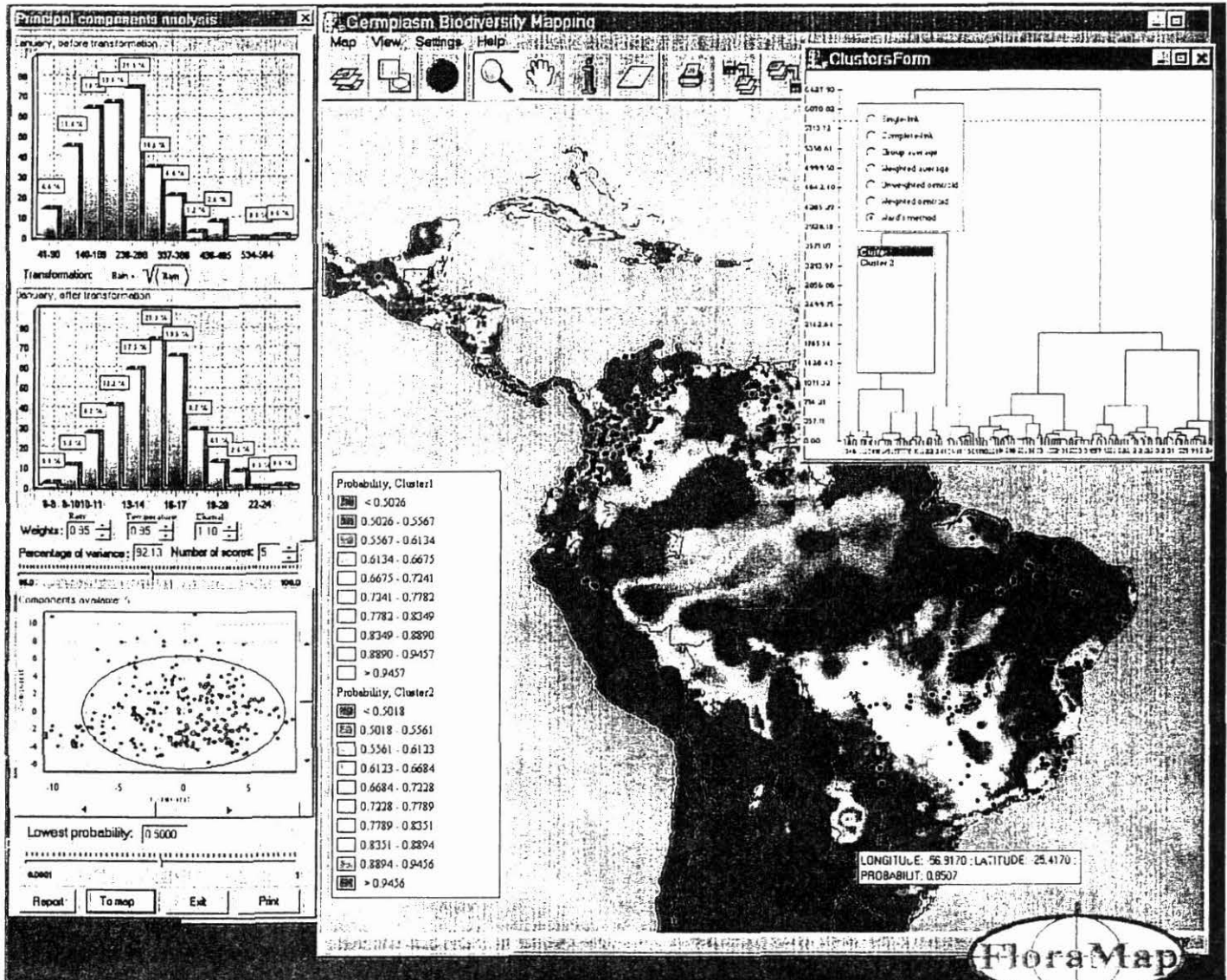


PE-4: Land Use Studies: Reconciling the Dynamics of Agriculture with the Environment

ANNUAL REPORT 1998



Centro Internacional de Agricultura Tropical (CIAT)
Cali, Colombia
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Cover Illustration.

A screen capture of a stage in an analysis of the distribution of *Stylosanthes guianensis* accessions using the **FloraMap** system. At the left side of the screen we see a typical histogram of monthly rainfall data for the calibration set. Under that is the histogram of the data after transformation. A scatter diagram of the first and second principal components is at the lower left. Upper right we see a cluster analysis of the climatic data. The map shows the estimated distributions of the two climate clusters selected in the cluster dendrogram.

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ANNUAL REPORT

1998

PROJECT PE-4

Land Use Studies: Reconciling the Dynamics
of Agriculture with the Environment



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Introduction

CIAT research in land use and sustainable land management continues under project PE-4 in the Natural Resource Management (NRM) division. Our focus is on agroecological studies, land use dynamics, agricultural biodiversity, and the application of geographical information systems (GIS) to NRM.

During the first two months of 1998, we initiated a new process for organizing our work and setting priorities. Planning was oriented towards managing change in accordance with the needs of our stakeholders. Our colleagues in other projects met with us and participated in the planning process. We prioritized our work according to criteria that match our long-range vision and the CIAT mission. As a result of these planning efforts, we have organized our project according to the CIAT benchmark sites and priority agroecosystems, in addition to continental scale work in Latin America, Africa, and Asia.

This annual report and our logical framework matrix are divided into seven thematic outputs. The outputs loosely follow the research and development process. Outputs 1 and 2 involve collecting information, preprocessing data, analyzing environmental limitations and opportunities and developing strategic databases for land use analysis. In these sections of the report, readers will find results of our remote sensing analyses, development of climate, soils and topographic data sets and baseline and time series information on land use and environmental indicators. Outputs 3 and 4 relate to developing frameworks and methodologies for organizing information and carrying out research. In output 5, the frameworks and methods are applied to defining environmental indicators and land use scenarios. Outputs 6 and 7 deal with technology transfer, stakeholder networks, decision-making support tools and scenario building.

We encourage readers to make frequent use of the table of contents and the activity numbers in the headers to locate items of interest. Those readers interested in our work in specific benchmark sites, agroecosystems, or other regions should use the following guide of activity numbers together with the table of contents for locating text relevant to their interests:

Central American Hillside	1.2	2.4	2.5	3.1	3.4	3.5	3.6	4.2	4.5	5.2	5.4	6.3
Tropical Forest Margins	1.2	1.4	2.1	2.2	2.3	2.5	3.3	3.4	3.5	4.2	4.3	5.7
Central America	1.3	3.2	3.4	3.5	5.3	6.2	7.1	7.2	7.3			
Tropical Savannas	1.2	2.1	2.5	3.4	3.5	4.4	5.7	7.4				
Latin America	1.1	1.5	4.1	5.1	5.2	7.3						
Africa	1.5	4.2	7.3									
Asia	2.5											

Annex 2 gives a list of the visitors we have received this year and gives some idea of the interest our work arouses. We also encourage readers of this report to visit our GIS laboratory web page at <http://gis.ciat.cgiar.org> and our Indicators project home page at <http://www.ciat.cgiar.org/indicators>.

Milestones

1. A framework for a conceptual land use model applied and tested in the Pucallpa study area.

The first phase of our land use dynamics research in the Pucallpa benchmark site is coming to a close with the development of a conceptual framework for understanding farming systems in the forest margins. This work developed methods for organizing land use systems research and understanding land management problems. The framework can be applied in areas of the tropics. See section 3.4.

2. A stochastic model of rainfall incorporated into a system for producing input to drive dynamic crop simulation.

Innovative research on rainfall was completed this year and is now being made available to agricultural scientists in Latin America. After many years of research in stochastic rainfall modeling, methods were developed to provide rainfall information for dynamic crop simulations. Beta testing is being carried out and the technology will be available in December on CD for use in Decision Support Systems for Agrotechnology Transfer (DSSAT) and other crop models. See section 1.5.

3. GIS coverages of administrative regions, climate, population, land use, and watershed data produced, documented, and made available for all continental Latin America.

Important advances were made in the development of strategic continental databases for geographic analysis. Our past efforts did not include the Caribbean countries. We now hold updated information on crop production, animal and human population, administrative districts, watersheds, and climate for every country in Latin America and the Caribbean. We have built in database procedures that allow us to update the information as new data become available. These data have been made available to our partners and others through our incorporation in the regional information networks. See section 1.1.

4. A continental network of users and developers of indicators of sustainability in Latin America.

We released our “Atlas de indicadores ambientales y de sustentabilidad para América Latina y el Caribe” in February 1998. Accompanying the release of the Atlas CD, Manuel Winograd appeared on *CNN en Espanol* and was the subject of several news articles. The Atlas CD contains a wealth of information on environment and agriculture in the region. The information is arranged in a framework that allows users to examine alternative scenarios for issues such as deforestation, biological conservation, and agricultural sustainability. The Atlas CD has been distributed to over 320 planners, policy makers, students, academics, and to a network of collaborators throughout the region. A second and improved version will be released in 1999. See sections 6.1 and 6.2.

5. Spatial extrapolation methods and cross-scale modeling.

We developed new methods to determine areas where knowledge gained in CIAT reference sites can be transferred to similar environments. Watershed similarity analysis has been performed from the village level to watersheds to administrative districts. These results will be used in the coming years to transfer CIAT technologies in community management of watersheds to wider areas. New methodological research is being carried out to understand scale dynamics in studies of agriculture and natural resources. Information from the Honduras agricultural and population census has been geographically referenced at the household scale and aggregated upwards to villages, districts, municipalities, and departments. This work aims to match problem dynamics with the appropriate scale of analysis. See sections 1.2.5, 2.4 and 3.6.

6. Human welfare indicators related to agricultural land use for Honduras.

Poverty maps were developed at multiple scales for Honduras and Pucallpa, Peru. We will combine these maps with information from the agricultural census in our efforts to target technologies to the farmers who need them most. See section 5.2.

7. Germplasm Mapping Tool.

The search for wild relatives of modern crops continues in our work to develop tools allowing agricultural scientists to study their germplasm collections in the context of the natural environment. This year we developed a beta test version of Peter Jones' model for predicting areas with climatic similarity to existing germplasm collections. The tool has several uses that include targeting areas for future collection and identifying potentially new populations based on geographic dissimilarity. Already we have conducted case studies for forage germplasm in South and Central America. The work will aid scientists and conservationists in the global effort to find wild relatives of modern crops before they are lost to genetic erosion. See section 7.3.

New Initiatives

The CIAT GIS laboratory became a node of the Interamerican Geospatial Data Network (IGDN) in late 1998. The network is a joint project of the United States Geological Survey (USGS), the United Nations Environment Program (UNEP), and the Pan American Institute of Geography and History (PAIGH). It aims to promote the use of geographic information for research and development in the Americas. IGDN comprises some of the top GIS laboratories in the region. As part of the IGDN implementation process we made important advances in the way we manage geographic information. We are providing metadata (data about data) for all the geographic information that we produce. We implemented internationally recognized standards for accuracy and precision in our digital maps and imagery. All these activities strengthen the scientific quality of the GIS laboratory.

