Decision-making tools for NRM in watersheds elaborated and presented**

Contributor: Hillsides Team guided by V. Zapata

Highlights

- Active participation in workshops and positive responses were given on the methodologies.
- Material on the different methodologies was requested.

Objective

To disseminate to potential users the methodologies that CIAT has developed.

Methods

The methodologies are being disseminated through workshops and in the training of individuals and groups. Training material was tested in Yorito, Honduras (May 28-29). Two workshops were held, one in Yorito (June 13-17) and one in San Dionisio, Nicaragua (August 1-5). Two training workshops were also held, one in Nicaragua (October 26-29) and one in Danli, Honduras (November 2-6).

Outputs

Individuals and groups are being trained in the use of DS tools.

Activity 3.2.2 Training handbooks and workshops

Contributor: Hillsides Team guided by V. Zapata

Highlights

- Nine methodological training guides for trainers have been produced.
- Nine new training handbooks for diffusing/teaching the CIAL methodology in Central America have been produced
- Two major workshops were organized to present and validate the above.
- During 1998, the Project entered into agreement with U. Nacional Agraria (Nicaragua) to train staff in the use of training materials developed by the Project.

Methods

Nine methodological training guides were presented and validated in a series of workshops with local and national organizations and institutions (see under 3.1). The training guides for trainers are for publication in October.

One of the training guides published is "Methodological tools for decision making in Natural Resource Management". The 12-page guide covers nine tools:

1. Participative method for identifying and classifying local indicators of soil quality at micro-watershed level
2. Photographic analysis of tendencies in soil use in hillsides
3. Mapping analysis and participative monitoring of natural resources in a micro-watershed
4. Methodology of stakeholder analysis for management of a micro-watershed
5. Identification and evaluation of market opportunities for small-scale rural agriculturists
6. GIS: Atlas of Yorito, Sulaco, Yoro Honduras
7. Identification of well-being levels to construct local profiles of rural poverty
8. Utilization of simulation models for ex-ante evaluation
9. Development of organizational processes at local level for collective management of natural resources

The guide has been use for both teaching and assessing the DS tools developed.

Outputs

Training guides have been published and are being used.

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Output 4 — Organizational models and principles have been developed that facilitate the use of the DS tools in participatory planning of watershed resource management

Activity 4.1 — At least three local operational committees (CLODEST), formed in the project sites, meet at least twice a year for the purpose of participatory planning of watershed resources, management, and testing the project's DS tools. One CLODEST in each of three sites by 1997,1998

Highlight

- Stronger links were made at local level through PPO workshops in Yorito Honduras (3-6 Feb) and in San Dionisio.

Objective

To promote and forward a true collaboration between actors at different levels (e.g., smallholders, local communities, organizations, and institutions both in the private and public sectors).

Methods

A formal PPO workshop was held 3-6 February 1998 for CLODEST – the local operating committee for the Tascalapa watershed in Yorito-Sulaco, Honduras. The proceedings are published. A formal agreement for cooperation exists with CLODEST. The participative method allowed coordination of fieldwork with a clear vision of shared responsibilities and the dissemination of results in an efficient and effective way.

This type of planning in a participatory manner allows the local society to evaluate its resources, measure its strengths, determine its risks, and decide upon the best route towards agricultural development.

The annual meeting with the Consultative Group/Executive Committee was held in February.

In San Dionisio, a PPO with the Asociación de Organizaciones Comunitarias de San Dionisio "Campos Verdes" and with the Asociación de los Comités de Investigación Agricola Local (CIALs), San Dionisio was organized.

A formal workshop was held in June 3-4 with the Hillsides Group in Central America and proceedings have been published.

Output

Stronger links have been made at a local level.

Activity 4.2 Local operational Communities provide input to the annual Consultative Group meeting on the utility of the project's DS tools and interactive digital information system

Activity 4.2.1 Annual meeting

Objective

To improve project results by dynamic interchange with Consultative Group members.

Methods

The annual planning meeting of the Consultative Group and Executive Directorate were held 9-12 February in Tegucigalpa and proceedings published.

Output

Proceedings of the meeting were published.