CIAT research directors approved a collaborative project with Peru's Instituto Nacional de Estadística e Informática (INEI) to study human welfare, natural resources and the agricultural sector in the forest margins benchmark site in Pucallpa, Peru. The research team will analyze agricultural census information for over 5000 households in 275 communities in the Aguaytia watershed. This research will focus on mapping human welfare indicators and understanding the factors that lead to the successes and failures of farming enterprises. See section 4.3. and 5.2.

This year we joined a Joint Research Center of the European Commission international study of forest change in the tropics. The "TREES" project is one of only two projects that monitor forest changes in the tropics on a global scale. The CIAT GIS laboratory will have the responsibility for analyzing forest change in 13 sites in Colombia, Ecuador, and Peru. The project compiles results from remote sensing specialists throughout the tropics to study the magnitude and extent of land use changes over the past decade. A future phase of the project will look at the forces behind these changes and will make recommendations for global scale action for forest conservation.

In August, the International Development Research Centre's (IDRC's) Ecosystem Approaches to Human Health (ECOHEALTH) program accepted our proposal "Health, biodiversity, and natural resource use in the western Amazon lowlands: an integrated systems approach." A review panel of five experts (two external to IDRC) was unanimous in recommending we receive one of the two grants being funded at the present time.

The World Bank is providing new funds for continuing work on environmental indicators for agricultural sustainability. This work will apply the same methodologies as in the Latin American CD published this year, but will focus on the Central American region. See sections 6.1 and 6.2.

The World Bank Information for Development (*InfoDev*) program approved a new PE-4 project to transfer information technologies related to agricultural research and development to national programs in Central America. The program focuses on the development of data products for improved analysis and use of agricultural information. Two workshops on the application of GIS in the agricultural sector will be held in 1999. A network of agricultural data providers will be created for Central America. See section 7.2.

During the 1997 Midterm Meeting in Brasilia, Grant Scobie led a group of Director Generals (DGs) and Deputy Director Generals (DDGs) of the Consultative Group on International Agricultural Research (CGIAR) in creating the Consortium for Spatial Information (CSI). The consortium grew out of our collaboration with UNEP-Arendal's "Initiative on the Use of GIS in Agricultural Research". CIAT will play a lead role in the development of this new phase of inter-center collaboration. Consortium participants will work on a broad variety of issues on the application of GIS to crop improvement, germplasm analysis, land degradation, human welfare, and technology transfer. PE-4 scientists will play key roles in the future of the consortium and the development of GIS technologies for agricultural research.

Project PE-4: Land Use Studies: Reconciling the Dynamics of Agriculture with the Environment

Project Overview

Objective: To improve policy and decision making for sustainable land and environmental management in Latin America through the scientific analysis of land and environmental patterns, anticipated dynamics, and policy indicators.

Outputs: Environmental opportunities and constraints identified and assessed. Land use patterns and their spatial distribution classified, and correlated with environmental and socioeconomic data. Determinants, dynamics, and impacts of land use in Latin America characterized and strategic options assessed. Environmental policy and sustainability indicators defined and reported.

Gains: Detailed georeferenced databases on land use, ecological, and socioeconomic factors. Environmental and sustainability indicators of land use, networking on the environment, land use, sustainable agriculture, and indicators. Verified scenario-assessment tools. A blend of theoretical, methodological, and field-based inquiry for decisions on sustainable agriculture and agroecosystem health.

Milestones:

- 1998 A framework for a conceptual land-use model applied and tested in the Pucallpa study area. A stochastic model of rainfall incorporated into a system for producing input to drive dynamic crop simulations. GIS coverages of administrative regions, climate, population, land use, and watershed data produced, documented, and made available for all continental Latin America. A continental network of users and developers of indicators of sustainability in Latin America. Spatial extrapolation methods and cross-scale modeling for Honduras. Human welfare indicators related to agricultural land use for Honduras. A CD-ROM based tool for mapping climate similarity of germplasm accessions.
- 1999 A stochastic land-use model developed for at least one of the study areas. Sustainability indicator systems applied in Central America and within Colombia in the Orinoquia region. First regional report on environmental and sustainability indicators published. A new version of stochastic rainfall model distributed to crop modelers in the tropics. Soil and land databases in the four benchmark watersheds developed with land use and soil risk and constraint maps. A report on the optimum scales for agriculture and land use analysis in Honduras. A Land Use laboratory developed in Pucallpa benchmark site. Full analyses and report on rural poverty and agricultural land use developed for CIAT Web page.
- 2000 A published assessment of alternatives for the restoration of degraded lands in at least one study area. A publication on the use of land-use models in assessing land-use scenarios and policy options. Database and sustainability indicators finalized for Central America. Land use scenarios identified and characterized in the context of environmental sustainability in Colombia. Scenarios identified and characterized in the context of environmental sustainability. A network of agricultural information providers with improved use of information in Central America.

CGIAR system linkages: Protecting the Environment (60%); Policies (20%); Breeding (10%); Biodiversity (10%). Contributes to the Tropical America Ecoregional Program.

CIAT project linkages: GIS studies assist SB-1, SB-2, IP-1, and PE-2; model development with PE-3, PE-5, and BP-1.

Project PE-4: Land Use Studies: Reconciling the Dynamics of Agriculture with the Environment

Project Objective

To improve policy and decision making for sustainable land and environmental management in Latin America through the scientific analysis of land and environmental patterns, anticipated dynamics, and policy indicators

Output 1	Output 2	Output 3	Output 4	Output 5	Output 6	Output 7
Baseline and time series information on CIAT priority for the analysis of land use and environmental patterns and dynamics	Analysis of limitations and potential of land use in the hillsides, savannas and forest margins ecosystems	Frameworks for analyzing land use dynamics and for using indicators of sustainability in the CIAT priority agroecosystems	Developed and defined policy-relevant environmental and sustainable indicators	Analyses, scenarios, and options for sustainable land use in Latin America in general and in the CIAT priority agroecosystems	Stakeholder networks at multiple scales within the CIAT priority agroecosystems for dialogue about land use options and scenarios	Trained professionals in the use of Decision Support tools and scenario building methods
<p>Updated strategic databases for Latin America, including administrative divisions, population, and animal and crop production</p> <p>Natural Resource Mapping of land use changes and trends in the CIAT benchmark sites: savannas, Hillsides, Forest Margins, and High des</p> <p>Baseline information on spatial models, indicators, and maps for Central America</p> <p>Analysis of issues related to population and land use dynamics at the regional level in Pucallpa-Ucayali</p> <p>A stochastic model of rainfall incorporated into a system for producing output to drive dynamic crop simulations</p>	<p>2.1 Land use options for the Colombian portions of the Orinoco and Amazon basins; constraint set for each of these options in function of climate, soils, elevation, and disease</p> <p>2.2 Analysis of agroecosystems issues in Pucallpa-Ucayali region and subregion</p> <p>2.3 Stakeholder analysis of Pucallpa-Ucayali</p> <p>2.4 Spatial extrapolation methods developed for Honduras</p> <p>2.5 Risk and constraint analysis of soil degradation problems in the CIAT agroecosystems</p> <p>2.6 Improvement of agricultural systems, northern Cauca</p>	<p>3.1 Framework and interfaces for community watershed management in the Hillsides benchmark sites</p> <p>3.2 Defined and harmonized conceptual framework for sustainability indicators in Central America. Indicator sets for rural sustainability in Central America</p> <p>3.3 Integrated conceptual framework for research in sustainable agroecosystems applied to Pucallpa-Ucayali</p> <p>3.4 New tools and methods to analyze cause-effect relationships of land use changes</p> <p>3.5 Indicator sets for rural sustainability in CIAT's agroecosystems and benchmark sites</p> <p>3.6 Multiscale modeling methodology for analyzing land use and</p>	<p>4.1 Environmental and Sustainability Indicators CD-ROM</p> <p>4.2 Biodiversity quantified and mapped at local, national, and regional scales</p> <p>4.3 Geographical, socioeconomic, and environmental data for rural development indicators, poverty, and biodiversity-Pucallpa-Ucayali</p> <p>4.4 Soil quality indicator maps showing agricultural constraints in Colombian study</p>	<p>5.1 Integrated pest management and GIS: spatial analysis of the white fly problem in Latin America</p> <p>5.2 Regional, National, and Local Poverty Assessments for Latin America, Honduras, and benchmark sites</p> <p>5.3 Indicator set for Water Resources in Central America</p> <p>5.4 Indicators of Environmental Sustainability: watershed state, and national case study for Tascalpa, Yoro, Honduras</p> <p>5.5 Analysis of land use scenarios for the Colombian portions of the Orinoco and Amazon basins</p>	<p>6.1 Survey regional and national users and databases in Central America</p> <p>6.2 Consolidate a regional network in Central America</p> <p>6.3 Biophysical and socioeconomic database on CD-ROM distributed with user-friendly interface</p>	<p>7.1 Training and Capacity building for Latin American countries and institutions, courses, workshops, etc.</p> <p>7.2 Information products for the agricultural Natural Resource Management sector: InfoDev project for Central America</p> <p>7.3 Germplasm mapping tool, with case studies for forage legumes in Central America and Arachis pintoi in South America</p> <p>7.4 Colombian government and National Agricultural Research Systems personnel trained in the use of developed DSS-options/constraints analysis, scenario analysis</p>

Narrative summary		Verifiable indicators	Means of verification	Important assumptions
GOAL	To improve the management of land resources in Latin America in a sustainable way, and to protect and enhance the environmental base for development	Changes in policy and planning at different levels attributable to the project	Consultation and documented cases	Scientific results will be taken into account by policy and decision makers; political will for environmentally sustainable development exists; distorting macroeconomic pressures do not dominate
PURPOSE	To improve policy- and decision-making for sustainable land and environmental management in Latin America through the scientific analysis of land and environmental patterns, anticipated dynamics, and policy indicators	Number and importance of instances of use of generated understanding by decision makers at various levels	Consultation and documented responses	
OUTPUT 1	Baseline and time series information on CIAT priority agroecosystems for the analysis of land use and environmental patterns and dynamics	New versions of climate, population, crop, and livestock distribution and other strategic databases 1998; documented databases on Interamerican Geospatial Data Network node in CIAT 1998; rainfall model beta tested (1998) and distributed to crop modelers in the tropics (1999).	Information on CIAT WWW site. Annual report. Information available on CD-ROM	Continued collaboration with universities, UNEP, IGDN, and our partners in the benchmark sites
	1.1 Updated strategic databases for Latin America, including administrative divisions, population, and animal and crop production	<i>New versions of digital databases developed, Latin America Population map integrated into UNEP-GRID global database</i>	<i>Information on Web, Annual Report, UNEP-GRID website addition</i>	Data collection trip to Caribbean carried out as planned, UNEP collaborates as planned
	1.2 Natural Resources Mapping of land use changes and trends in the CIAT benchmark sites: Savannas, Hillsides, Forest Margins, and High Andes agroecosystems	Images classified, maps produced, studies of changes and trends 1999	Maps in CIAT database and on World Wide Web, Annual Report	Radar images made available by our partners, purchase of RESURS images, availability of complementary data

PE-4 Logframe. Continued.