Activity 4.2.2 Workshop planning and implementation

Contributor: Hillsides Team

Highlight

- 136 participants from NARS, NGOs, and local, international, and regional organizations in Central American Hillsides Project training and workshops, 1998.

Objective

To test DS tools and evaluate their use with different stakeholders.

Methods

Members of the Consultative Group have participated actively in planning and implementing two major workshops in the project sites, and in a university-level course organized by UNA, Nicaragua. These were designed to test teach the use of the project's interactive digital information system for Honduras and the associated DS tools, and to evaluate their utility with several different types of stakeholders, including development practitioners from NGOs, farmers, and technical professionals. Table 12 shows participation by different types of institution in these events.

Table 12. Participants in Central American Hillsides Project training and workshops in Honduras and Nicaragua (1998).

Type of participants[a]	Total (no)	%
NARS	32	23
NGOs	18	13
Local organizations	45	33
International organizations	13	10
Regional organizations	19	14
Other	9	7
Total	136	100

a. NARS = National Agricultural Research Systems, NGOs = nongovernment organizations.

Outputs

Stronger links were formed or maintained with participating organizations and individuals. The project's interactive digital information system for Honduras and associated DS tools were test-taught and evaluated successfully.

94619

Output 5: Stakeholders' experimentation with improved land management

Activity 5.1 Alternative policy and land use scenarios developed with community participation have been evaluated in at least two project sites starting in 1999, using the project's DS tools

Contributor: Rubén Darío Estrada

Highlight

- In Colombia, the Project is field-testing, in collaboration with the Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN) unique technical assistance policies that create incentives for those in the "highest" well-being classification to create employment specifically for those falling in the "lowest" well-being classification. The Cauca case study is using blackberry production as the vehicle to create employment.

Methods

In collaboration with CONDESAN and other institutions or national groups of the Andean zones, we are evaluating policies through various activities. Collaborating institutions include the: Federacion de Cafeteros, Fundacion Dario Mayo, Postobon, Alpina, Asociación civil para la investigación y Desarrollo Forestal (ADEFOR), Nestle, ACESCO, Fundacion Eduquemos, Universidad de Caldas, Universidad de Palmira, Colciencias, Ecofondo, Municipio de Pensilvania, Gobernacion del Cauca, Profrutales, Corpocapacitar, and Pademer. Table 11 shows the stage of different activities with objectives and collaborators.

All activities fall into one of the following groupings:

1. Empowerment of local communities through analyses of trade-off between equitable sustainability and productivity. This has permitted the community to become an efficient interlocutor in the negotiations on the distribution of hydroelectric project benefits in the Rio la Miel watershed.

2. Integration of impresarios and small-scale producers to capture tax benefits through the Paez law in Cauca Department.

3. Disposition of territory at municipal level and realization of integrated projects to have access to the incentives generated by carbon sequestration.

4. Financing of small-scale producers through price support by impresarios in the long term.

5. Extrapolation of the well-being methodology and exclusion criteria for population's selection.

6. Adjustment and validation of simulation models to evaluate, at watershed level, hydrological balances, soil degradation, sediment generation in rivers and dams, possible value of sediments and water, and optimum occasions for intervention.

7. In-service training of university professors as a method of extrapolation of complex trade-off analysis.

Table 11. Activities underway in hillside zones in various countries and integrated with the Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN).[a]