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 1 Continued	1.3 Baseline information for spatial models, indicators, and maps for Central America	Database and sustainability indicators finalized for Central America 2000	Compact Disk 1999	Data availability and cooperation with partner institutions
	1.4 Analysis of issues related to population and land use dynamics at the regional level in Pucallpa-Ucayali	Information gathered, analysis completed 1999	Conceptual framework document	Continued collaboration of complex systems research group
	1.5 A stochastic model of rainfall incorporated into a system for producing input to drive dynamic crop simulations	Data analyzed, model completed 1998	Compact Disk 1998	Data availability, continued collaboration with P. Jones
OUTPUT 2	Analysis of limitations and potential of land use in the hillsides, savannas, and forest margins agroecosystems	Information gathered and analyses completed; key variables indicating potential land use analyzed and mapped for three CIAT priority agroecosystems	Annual Report, CIAT report to Colombian government, Working Documents, field verification, student intern reports, land use plans	Sustained funding from Colombian government, continued collaboration with CIAT soils group, University of Guelph, and others in complex systems group
	2.1 Land use options for the Colombian portions of the Orinoco and Amazon basins; constraint set for each of these options in function of climate, soils, elevation, and disease	Information gathered, analysis completed 1999	Annual Report, CIAT report to Colombian government, land use plans.	Funding from Colombian government sustained
	2.2 Analysis of agroecosystem issues in Pucallpa-Ucayali region and subregion	Information gathered, analysis completed 1999	Working documents	Continued collaboration of complex systems research group
	2.3 Stakeholder analysis of Pucallpa-Ucayali	Information gathered, analysis completed 1999	Working documents	Continued collaboration of complex systems research group
	2.4 Spatial Extrapolation methods developed for Honduras	Methodology for quantifying site similarity developed 1998	Field verification of sites identified as similar	Data availability

Continued

PE-4 Logframe. Continued.

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 2 Continued	2.5 Risk and constraint analysis of soil degradation problems in the CIAT agroecosystems	Databases in the four benchmark watersheds developed; risk and constraint maps made; recommendations developed 1999	Student intern reports, Annual Report	Students complete internships as planned, continued collaboration with Soils group (PE-2)
	2.6 Improvement of agricultural systems, northern Cauca	Farmer participatory field trials for rice, beans, cassava and forrages	Reports by farmer participants	Continued local community interest
OUTPUT 3	Frameworks for analyzing land use dynamics and for using indicators of sustainability in the CIAT priority agroecosystems	Indicator sets and frameworks developed in consultation with our partners and stakeholders; data interfaces developed for analyzing indicators of sustainability	Beta version Compact Disk for CIAT priority agroecosystems; new models incorporated in Indicators CD; workshop reports and proceedings, peer reviewed papers	Continuation of the planned collaboration with CIAT researchers working in benchmark sites, data availability; collaboration with NARS as planned
	3.1 Framework and interfaces for community watershed management in the Hillside benchmark sites	Data processed and interfaces developed 1999	Beta Compact Disk developed, field test Decision Support Systems	Continued collaboration from Hillside group, postdoc hired, UGA input delivered as planned
	3.2 Defined and harmonized conceptual framework for sustainability indicators in Central America. Indicator sets for rural sustainability in Central America.	Indicator set defined 1999	Workshop Proceedings and Trip Report to Central American countries and institutions	Workshop participation and cooperation by partners in Central America
	3.3 Integrated conceptual framework for research in sustainable agroecosystems applied to Pucallpa-Ucayali	<i>Meetings and communication for development of the conceptual framework 1998</i>	Conceptual framework document	Continued collaboration with Canadian scientists, travel for ER to Canada
	3.4 New tools and methods to analyze cause-effect relationships of land use changes	Spatial models defined and models developed 2000	Trip Report (AF), Models integrated into Compact Disk	Data availability, cooperation, and agreement with partner institutions
	3.5 Indicator sets for rural sustainability in CIAT's agroecosystems and benchmark sites	Indicator set defined 1999; Beta version 2000	Beta version Compact Disk for each agroecosystem	Collaboration and participation from CIAT's agroecosystem projects, time and personnel availability, data availability
	3.6 Multiscale modeling methodology for analyzing land use and agricultural dynamics	Methodologies developed 1998; Optimum scales identified for the Honduras work 1999	Workshop reports and peer reviewed papers	Postdoc and JRF hired

PE-4 Logframe. Continued.

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 4	Developed and defined policy relevant environmental and sustainable indicators	Continental Indicators CD release (1998) with 300 users, New and Improved version (1999); Beta version biodiversity toolbox 1999, new release 2000; Data dictionary (1998) for Pucallpa indicators, GIS lab developed in Pucallpa; Honduras workshop to define indicators	Latin American CD and manual; Data dictionary report, CIAT report to the government of Colombia; Reports on CIAT WWW page, workshop proceedings, peer reviewed papers	Continued collaboration with universities, UNEP, ICRAF, IPGRI, CIFOR, and our partners in the benchmark sites; external funding for Pucallpa Land Use Laboratory, relationships discovered that permit broad scale extrapolation
	4.1 Environmental and Sustainability Indicators CD-ROM	1998 version and update version of CD for Latin America 1999	Release of compact disk	UNEP funds available
	4.2 Biodiversity quantified and mapped at local, national, and regional scales	Methodology developed 1998; beta version toolbox developed 1999	Peer reviewed paper	Continued interest by partners and participants
	4.3 Geographical, socioeconomic, and environmental data for rural development indicators, poverty, and biodiversity Pucallpa-Ucayali	Data dictionary developed and database installed at Pucallpa field office 1998; Land Use Laboratory in place 1999	Data dictionary with report put on CIAT intranet web page and posted to CGIAR-Pucallpa list	Continued collaboration with INEI, ICRAF, IPGRI, and CIFOR; external funding for Land Use Laboratory proposal approved
	4.4 Soil quality indicator maps showing agricultural constraints in Colombian study sites	Extrapolation of information obtained in the field to broad-scale 1999	CIAT reports to Colombian government and Annual Reports, peer reviewed paper	Relationships are found between field-based indicators and broad-scale environmental conditions that allow extrapolation of field data
	4.5 Human welfare indicators related to agricultural land use for Honduras	Indicator set defined and obtained, poverty-natural resource relationship analyzed, crop risk mapped, DSS prototype, extrapolation methods completed 1999	Internet access, scientific publications, field verification, workshop with poverty experts in Honduras	Climate surfaces and software are available

Continued

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 5	Analyses, scenarios, and options for sustainable land use in Latin America in general and in the CIAT priority agroecosystems	Indicators product developed (2000), full analyses reporting of rural poverty and the agricultural land use developed for CIAT Web page (1999), scenarios identified and developed	CIAT poverty Intranet page; interpretive maps; CIAT report to Colombian government; Annual Report	Data availability, continued collaboration with poverty experts, indicators stakeholders, collaboration from national programs
	5.1 Integrated Pest Management and GIS: spatial analysis of the white fly problem in Latin America	Problem areas identified and interface for visualization developed 1998, statistical analysis performed, virus distribution, environmental conditions, and crops mapped 1999.	Correlation between pathogen and environmental/crop systems that affects vector dynamics. Adoption of suitable control measures.	Climate surfaces available, model for mapping crops complete
	5.2 Regional, National, and Local Poverty Assessments for Latin America, Honduras, and benchmark sites	CIAT internet page developed 1998, subnational problem addressed, country by country assessment of rural poverty related to agriculture 1999	CIAT Poverty Internet Page, maps printed, Proceedings of Norway poverty workshop	Continued collaboration with poverty experts, data availability
	5.3 Indicator set for Water Resources in Central America	Development of Indicators product	Indicator Set Product	Collaboration and participation from CIAT's PE-3, JRF hired for project, data availability, partner participation
	5.4 Indicators of Environmental Sustainability: watershed, state and national case study for Tascalapa, Yoro, Honduras	Development of Indicators product	Indicator Set Product	Collaboration and participation from CIAT's PE-3, JRF hired for project, data availability, partner participation
	5.5 Analysis of land use scenarios for the Colombian areas of the Orinoco and Amazon basins	Scenarios identified and characterized in the context of environmental sustainability 2000	CIAT report to Colombian government and Annual Reports	Sustained funding from Colombian government, collaboration from national programs
OUTPUT 6	Stakeholder networks at multiple scales within the CIAT priority agroecosystems for dialogue about land use options and scenarios	Agricultural and NRM professionals attending workshops in Central America	Beta Compact Disk developed, Workshop proceedings, activities with institutions, web page traffic	Participation and cooperation of partners

Continued

PE-4 Logframe. Continued.

	Narrative summary	Verifiable indicators	Means of verification	Important assumptions
OUTPUT 6 continued	6.1 Survey regional and national users and databases in Central America	Workshops planned and completed for 1998, Network established, visits to region	Proceedings of workshop trip reportss	Participation and cooperation of partners
	6.2 Consolidate Regional Network in Central America	Workshops planned and completed, Network established, visits to region 1998	Proceedings of workshop, trip reports	Participation and cooperation of partners
	6.3 Biophysical and socioeconomic databases on CD-ROM distributed with user-friendly interface	Data preprocessed	Beta Compact Disk developed	Continued collaboration with Hillsides, Postdoc hired
OUTPUT 7:	Trained professionals in the use of Decision Support tools and scenario building methods	Indicators technology, X NRM professionals trained in Central America; GIS-NRM-AG-based information product development training (18 persons in Central America); germplasm mapping tool tested, refined, and distributed to national programs in Africa and Latin America; training workshops in Colombia	Training workshop proceedings; DS toolbox, training materials, web pages	Funding obtained, NARS collaboration, software licensing for germplasm tool worked out, training manuals and tutorials
	7.1 Training and capacity building for Latin American countries and institutions, courses, workshops etc.	Training workshop, seminar, and courses held at CIAT	Proceedings of workshop and training materials	Funding source identified and funding obtained
	7.2 Information products for the agricultural NRM sector: <i>InfoDev</i> project for Central America and the Caribbean	Workshops planned for Network established 1998; workshop held in 1999; workshops and products 2000	CIAT Web page showing project plan, trip reports	World Bank gives final approval and finances the project, NARS collaboration
	7.3 Develop germplasm mapping tool, with case studies for forage legumes in Central America, <i>Arachis pinto</i> in South America	Beta version interface developed and case study carried out 1998; final version 1999	Beta version Compact Disk with user manual for partners	MapObjects licensing worked out, continued collaboration with P. Jones and CIAT germplasm specialists
	7.4 Colombian government and NARS personnel trained in the use of developed DSS options/ constraints analysis, scenario analysis	Workshops held 2000	Proceedings of workshops, tutorial training materials	Sustained funding from Colombian government

Main Research Highlights 1997-98

OUTPUT 1. Baseline and time series information on CIAT priority agroecosystems for the analysis of land use and environmental patterns and dynamics

- Updated datasets are now available at the continental level for administrative divisions, population, crops, climate, and hydrography. We have developed a new database for Central America with environmental and socioeconomic indicators. This database holds information that can be input into six categories of land use models.
- Improved remote sensing and spatial analysis methods have been developed and applied to CIAT priority agroecosystems. Methods for recognition of native and improved pastures in Puerto Lopez area using RADARSAT images allow us to focus our field research in three distinct sectors. A 1996 land use map of the Pucallpa site was created from a classification of two adjacent LANDSAT TM images, providing clearer information for decision-makers, planners, and researchers, plus input for land use models. Radar images of the JERS-1 SAR were acquired and georeferenced over the Pucallpa benchmark site, permitting us to choose three sectors for more detailed analysis of vegetation succession in secondary forest. A 1995 forest cover map for Meta Department, Colombia, and the States of Acre and Rondonia, Brazil allow a quick and clear definition on which to base land use assumptions and decisions. We cut time and costs of producing digital orthophotos and DEMs from areal photographs by about a factor of 5.
- The first reliable rainfall model for tropical climates was produced and is available on CD-ROM. The data and model are easy to use for climate risk assessment, crop-modeling, and climate mapping.

OUTPUT 2. Analysis of limitations and potential of land use in the hillsides, savannas, and forest margins agroecosystems

- Analyses of environmental patterns and processes were completed in the Colombian savannas benchmark site. Biomass analysis of gallery forests for Yucao watershed allows us to calculate regional-level changes in carbon stocks under different scenarios of future land use. We assessed the natural dynamics and current uses of gallery forests. Possible threats from land use intensification were identified. Land use analysis in Puerto Lopez municipality will aid future planning of land use change.
- A non-parametric statistical method was developed to determine homologies with benchmark sites, allowing better selection of contrasting sites. Land use limitations and opportunities in our reference sites can be estimated for areas where we lack field work.

OUTPUT 3. Frameworks for analyzing land use dynamics and for using indicators of sustainability in the CIAT priority agroecosystems

- A Group Decision Support System framework and software for community watershed management was developed as a technological tool to facilitate the mutual understanding of perspectives held by different stakeholders.
- An integrated conceptual framework for farming systems analysis provides a process for farmers, researchers, decision-makers, and all involved stakeholders to learn how to increase sustainability in Pucallpa-Ucayali.
- An indicators set and beta version of an information system was developed for Meta Department in the Colombian savannas as a tool to support land use planning.
- A model for interactive exploration of spatial point patterns across geographic scales is now available at our website. The method permits the multiscale characterization of Honduran agroecoeconomic systems for targeting problems, priority areas, and beneficiaries.

OUTPUT 4. Developed and defined policy relevant environmental and sustainable indicators

- Version 1 of the Indicators Atlas CD was distributed to 320 planners, analysts and decision-makers (in particular to Central American countries) and a press conference was held in Washington to promote its use.
- We developed parametric and non-parametric statistical methods for gradient analysis. The methods can be used to predict where we are more likely to find, for example, a hot spot of pests similar to those already detected. The methods can also be used to fine-tune breeding programs by finding the estimated growth response of plants in different areas.
- A method for computing intraspecific diversity based on genetic distances was developed and successfully applied to *Irvingia* distribution in West Africa. The method can be applied to other species and is implemented through an interface on our web site.

OUTPUT 5. Analyses, scenarios, and options for sustainable land use in Latin America in general and in the CIAT priority agroecosystems

- We have developed a user-friendly interface that integrates data of all biophysical and epidemiological information available for the whitefly project. The interface enables end-users to update the database, query areas of interest, and perform site characterization. We developed parametric and non-parametric statistical methods developed for analyzing and mapping presence-absence data of poor spatial accuracy. This work will aid CIAT virologists to characterize critical areas for Integrated Pest Management.
- Indicator sets for Water Resources in Central America were defined for decision-making at the scale of the water sector. Following visits to obtain data and harmonize methodology, we developed general indicator sets at national and local levels in Honduras.
- Several indicators of poverty were derived from unit-level census data, 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. Improved geographic poverty targeting aids decision-makers in prioritizing projects and assigning funds appropriately in Honduras.

OUTPUT 6. Stakeholder networks at multiple scales within the CIAT priority agroecosystems for dialogue about land use options and scenarios

- We visited 50 institutions in Central America (6 regional, 44 national, see Annex 1) to acquire data and to promote the use and preparation of indicators. The network will develop tools for supporting decision and policy making related to land use and quality, and rural development. We updated our Internet homepage to include the new project, to promote networking activities and to disseminate project information.
- The first version of the Honduras atlas CD-ROM has been released and tested in a 1-day workshop with 25 participants. The Atlas CD will be available through a distribution network in December 1998.

OUTPUT 7 Trained professionals in the use of Decision Support tools and scenario-building methods

- New initiatives were launched in Central America for improved relations and intercommunication with other institutions. A series of activities to disseminate and train people in the region was organized around several topics including sustainability indicators, DSS tools, information technology, GIS, and remote sensing. These efforts are aimed at improving decision-making through better use of information.
- The beta version of a user-friendly package for mapping germplasm and biodiversity was developed. The tool has several uses, including targeting areas for future collection and identifying new populations based on geographic dissimilarity. Any user with a CD-ROM reader can access the tool.

Acknowledgements

We would like to acknowledge our many donors and partners who have worked with us during the past year. We would especially like to thank the Environmental Systems Research Institute (ESRI) of Redlands, California and PROSIS S.A. of Bogota, Colombia for their support of our GIS activities.

PE-4 at CIAT currently receives funds for specific projects from the countries and organizations listed below. We gratefully acknowledge their commitment and contributions.

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 DGIS, the Netherlands
 IDRC, Canada
 IDB
 Ministry of Foreign Affairs, France
 ORSTOM, France
 ODIN, Norway
 Swiss Development Cooperation (SDC), Switzerland
 UNEP
 World Bank

Output 1 Baseline and time series information on CIAT priority agroecosystems for the analysis of land use and environmental patterns and dynamics

Activity 1.1 UPDATED STRATEGIC DATABASES FOR LATIN AMERICA, INCLUDING ADMINISTRATIVE DIVISIONS, POPULATION, AND ANIMAL AND CROP PRODUCTION

Activity 1.1.1 GIS Strategic Databases

Contributors: Elizabeth Barona, Silvia Elena Castano, Nathalie Beaulieu, Glenn Hyman, Justine Klass, Grégoire Leclerc, Andy Nelson, Jose Hernan Trejos, German Lema, Victor Soto, Rosalba Lopez, Humberto Becerra, Carlos Nagles, Marisol Calderon, Ligia Garcia, Alexander Cuero, Rafael Hoyos, Manuel Winograd, Otto Madrid, Jorge Cardona, Luz Amira Clavijo.

Highlights

- Updated datasets are available for administrative divisions, population, crops, climate, and hydrography; data are disseminated through the web.
- Data are standardized, quality controlled, checked for integrity and updated daily.

Objective

The objective is to enable easy and efficient retrieval of information and maintain data quality and integrity with proper documentation.

Methods

For many years, CIAT has been working on strategic geographic databases for our research in a wide range of areas, including geographic targeting of germplasm, spatial analysis of pest and disease problems, and analysis of rural sector poverty. We are focusing on Latin America but have also developed geographic information for Africa and Asia. Many CIAT scientists use the information in a wide range of applications. We have made these data available to our clients and partners throughout the world and CIAT scientists and partners can access most of the data from our web site (<http://gis.ciat.cgiar.org>) (Figure 1).

In 1999, our strategic databases will be registered on the CIAT node of the IGDN. We are now testing our system for inclusion in the network. We will become a full Level-I IGDN node by the middle of 1999. For CIAT users of the GIS database, new applications have been developed allowing database searches, review of documentation data, and rapid visualization of the more than 2000 digital maps and 5000 paper maps that we hold. We are closely monitoring data use to

help us improve the information and to assess the impact of these efforts on research and development in agriculture and natural resources.

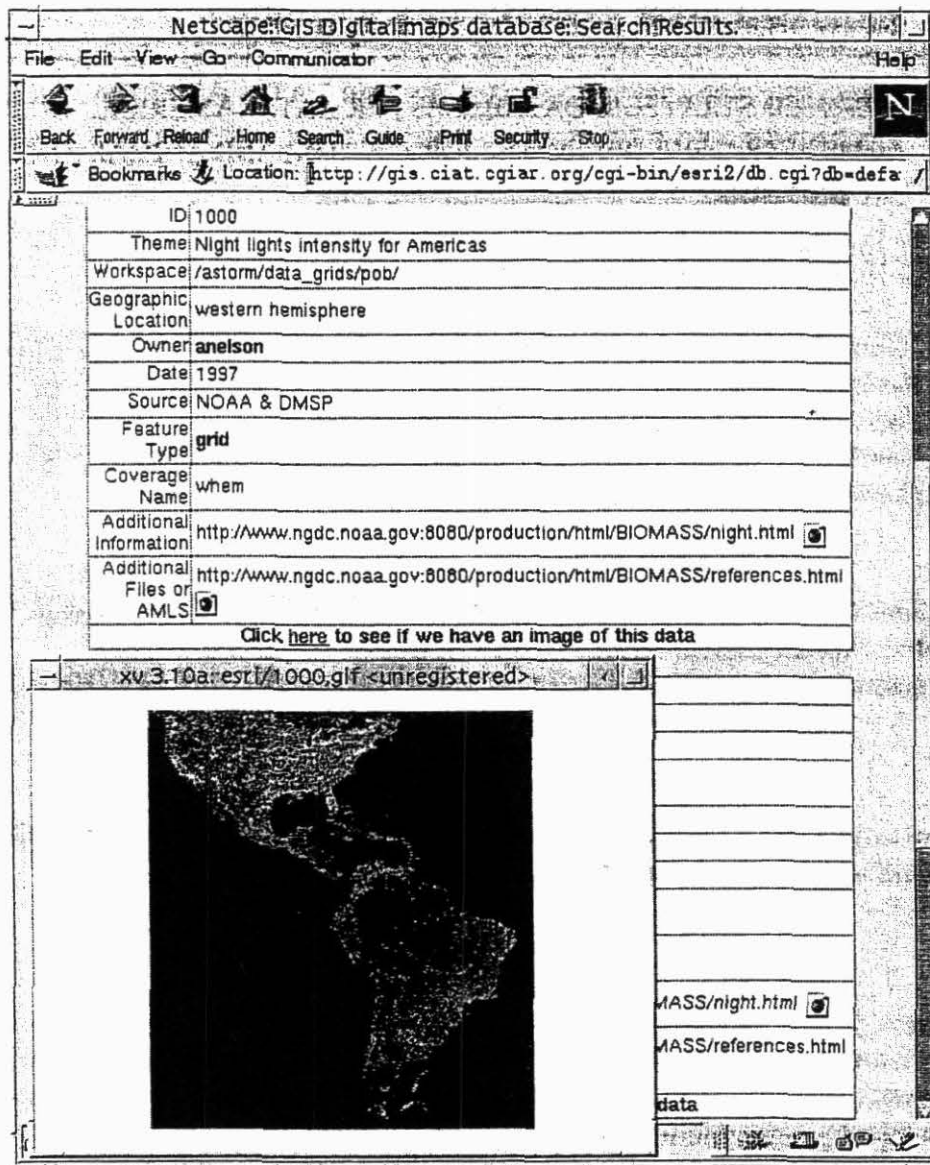


Figure 1. CIAT website for GIS digital maps database (<http://gis.ciat.cgiar.org>).