Activity	Country	Collaborators	Policy objective	Stage of development
Mora production in Cabuyal	Colombia	FIDAR, CIPASLA	Stimulate adoption of soil management practices through cultivation of high-value or commercial crops Stimulate local agricultural enterprises	Process consolidated where each initial producer finances and capacitates five more. 10 initial producers and 50 potential ones.
Enterprise producing avocados in Rio Vejas	Colombia	Profrutales, Caldono Mayor's office, Cauca Secretariat of Agriculture, CIPASLA, National Tax Administration, private enterprises	Incorporate regional impresarios through the incentives of the Paez law	6000 avocados produced, the population's objective selected, slope of lots measured, impresarios of zone visited, contacts made with Cauca Tax Administration
Aromatic plants produced in Cauca	Colombia	Corpocapacitar, Cauca Secretariat of Agriculture, Pademer private company	Incorporate national impresarios through the incentives of the Paez law	1500 producers given card identification, 200 families selected to start plantings, Medellin impresarios and seed producers contacted
Arachis production in Pensilvania	Colombia	Pensilvania Mayor's Office, UMATA, private enterprises	Integrate local and national enterprises in financing the countryside. Part of the package of activities to capture resources for carbon sequestration	200 families surveyed, 50 lots selected, 30 lots of 200 m^2 planted, contacts made with Nestle to buy seed, capacitation of UMATA for planting
Fondo Ganadero in Pensilvania	Colombia	Pensilvania Mayor's Office, UMATA, private enterprise, timber companies, Fundacion Dario Mayo	Integrate private enterprise and the financing of the countryside - Part of the package of activities to capture resources for carbon sequestration	200 heifers produced, beneficiaries selected, planting of *arachis pintoi* initiated
Production of *mora* in Pensilvania	Colombia	Postobon, Alpina, Pensilvania Mayor's Office, Fundacion Dario Mayo, Federacion Cafeteros, UMATA	Integrate enterprises, local government, and local impresarios in support of alleviating critical poverty - Part of the package of activities to capture resources for carbon sequestration	Committee conformed, stakes produced for 100 ha, contracts made with commercial companies, 200 families surveyed, beneficiaries selected. Alternatives designed to incorporate the landless.

Table 11. continued.

Activity	Country	Collaborators[a]	Policy objective	Stage of development
Renovation of coffee plantations, Pensilvania Municipality	Colombia	Pensilvania Mayor's office, Fundacion Dario Mayo, Federacion Cafeteros, UMATA	Integrate enterprises, local government, and local impresarios in support of alleviating critical poverty - Part of the package of activities to capture resources for carbon sequestration	Proposal written for a CONDESAN study on financing the process and the benefits it should generate. Proposal being studied by the Pensilvania Municipality and the Federacion de Cafeteros
Education of children of Pensilvania Municipality producers	Colombia	Pensilvania Mayor's office, Fundacion Dario Mayo, Federacion Cafeteros, SENA, Technical College of Pensilvania	Integrate enterprises, local government, and local impresarios in support of alleviating critical poverty - Part of the package of activities to capture resources for carbon sequestration	Proposal written for a CONDESAN study on financing the process and the benefits it should generate. Proposal being studied by the Pensilvania Municipality and the Federacion de Cafeteros
Analysis of Paez law	Colombia	Cauca Secretariat of Agriculture	Know and dominate the forms of financing the countryside with government tax discounts. Basic work to design alternative policies.	Final document finished
Analysis of credit system	Colombia	-	Know the distortions for inflation and incidence in cash flows. Basic work to design alternative policies.	Simulation model ready to analyze specific cases. Adaptation to user-friendly form by Tomas Bernet.
San Antonio watershed	Colombia	Fundacion Eduquemos, Caldas University, COLCIENCIAS	Analyze the capture of the incentives generated by the sale of energy.	Final report presented in the Latin American Symposium of Investigation and Extension of Production Systems, Lima. Work selected as one of the best five presented.
Doña Juana watershed	Colombia	CORPOICA, Caldas University, Dorada municipality	Analyze the capture of the incentives generated by new alternatives in natural resource use	Final report presented in the Latin American Symposium of Investigation and Extension of Production Systems, Lima.

Continued.

Table 11. continued.