This year we made a major effort to complete the Third Order Administrative database by incorporating information from the major Caribbean countries. Because of scale considerations we focused on the large islands – Cuba, Dominican Republic, Haiti, Puerto Rico, Jamaica, and Trinidad and Tobago. The database holds subnational boundaries for some of the smaller island nations, but for most of these small countries we only hold the national boundary. A most important feature of this dataset is that it holds the official administrative district codes of each country. Anyone who has government-generated subnational tabular data can link their

information with these maps. The chief advantage of GIS is that once data are geographically referenced to maps, they can be compared to other spatial information in the same reference system.

We began collecting climate information nearly 20 years ago and developed one of the most comprehensive climate databases for the tropics. The information has been available by contacting CIAT and making a simple request. This year we put the data on our website so that users could simply download the information. We changed our information storage process by putting the data in an Oracle database with a user interface allowing quick error checking, correction, and the incorporation of new information as it becomes available. The CIAT climate database has been and will continue to be used for inputs to crop models, agroecological site matching of germplasm, studies of drought risk, and environmental classification.

Hydrographical information has been obtained at the continental scale for Latin America in partnership with UNEP-Mexico and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) International Hydrological Program. We digitized the major watersheds and hydrogeological features, and have obtained digital maps of the major water courses. Our partners will use these databases combined with climate and reservoir information to analyze effects of agriculture on watersheds and the hydrological balance.

We updated our crop database to include the countries of the Caribbean this year. The work is part of continual efforts to study the distribution of production for CIAT focus crops and for any other crops for which we can obtain information. Last year we developed automatic methods to create point distribution maps. Thus, the database and methodology together comprise a digital atlas of crops for the entire Latin American and Caribbean region. Next year we will publish this information in our efforts to aid our clients in their research and development. We are using crop production information for economic studies, germplasm targeting, ex-ante impact assessment, and for many other uses.

In 1997, we began collecting the latest population information for Latin American countries. Subsequent to the start of this effort, scientists from UNEP's Global Resources Information Database (GRID) asked us to develop the Latin American portion of this worldwide population database. This is the last major part of the population dataset at the global scale. Next year the dataset will be officially incorporated into GRID in the form of a raster digital map. The database will be for global modeling of environmental and socioeconomic problems and will be used by many different scientists.

Outputs

Development of environmental and socioeconomic databases is not one of the more visible and exciting parts of our work. However, reliable data are the essential basis for research worldwide. We are committed to providing and maintaining reliable, high quality data to CIAT scientists, clients, and partners.

Activity 1.1.2 Databases to develop indicators and models

Contributors: Manuel Winograd, Marta Aguilar, Jose Hernan Trejos, Silvia Elena Castaño and Glenn Hyman

Highlight

- The updated database for Latin America and the Caribbean is being developed. It will be fully operative in December 1999.

Objective

The development and updating of the database to develop indicators and models for Central America and to update the database for Latin America and the Caribbean (LAC).

Methods

Figure 2 describes how the work on environmental and sustainability indicators is being approached at different levels. Activity 1.1.2 describes the work at regional and subregional levels.

The development and updating of the database is based upon:

- Continual updating and consolidation of the database for indicators prepared in phase I of the project for LAC and databases available in CIAT's land use unit;
- Identifying new sources of data and information to create a database for the new indicators selected for the monitoring of land use, land quality, and rural development in Central America;
- Creating the database for the spatial models of land use in Central America; and
- Developing and testing common methods for analysis, aggregation, and use of databases and information.

National and regional institutions were visited to obtain data and bring into line methodologies and the use of the selected indicators (Aguilar et al 1998). An effective communication with the people and institutions selected to collaborate and test the information was put into practice.

Outputs

The database for Central America based on population and agriculture censuses for two dates (1970s-80s and 1990s) to develop indicator sets is being advanced. It will be operative in December 1998. The updated database for LAC is under development and will be operative in December 1999. Agreements of exchange of information with partner institutions are operative.

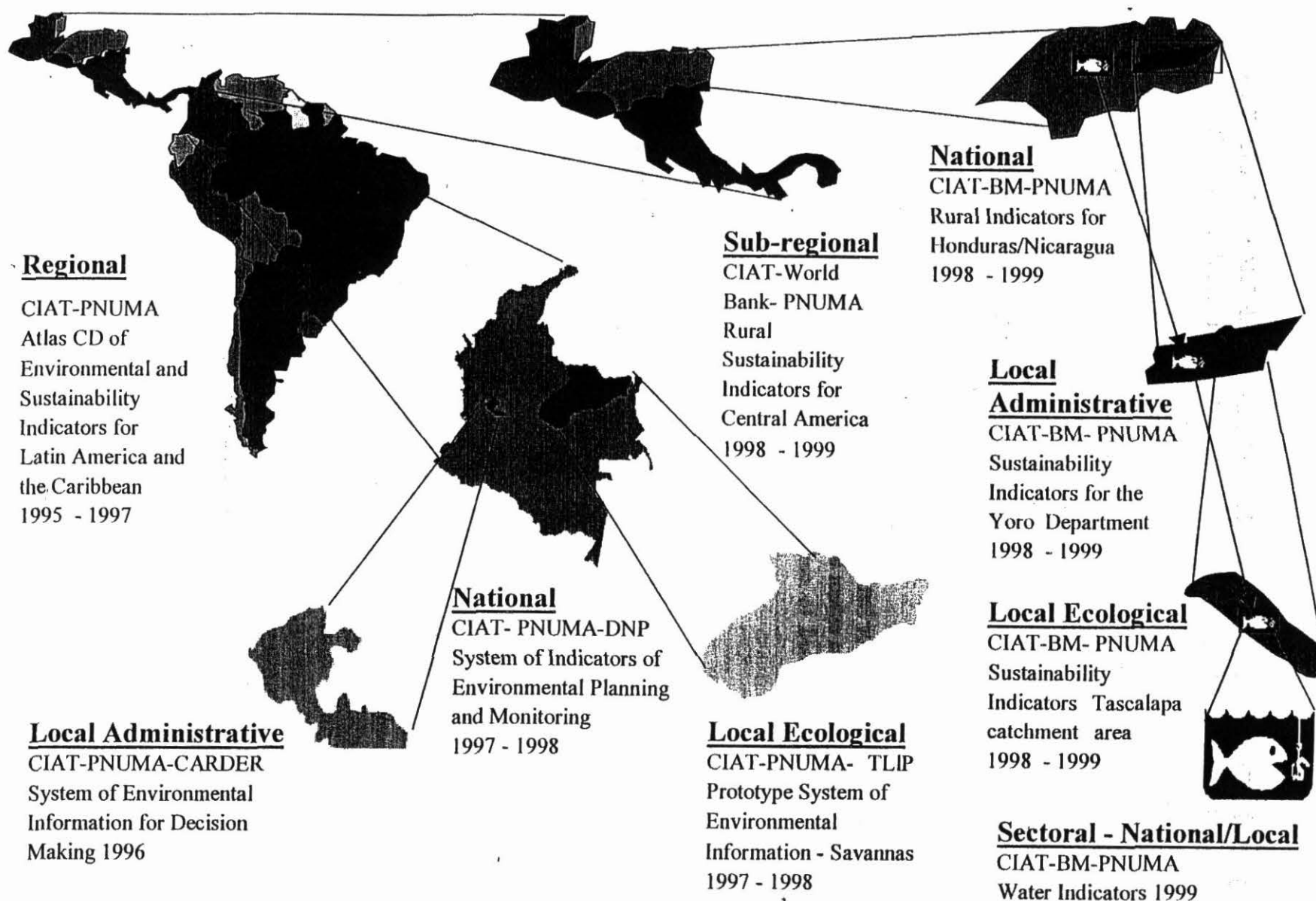


Figure 2: Environmental and sustainability indicators: working at different scales

Activity 1.2 NATURAL RESOURCES MAPPING OF LAND USE CHANGES AND TRENDS IN THE CIAT BENCHMARK SITES: SAVANNAS, HILLSIDES, FOREST MARGINS, AND HIGH ANDES AGROECOSYSTEMS

Activity 1.2.1 Analysis of land-use changes in the Puerto Lopez municipality (1988 – 1996)

Contributors: Nathalie Beaulieu; Ahmed Allam (Matrouh resource monitoring project, International Center for Agricultural Research in the Dry Areas [ICARDA]/Egypt, in training at CIAT), Patrick Hill and Javier Puig

Highlights

- Land use is being classified for January 1988 and January 1996
- We mapped changes in forest extent between the two dates (clearing and regrowth)
- Radar images are being used to complete the missing portion of the 1996 classification caused by a haze cloud

Objective

Our aim is to understand the current tendencies of land use change to help the Puerto Lopez municipality plan future land use changes, and to determine if the area tends to be a carbon source or a carbon sink.

Methods

Images of the LANDSAT-TMs of January 1988 and January 1996 are being analyzed to determine land use changes between the two dates. This work continues that of Crawford (CIAT 1997a). We are classifying the images of both dates on the basis of Crawford's 1996 fieldwork. We are trying to minimize ambiguities between transitional vegetation, improved pasture, and native pasture. By the end of October, we will present estimates of the percentage of conversion from natural to cultivated pastures in the area covered by the image. This area leaves out a small portion of the municipality. Allam (1998) and Beaulieu et al (1998) set out the technical details of the classifications. A haze cloud affected the 1996 image; thus we have to leave out the affected portion in our estimates of land use conversion areas. The land use map of the municipality is being updated and completed using radar images from the Japanese JERS-1 and the Canadian RADARSAT satellites.

At this date, we have completed an analysis of the change in forest cover based on the normalized difference vegetation index (NDVI). This index is calculated, for each pixel, as the difference in the digital number (DN) of bands 3 (red) and 4 (near-infrared), divided by the sum of digital numbers in both bands:

$$NDVI = \frac{DN_3 - DN_4}{DN_3 + DN_4}$$

This index has the advantage of being less sensitive to the presence of haze than is the digital number of each band taken separately.

Thresholds have been established to create binary images of the forest for both dates from the images of the NDVI index. Logical operations of these images allowed the creation of images of forest regrowth and forest clearing between both dates. Unfortunately, a slight decrease of the vegetation index's intensity in the area affected by the haze cloud continues to affect our analysis. The analysis shows significant forest or transitional vegetation regrowth south of the municipality and at its northeast, north of the confluence of the Meta and Upía rivers. It also shows a few rubber and palm plantations.

The new trees and bushes trap carbon in the atmosphere, and carbon sequestration is becoming a potential source of international funding with the current concern for global warming. Conversely, some areas show a decrease in forest cover because some segments at the extremities of streams have completely disappeared. This is extremely detrimental to water quality, stream bank stability, and wildlife. As the Colombian municipalities are planning their development and wish to influence their future land use tendencies, an opportunity exists to emphasize the many roles played by the gallery forest in the savanna ecosystem and to consider alternate burning regimes for natural pastures.

The analysis shows that many more native pasture areas were burned in January 1988 than in January 1996. However, we cannot conclude that burning rates were higher in 1988 because this may simply correspond to the particularly dry conditions of that period. January 1988 was a good month for the acquisition of satellite imagery. During that period, the TM sensor aboard the LANDSAT satellite acquired almost cloud-free coverage of most of the Colombian savannas. Given the fact that no more recent cloud-free images are available, we have purchased the 1988 images necessary to extend our study to the rest of the Colombian savannas. We are coordinating the acquisition of images of the next dry season with the Brazilian Instituto Nacional de Pesquisas Espaciais (INPE), who operate the ground receiving station for our area.

Output

Advances have been made in classifying land use for the Puerto Lopez municipality. When completed, this will help in planning future land use changes

Activity 1.2.2 Native savannas mapped with RADARSAT images for the municipality of Puerto Lopez

Contributors: Nathalie Beaulieu and Patrick Hill

Highlights

- The mapping of native pastures was improved by using RADARSAT images.
- Separate classifications were made of three images not affected by rain.

Objective

Our objective was to produce clearer definitions of land use mapping in the Puerto Lopez area by using RADARSAT images.

Methods

We reported earlier work in this area last year (CIAT 1997b, p 30-32). In addition to the RADARSAT images acquired May 2nd and May 26th 1997, we acquired further images in December 1997 and March 1998. The studied plots were mostly of native and cultivated pastures, the latter being almost exclusively *Brachiaria*. For comparison purposes, we included a few plots of other land uses, such as rubber and pineapple plantations. We also took notes of pasture type for almost 400 extra plots.

Graphs of the average backscattering coefficient (a calibrated measure of radar reflectivity) of plots in function of measured phytomass (dry and moist) showed that phytomass was not the main factor affecting the radar response. Native pasture plots always showed low backscattering values (under -12.5 dB) and a dark tone on the radar images, regardless of phytomass, the height of the vegetation, or ground cover. Most of the improved pasture plots showed greater values, although some of them also presented low backscattering coefficients when the field conditions were very dry, indicating that a certain level of confusion should be expected in classifications made on the basis of this parameter. Heavy rain affected the image acquired on May 26th, and the soil moisture and raindrops on the vegetation made the distinction of native savanna impossible in some areas. We attributed the lower backscatter in native pasture to the lower soil roughness and to plant architecture. Sowing and managing cultivated pastures involves plowing and occasional harrowing, which increases soil roughness and therefore radar backscatter.

Separate "classifications" of the three images unaffected by the rain were conducted on the basis of the backscattering coefficient. The classes defined are water, natural pastures, improved pasture or crops, and gallery forest or plantations. The best result was obtained for the May 2nd image (CIAT 1997b) where the rainy season was well under way but it had not rained in the area for 2 days. Beaulieu et al (1998) give a detailed description of the methodology used in this study. We are presently verifying the classification accuracies on the basis of complementary field data.

Outputs

Using RADARSAT images alone has allowed us to distinguish natural pastures from cultivated or “improved” pastures in moderate to flat topographies. When combined with Landsat TM imagery, they allow a more precise classification of land use. This will help research on land use, planning of land use changes, and the quantitative evaluation of carbon emissions caused by the burning of the savannas.

Activity 1.2.3 LANDSAT TM images of 1996 classified for the Pucallpa benchmark site and Ucayali region

Contributors: Nathalie Beaulieu, Javier Puig, Scott Cecchi and Grégoire Leclerc

Highlights

- Two adjacent 1996 LANDSAT TM images were acquired, georeferenced, and digitally classified.
- A land use map was created from this classification.

Objective

The objective was to obtain a land use map of Pucallpa and the Ucayali region, using the most recently available cloud-free satellite images.

Methods

Two adjacent LANDSAT TM images of 1996 were purchased, georeferenced, and digitally classified to create a land use map. The area covered by this image classification is 37,713 km² and includes the watershed of the Aguaytia River, the area of influence of the Ucayali River on the town of Pucallpa, and most of the area of influence of the Federico Basadre highway. It also includes the smaller Pucallpa benchmark site, which covers 4093 km². Both images were acquired at different dates. The image covering the western portion of the area is from September and that covering the eastern portion is from October. Because of these two different dates, the crop, moisture, and illumination conditions were different in both images. They were therefore classified separately, then the classifications were joined to form the final map. Puig and Beaulieu (1998) give the technical details of this classification.

The approach used was a supervised classification, with almost 200 training sites divided into 19 classes. These training areas were defined on the basis of a field survey conducted in April 1998, using a global positioning system (GPS) receiver to locate sample plots and areas. The African palm plantations presented spectral signatures highly similar to primary forest and the mango plantations were spectrally similar to secondary forests. To avoid confusion, all plantation samples were removed from the training areas. The plantations were located in the field and their extent was mapped through visual interpretation of the images on the screen. Field checking was needed to distinguish plantations from secondary forests. Secondary forests that develop on

abandoned agricultural land often have large regular shapes, as do plantations. In other sites, we have seen crops such as sugar cane and banana confounded with secondary forest. When the image was taken it appears that the sugar cane fields near Pucallpa were in a post-harvest phase, and no other high-chlorophyll crops were present on large enough areas to allow comparison of crop and forest signatures. Secondary forests that are not fully developed can be distinguished from primary forests because they have a higher reflectance in the near-infrared band, because of the higher chlorophyll content of the new leaves of growing trees.

When only the training areas are considered, the overall accuracy of the classification is 85%. We are analyzing the accuracy of the classification based on the verification data acquired in the field in July.

Outputs

A 1996 land use map of the Pucallpa site has been achieved using two adjacent LANDSAT TM images. This provides clearer information for decision-makers, planners, and researchers, and provides input for land use models.

Activity 1.2.4 Multitemporal radar images of the Pucallpa benchmark site have undergone preliminary analysis for mapping forest regrowth in agricultural land

Contributors: Nathalie Beaulieu, Javier Puig, Grégoire Leclerc, and Erik Veneklaas

Highlights

- Images of the JERS-1 SAR were acquired and georeferenced over the Pucallpa benchmark site and three sectors chosen for more detailed analysis to help identify areas of forest regrowth and secondary forest
- The February 1996 image shows extension of high water levels, useful for agricultural planning.

Objective

The objective was to identify sectors for more detailed analysis.

Methods

Full resolution images (with 12.5-m pixel size and 25-m resolution) of the JERS-1 synthetic aperture radar (SAR) were acquired and georeferenced over the Pucallpa benchmark site. Four adjacent images are needed to completely cover the site. A full coverage was acquired for June 1996, but most of the site has been covered with two images, each acquired at different dates. In our georeferenced database, we have images of the southern portion of the site for five dates between August 1994 and June 1996, and for the northern portion of the site for eight dates between August 1994 and April 1997. When these images are combined in a color composite, highly intense color changes appear because of changes in the water level and moisture conditions. When images with apparently similar moisture conditions are compared, some

Because the complete block adjustment is extremely robust, the number of GCPs to be collected in the field is greatly reduced. Basically, one GCP is needed for every three air photos (instead of six GCPs per pair in the past) for maximum precision in elevation. To guarantee the stability of the solution, GCPs have to be well distributed within the area of interest, and a ring of GCPs must be outside the area that defines a polygon that completely encloses it. Fieldwork has therefore been shortened considerably compared with our past experience.

The digital orthomosaic and digital elevation model (DEM) of the Calico River watershed, near Matagalpa, Nicaragua, has been processed using this new methodology. We obtained permission from the Instituto Nicaraguense de Estudios Territoriales (INETER) to use the 1:40,000 scale air photos (80% side overlap) of a 1995 flight by Geographical Air Survey Ltd. These were scanned at 1400 dpi by Land Data Technologies Inc., and delivered to us on CD. The Socet Set software was installed on a Sun UltraSparc 30, dual 250MHz CPU, 128MB RAM, and 13GB of disk. It is equipped with dual monitor, where the stereo monitor is a 21" with NuVision polarimetric filter, which minimizes operator eyestrain. Training in the use of Socet Set from UGA personnel was done through the processing of the Calico River watershed photo-mosaic. Twenty-eight GCPs were amply sufficient for the 26 photo-mosaic to be processed with maximum precision. They were obtained with dual-frequency geodetic GPS receivers, Leica SR300 (maximum precision: 5 mm).

Table 1 shows the amount of work that was required compared to a previous project of similar size (the Tascalapa River watershed, near Yoro, Honduras).

Table 1. Time required (working days) for processing orthophotos.

Work required ^a	Orthophotos		
	Yoro (39 photos) ERDAS Orthomax	San Dionisio (26 photos) LEICA Helava Socet Set	Yoro (39 photos) estimate LEICA Helava Socet Set
GPS planning	10	4	5
GPS survey	40	7	10
Ortho/DEM generation	40	4	5
Mosaic	20		
Total	110	15	21
Time per photo	2.8	0.6	0.5

a. GPS = global positioning system, DEM = digital elevation model.

Outputs

Time and costs have been reduced by about a factor of 5. We are now training a technician in the use of Socet Set, and will soon be in a position to offer the service of photogrammetry to other CIAT projects and to our partners, at low cost and short delivery time.

Activity 1.2.7 SAR processing and DEM generation

Contributors: Grégoire Leclerc, Nathalie Beaulieu, William Bell (IS), Bethlem Rosich (European Space Agency [ESA]), and Jaime Jaramillo (Instituto Geografico Agustin Codazzi [IGAC])

Highlights

- The first images were obtained from processing of raw SAR signal data.
- DEMs were generated using RADARSAT imagery and their accuracy assessed, for the Rio El Angel watershed, Carchi, in Ecuador, and for the Manizales area, in Colombia.

Objective

The general objective is to expand our capacity to use Synthetic Aperture Radar imagery using state-of-the-art software. We believe that in-house processing of raw SAR signal data opens new ways of mapping and DEM generation. We can now generate imagery with custom processing parameters such as number of looks, produce imagery with a resolution superior to the one commercially available, and produce complex imagery and interferograms that can be used for improved mapping and to generate precision DEMs. SAR also has great potential for quick generation of DEMs through interferometry, radargrammetry, or stereo radar (the radar equivalent of photogrammetry). Our objective was to evaluate the precision of automated radargrammetry-derived DEMs in mountainous areas, either absolute or relative, with respect to elevation or slope.

Method

SAR processing is a highly technical field, typically the domain of electrical engineers and physicists. A commercial software package, the Advanced Precision Processor from Atlantis, allows a non-expert to process SAR data, and is now available. With the support of ESA personnel we were quickly able to understand the basics of SAR processing and the meaning of the parameters that come into play. We produced RADARSAT imagery for the Rio El Angel watershed in Carchi, Ecuador, at a pixel spacing of 6.25 m and used it to generate a DEM by radargrammetry.