Activity	Country	Collaborators[a]	Policy objective	Stage of development
Generating employment in the Encañada watershed	Peru	GTZ, Encañada district Mayor's office, Pronamachs, Cajamarca University	Generate new forms of employment for landless agricultural workers	Agreements made with ADEFOR to initiate the programs, population's objective selected, first 100 jobs implemented. Comparison between the population's objective by the complete census method and by the successive approximation method for criteria to be included and excluded.
Pigs and milk project	Colombia	Antioquia University, CORPOICA, UMATA	Estimate environmental cost of contamination of waters by organic waste. Efficiency of applicable estimates.	Final report ready for COLCIENCIAS
Flower study, Rio Angel	Ecuador	Carchi coordinating board	Estimate environmental cost of flower production. Trade-off for policy fixation	Part reported
Potential hydrology, Rio Angel watershed	Ecuador	Angel municipality	Estimate trade-off between productivity and equity in the use of the watershed's water. Optimum moment for intervention.	Final report ready
Production systems in irrigated areas	Ecuador	Angel municipality, Palmira National University	Cost of water vs. efficiency of use	Final report ready
Hydrological balances and sediment flow in the Encanada watershed	Peru	Colombia National University, Palmira and Cajamarca Universities	Improve the approximation of sediment transport in the watersheds	Sediments, hydrology, and flow balances calculated in five micro-watersheds
DSSAT model adjustment for *arachis pintoi*	Colombia	-	Improve decision making for high altitudes where this species has not systematically been planted	Students have begun work in Palmira
Modernization of cattle farming in Colombia	Colombia	CORPOICA	Orient local cattle farming to confront the economic open market	Final report ready

Continued.

Table 11. Continued.

Activity	Country	Collaborators[a]	Policy objective	Stage of development
Capacitation in ex-ante analysis in Central America	Central America	Colombian National University, Caldas University	Capacitate universities and technicians in ex-ante analysis	Final report in process
Radar model to measure elevation, Rio Angel watershed	Ecuador	ECOCIENCIAS, FLACSO	Reduce the duration of georeferencing work in high altitude zones	Final report ready
Survey of systems characterization of production in Rio Angel	Ecuador	FLACSO	Impact of the use of water on the quality of life. Trade-off between use of paramo and productivity of middle and low zones	Final report ready
Model of milk production for Carchi	Ecuador	Wageningen University	Trade-off between productivity, equity, and sustainability to assign policy priorities in the assignation of water	Model in use in Ecuador

a. Acronyms used in Table: FIDAR = ?, CIPASLA = Consorcio Interinstitucional para una Agricultura Sostenible en Laderas, Colombia, GTZ = Deutsche Gesellschaft für Techische Zusammenarbeit, UMATA = ?, SENA = ?, COLCIENCIAS = ?, CORPOICA = Corporacion Colombiana de Investigación Agropecuaria, ADEFOR = Asociación civil para la investigación y Desarrollo Forestal, ECOCIENCIAS = ?, FLACSO = Facultad Latinoamericana de Ciencia

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Workshops and Conferences

1997:

Sept 22-25	Strengths, Weaknesses, Opportunities, and Threats self-analysis Workshop, Montelimar, Nicaragua

1998:

Feb 3-6	PPO workshop for CLODEST, local operating committee for the Tascalapa watershed in Yorito-Sulaco, Honduras. Lago de Yojoa, Cortes.
Feb 9-12	1998 Project Planning Meeting with the Consultative Group, Tegucigalpa, Honduras
Mar 4-6	Workshop on exchanging experiences about sustainable hillsides agriculture in Latin America. COSUDE-INTERCOOPERATION
Apr 20-23	PCCMCA- Nicaragua
June 3-4	Workshop Hillsides Group Central America, Managua, Nicaragua
June 13-17	Methodological instruments workshop, Yorito, Honduras
Aug	Participatory research management (PRM)- Proyecto Regional de Frijol para Centro América, México y el Caribe (PROFRIJOL) planning meeting, Guatemala
Aug 1-5	Methodological instruments workshop, San Dionisio, Nicaragua
Oct 7	Introduction to CD-ROM Electronic Atlas for Honduras, Tegucigalpa, Honduras
Oct 8	REASIG Workshop, Tegucigalpa, Honduras
Oct 9-10	Introductory and Evaluation Workshop for Multiple-Stakeholder DSS, Tegucigalpa, Honduras
Oct 2-30	Methodological instruments workshops, Ticuantepe and Santa Teresa, Nicaragua
Nov 4-7	Methodological instruments workshop, Danlí, Honduras
Nov 10-11	1999 Project Planning Meeting with the Consultative Group, Managua, Nicaragua
Nov 12-13	Annual Project meeting for preparation of 1999 Work Plans