RADARSAT is the first satellite equipped with a SAR that allows the taking of imagery incident angles specified by the user. If we combine two different viewpoints of the same area, stereo vision is possible (Figure 3) as for a pair of areal photographs. Parallax measurement from a SAR stereo pair allows ground elevation to be estimated, just as with a pair of airphotos, but with the special SAR geometry. Automated parallax measurement can be done through the unsupervised detection of corresponding points in the stereo pair. For a grid of point in the left image, the algorithm does a multi-resolution search maximizing correlation to find the same points in the right image, so we obtain an elevation value for all points for which a match is found. Software such as VECSEL (15-m RMS reported precision) became available in 1997, and at the beginning of 1998, ERDAS (still beta version) and PCI (RSDEM 6.2 and Orthoengine 6.2). We used the first package available commercially, RSDEM release 6.2 from PCI. This software

coloration can be seen in agricultural areas. These colors are caused by higher backscatter in some dates than in others that are caused by changes in agricultural practices or forest regrowth. Three sectors were chosen for detailed analysis where questionnaire surveys will be conducted with farmers to determine the history of the plots.

An image acquired February 9th, 1996 shows the extension of high flooding along the Aguaytia River. The microwave radiation emitted JERS-1's SAR, with its long wavelength (23 cm, L-band), partially penetrates the forest canopy and reaches the flooded ground surface. The flooded forest appears noticeably brighter than the non-flooded forest because it produces double bounces of the radiation on the water surface and tree trunks. This flooding is impossible to map from electro-optical images such as from the SPOT and LANDSAT satellite, because the canopy hides it. A line, delineating the extension of the flooding, has been digitized from visual interpretation of the image. A map showing the radar image and flooding extent was given to the Aguaytia local office of the Peruvian Ministry of Agriculture. The representatives of this office, during their visit to CIAT, have manifested great interest in using this map for their planning of crops to promote with farmers. Some crops such as camu camu grow well in flooded environments.

Outputs

The preliminary analysis of JERS-1 SAR images narrowed the area for detailed analysis to three sectors. This will help identify forest regrowth areas more clearly and will help cost effectiveness in research on the site by demarcating the best areas for studies.

Activity 1.2.5 1995 forest cover mapped from JERS-1 radar images for the southern portion of the Colombian Orinoco basin, the Colombian Amazon, and the States of Acre and Rondonia, Brazil

Contributors: Nathalie Beaulieu, Javier Puig, and Alexander Cuero

Highlights

- The 1995 mosaic of images by JERS-1 SAR was classified.
- Land use was classified for Acre and Rondonia, Brazil.

Objective

The objective was to classify land use in the areas of the Colombian Orinoco basin, Colombian Amazon, and the States of Acre and Rondonia in Brazil to give clearer mapping for easy identification.

Methods

A mosaic of images acquired in October 1995 by the JERS-1 SAR has been created by the Japanese National Space Development Agency (NASDA). This mosaic covers the whole of the Amazonian basin of Brazil, Peru, Ecuador, Colombia, Venezuela, and some surrounding areas. Each pixel is the result of the averaging of 64 pixels of the initial full resolution images. This

averaging provides high radiometric quality with minimal speckle noise. The L-band used by JERS-1 discriminates well between forested land and short vegetation. The mosaic was classified with a combination of digital separation (on the basis of the digital number) and visual interpretation. In the case of Acre and Rondonia, the non-forested land was separated into large holdings in forest context, smallholdings in forest context, large holdings in savannas, savannas with no visible agricultural activity, and water and flooded vegetation.

Validation of the maps will be conducted in collaboration with the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) stations of both states.

Outputs

The mapping of the 1995 forest cover for these areas is of help to researchers and decision-makers in that it gives a quick and clear definition on which to base assumptions and decisions.

Activity 1.2.6 Improved methodology for photogrammetry

Contributors: Grégoire Leclerc, Javier Puig, and William Bell (IS)

Highlight

- Softcopy photogrammetry workstation Helava/Leica was used to produce orthophotos and a DEM for the Rio Calico watershed, Matagalpa, Nicaragua.

Objective

The objective was to improve our capacity to produce high-resolution orthophotos and DEMs from airphotos.

Method

The method we have previously used to produce orthophotos and DEMs was hindered by the performance of the Orthomax package, a relatively low-cost module of the ERDAS image processing software. In effect, air photos were processed two by two, the stereo model being computed for every stereo pair, which needed a large number of ground control points (GCPs). In addition, this approach produced orthophotos and DEMs that had to be mosaicked manually, needing considerable operator time and enormous amounts of disk space. The DEMs produced were of acceptable quality but had holes (no data) in steep terrain. We found that this approach was not a viable option and had to be vastly improved to reduce both the cost and the time to deliver these highly strategic products.

Through the CIAT/University of Georgia (UGA) contract on Decision Support System (DSS) development in the hillsides, we were able to license the best photogrammetry software available at a marginal cost. Socet Set, from Helava/Leica, allows us to process a full block of air photos in one step, produces high quality DEMs, and allows automosaicking with automatic contrast balance. Air photos are always kept in their raw (uncorrected) format until the end product, reducing the disk space needed. GCPs are identified in stereo, which maximizes accuracy.

works in double-monoscopy (i.e., the orbital model is computed for each image separately, the control points being taken in monoscopy). Table 2 describes the study areas and the images available and processed (underlined).

The first step consists of the interior orientation of the stereo pair. Based on vector coverages of the drainage and transportation network, we took about 100 GCPs in each image that were reduced to about 50 while optimizing the orbital model. GCP elevation was extracted from the reference DEM. The resulting planimetric error was about 20-30 m. Then RSDEM was setup to generate DEMs with the best detail (i.e., full resolution images were matched). The total processing time per DEM is about 1 day, depending on the availability of reference vector coverages. The time taken is several orders of magnitude less than traditional methods.

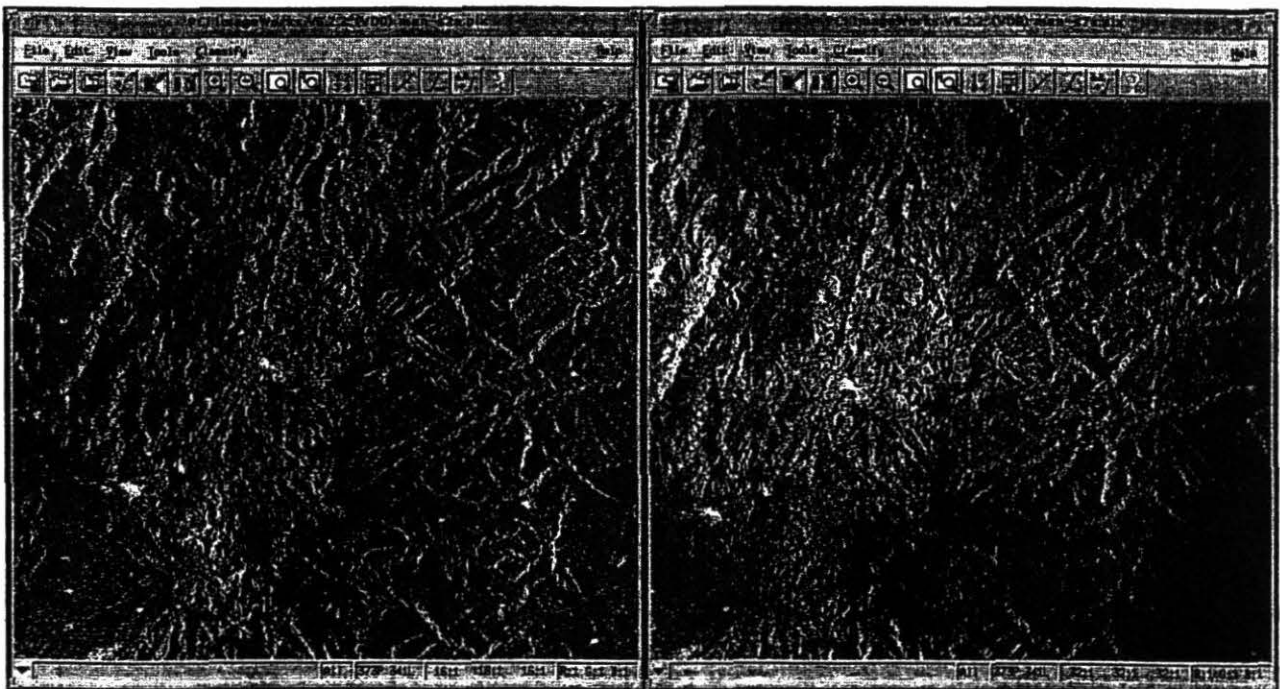


Figure 3. Stereo pairs (S2-S7) used for the Manizales study area.

Finally, we analyzed the effect of various preprocessing factors, such as filtering and the number of GCPs, and some post processing such as polynomial adjustments. The results, summarized in Table 3, are given in full detail in Leclerc et al (1998). The resolution of the resulting DEMs corresponded to a 1:100,000 scale.

Table 2. Images available and processed (underlined) for the two study areas, and description of study areas with information available.

	Study area	
	Rio Angel, Carchi, Ecuador	Manizales, Colombia
Description:		
Land use	Paramo, vegetable crops, pasture, degraded land, irrigated crops	Coffee, forest patches, pasture, paramo, rocks, and snow
Topography	Strong elevation gradient N-S, rolling on the upper part, volcanoes, steep slopes on the lower part	Steep slopes, rugged, strong elevation gradient
Reference info	Topographic maps 1:25,000 scale digitized. DEM based on contour lines every 25 m	Topographic maps 1:25,000 scale, DEM based on contours every 100 m
RADARSAT images	<u>F1</u> and <u>F4</u> ascending, <u>F1</u> descending, Path image plus (3.25-m pixel size) and processed with APP (6.25-m pixel size)	<u>F2</u> , <u>F5</u> , <u>S2</u> , <u>S4</u> , <u>S7</u> ascending, path image (12.5-m pixel size)

Table 3. Summary of results.

Characteristic	Rio el Angel, Ecuador	Manizales, Colombia
Stereo pair	F1-F4	S2-S7
Mean error (m)	15-51	-5.5-10.1
Standard deviation (m)	47-110	82-164
Half-height width (m)	70-120	130-182
Pixel size (m)	3.25-9.75	12.5
Number of looks	1-14	4
DEM pixel size (m)	9.75-39	50

Figure 4 shows the reference DEM and radargrammetry-derived DEM for the two study sites.

If few GCPs are available, we do not see any practical interest in using RSDEM (in its current release form) for DEM generation. In the case of SAR, double monoscopy is highly error prone, and we have to go for a more robust setup. OrthoEngine 6.2, a package just released from PCI, will be tested shortly. Preliminary results have shown a drastic improvement over RSDEM. We believe that this method is very attractive if DEMs are needed quickly, or for areas where topographic information is non-existent or of doubtful quality.