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Journal and Book

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Abbreviations

AOP	annual operative plans
DEM	digital elevation model
DS	decision support
FPR	farmer participatory research
GO	government organization
GPS	global positioning system
IGDSS	interactive group decision-support system
NGO	nongovernment organization
PRM	participatory research management
SQS	soil quality score card
UBN	unsatisfied basic needs
USLE	universal soil loss equation

Acronyms

ACESCO	Acerías de Colombia, S.A.
ADEFOR	Asociación civil para la investigación y Desarrollo Forestal, Peru
ASIAVA	Asociación de Ingenieros Agrónomos del Valle
ASOBESURCA	Asociación de Beneficiarios de la Subcuenca del Río Cabuyal
CARE	Cooperative for American Remittances Everywhere
CDM	Current Decision-making Methodology
CESAC	Centro de Ecología de los Sistemas Acuáticos Continentales, France
CIAL	Comité de Investigación Agricola Local
CIESIN	Consortium for International Earth Science Information Network
CIMMYT	Centro Internacional de Mejoramiento de Maize y Trigo, Mexico
CIP	Centro Internacional de la Papa, Peru
CIPASLA	Consorcio Interinstitucional para una Agricultura Sostenible en Laderas, Colombia
CLODEST	Comité Local para el Desarrollo Sostenible de la Cuenca del río Tascalapa
COHDEFOR	Corporación para el Desarrollo Sostenible de la Región Ucayali, Peru
COLCIENCIAS	(Estrada table)
CONDESAN	Consorcio para el Desarrollo Sostenible de la Ecorregión Andina
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
COSUDE	Cooperación Suiza para el Desarrollo
CURLA	Centro Universitario Regional de Litoral Atlática
CVC	Corporación autónoma regional de Valle del Cauca, Colombia
DICTA	Dirección de Ciencias y Tecnología Agrícola, Honduras
DSS	Decision Support System
EAP	Escuela Agrícola Panamericana, Honduras
FAO	Food and Agriculture Organization of the United Nations
FEBESURCA	Federación de Beneficiarios de la Subcuenca del río Cabuyal
FHIS	Fondo Hondureño de Inversión Social
FIDAR	Fundación para la Investigación y Desarrollo de la Agricultura Rural
FLACSO	Facultad Latinoamericana de Ciencias Sociales, Ecuador

G/DSS	Group Decision Support System
GIS	Geographic Information Systems
GTZ	Deutsche Gesellschaft für Techische Zusammenarbeit
IDB	Inter-American Development Bank
IDRC	International Development Research Centre, Canada
IFPRI	International Food Policy Research Institute, USA
IHCAFE	Instituto Hondureño de Café
IICA	Instituto Internacional de Cooperación para la Agricultura, Holland
IIMI	International Irrigation Management Institute
INTA	Instituto Nacional de Tecnología Agropecuaria, Nicaragua
ISNAR	International Service for National Agricultural Research, the Netherlands
NARS	National Agricultural Research Systems
NRM	Natural Resource Management
MIP-ZAMORANO	Manejo Integrada de Plagas (at E.A.P., Zamorano, Honduras)
PASOLAC	Programa de Agricultura Sostenible de Laderas en Centro America
PAT	Polygon Attribute Table
PCCMCA	Programa Cooperativo Centroaméricano para el Mejoramiento de Cultivos Alimenticios
PPO	Program Planning by Objectives
PROFRIJOL	Proyecto Regional de Frijol para Centro América, México y el Caribe
P-S-I-R	Pressure-State-Impact-Response framework
RENASIG	Red Nacional de Sistemas de Información Geográfica, Honduras
RRNN	Recursos Naturales
SDC	Swiss Development Corporation
SECPLAN	Secretaria de Planificación Coordinación y Presupuesto, Honduras
SENA	Servicio Nacional de Aprendizaje
UGA	University of Georgia, Atlanta
UMATA	Unidad Municipal de Asistencia Técnica Agropecuaria
UNA	Universidad Nacional Agraria, Nicaragua
UNDP	United Nations Development Program
USGS	United States Geological Survey