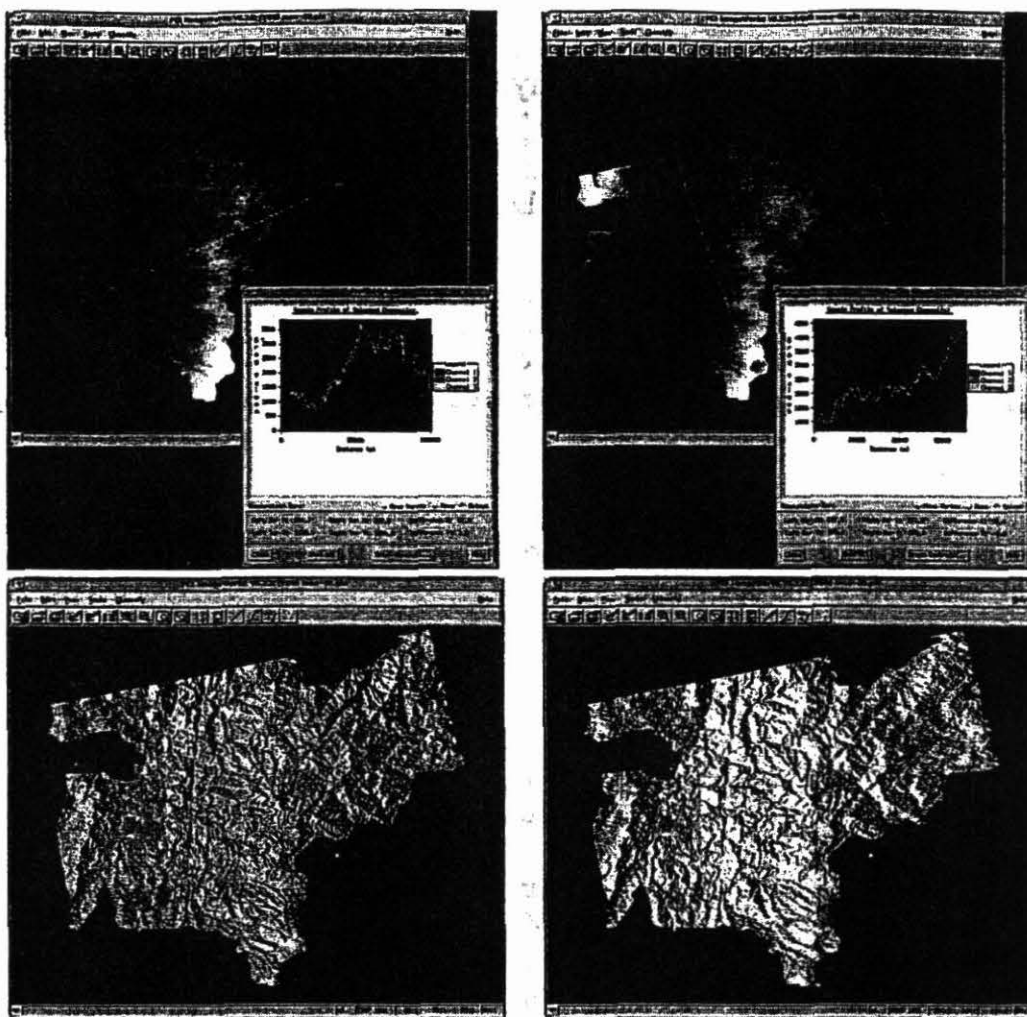


Figure 4. The reference digital elevation model (DEM)(left) and radargrammetry-derived DEM (right) for the Manizales area.

Outputs

SAR processing appears to be a viable (and low-cost) alternative to commercial imagery. It allows us to custom-define image parameters, and to produce state-of-the-art products such as interferograms and coherence imagery, which have great potential for mapping and DEM generation. It takes about 40 minutes to process a fine-mode RADARSAT scene on an UltraSpark 2 with dual 300MHz CPU, 750MB RAM, and 40GB RAID disk.

With the first version of RSDEM, radargrammetry allowed us to generate 1:100,000 scale DEMs in 1 day, based on RADARSAT stereo pairs. We found high systematic errors (as much as 2500 m for the Manizales area) that stress the extreme sensibility of the orbital model with respect to the precision, number, and distribution of GCPs. Orthoengine 6.2 is likely to eliminate this error.

Activity 1.2.8 Landscape ecology and hydrology watershed research, El Tambito, Cauca

Contributor: Mauricio Rincon (King's College, London), Herman Usma

Highlight

- Field data were collected in the reserve of Rio El Tambito, Cauca.
- The data were used to produce a model of the environmental sensitivity of the landscape.

Objective

The objective is to produce a model of the Rio El Tambito Reserve, Cauca, which reveals the environmental sensitivity of the landscape.

Methods

Within the cooperational agreement between the CIAT GIS laboratory and Department of Geography of King's College London, the logistic and operational support was given in landscape ecology and hydrology watershed research.

A PhD research student, Mauricio Rincon, is carrying out the Landscape Sensitivity in a Hillside Tropical Rainforest in the Biological Reserve of Rio El Tambito ('Fundacion Proselva' of Cauca University, Cauca Department). His research will point out the environmental sensitivity of this landscape through dynamic spatial GIS modeling, using temporal, physical, climatological, and hydrological variables. The model is working in 2D, based on a grid cell size of 25-m covering an area of 2000 ha.

Output

The model will help decision-makers in watershed management. Results will be used for future work in landscape sensitivity evaluations.

Activity 1.3 BASELINE INFORMATION FOR SPATIAL MODELS, INDICATORS, AND MAPS FOR CENTRAL AMERICA

Contributors: Manuel Winograd, Andrew Farrow, Marta Aguilar, Grégoire Leclerc, Jose Hernan Trejos, Silvia Elena Castaño and Glenn Hyman

Highlight

- A database containing data for the six categories was created for the land use models.

Objective

To be able to carry out analyses and adequate monitoring of the environment, land use, and processes of rural development, we must have available reliable socioeconomic, environmental, and land use data.

Methods

The spectrum of data is broad, but by defining the variables we can determine the data requirements for the development of indicators. To have a harmonized database, indicators, and methodologies, we will base the search and use of data on existing data (e.g., agriculture and population census, global and national Soils and Terrain [SOTER] database, and Global Assessment of Soil Degradation [GLASOD] maps). The structure of the model defines ecosystems or agroecological zones as a set of compartments that represent different categories of land use and ecological conditions, with structural, functional, and productive characteristics. These categories are the same ones used for land cover/land use maps (Food and Agriculture Organization [FAO]; National Aeronautics and Space Administration [NASA], and others) and include natural land, pasture, agricultural land, altered land, urban land, and wasteland. The database is being developed for each of these categories.

Outputs

The database for the models has been created. The database to run Conversion of Land Use and its Effects (CLUE) models will be finished in December 1998. It will contain data for the six categories of land use models.

Activity 1.4 ANALYSIS OF ISSUES RELATED TO POPULATION AND LAND USE DYNAMICS AT THE REGIONAL LEVEL IN PUCALLPA-UCAYALI

Contributors: Ernesto F. Ráez-Luna, Tamsyn Murray, and David Walter-Toews (University of Guelph)

Highlights

- Basic issues affecting the benchmark site are analyzed and interactions between them identified, as well as major gaps.
- This work provides a clearer picture of factors or driving forces that escape our own capacity of action, but are still of paramount importance in the behavior of the system.
- Interactions are highlighted, facilitating discussion of decisions and actions.
- Recommendations are given for the enhancement of the CG centers' activities and impact in the Pucallpa benchmark site.

Objectives

The main objective was to provide an integrated view of the pressing issues in the Ucayali region of Amazonian Peru.

Methods

We used a systems-oriented, integrated approach to the research. To identify issues we followed a three-pronged approach. A first path involved independent brainstorm exercises with CIAT scientists working in the benchmark site (March 1997) and with Peruvian local experts (May 1997). We arranged the suggested issues thematically, identified common issues between CIAT scientists and local experts, and falsified the suggested issues against available evidence. A second related path involved a wide consultation of bibliographic material published in the last three decades, mostly from Peruvian sources. Third, we repeatedly interviewed a wide range of people representing government organizations (GOs), nongovernment organizations (NGOs), and grassroots organizations - international, national, and local. We consider this active dialogue and crosschecking of views and data a crucial strength of the research method. However, grassroots representatives and direct practitioners are still under-represented.

An important initial finding is that the spatial reference for sustainable development in the study area is dramatically different between CIAT researchers and national researchers and policy-makers. CIAT scientists refer to "Pucallpa" and a "benchmark site" area about 100 km² in size, but local experts repeatedly refer to the whole Ucayali region, a territory 100,000 km². Indeed, CODESU, the broad-base NGO that is the CGIAR's main local partner in the Pucallpa benchmark site is named Consortium for the Sustainable Development of Ucayali. Nationals assign strategic importance to the natural resources offered by the Ucayali region outside of the benchmark site and the Pucallpa subregion, and to the historical exploitation of those resources.

Activity 1.5 A STOCHASTIC MODEL OF RAINFALL INCORPORATED INTO A SYSTEM FOR PRODUCING INPUT TO DRIVE DYNAMIC CROP SIMULATIONS

Contributors: Peter Jones (consultant) and Philip Thornton (International Livestock Research Institute [ILRI], Kenya)

Highlights

- A third-order Markov rainfall model was fitted to interpolated climate surfaces.
- This is the first rainfall model to be produced that is accurate for tropical climates.
- A user-friendly CD-ROM with manual will be available in December 1998.

Objective

The objective was to develop a rainfall model for any point in the tropics that would be easy to use for climate risk assessment, crop modeling, and climate mapping.

Methods

We used the methods previously described in Jones and Thornton (1993 and 1997). The present work developed the fitting of parameters to surfaces. The model was fitted to 9221 calibration stations (Table 4). The method allows updating as new data are acquired.

For each station, we calculated the climate normals for rainfall, temperature, and diurnal temperature range. The climate normals reflect the timing of climatic events throughout the year at each station. To eliminate this effect we rigidly rotated the data to a standard time. We used the 12-point Fourier transform (Jones 1986) in a modified form to take out the first phase angle of the transformed rainfall data. Upon retransformation to rotated climate normals we found that similar climates from opposite hemispheres could be matched.

We then used the rotated data in a two-pass leader cluster algorithm to reduce the calibration data to 664 clusters. Taking the cluster seed (the first station allocated to the cluster) as the cluster centroid, we mapped the cluster membership for each pixel in the CIAT interpolated climate surfaces (Jones 1991) for Latin America and Africa. Figures 6 and 7 show the climatic distance to cluster seed for the two continents. The maps show distances to cluster seeds, the nearest of which may be elsewhere in the world. The distance is scaled such that 1 equals the critical distance for cluster membership. All values less than this distance on the map imply that the pixel is a member of a known cluster. Values greater than 1 indicate that the model is extrapolating from known clusters.

For each cluster we then fitted regressions to estimate the Markov parameters. We first used stepwise regression to determine the optimum range of variates to use. We then fitted the same maximal regression to each of the 12 beta parameters, gamma shape parameters, and beta standard errors. We applied different maximal regressions to the three lag parameters. Because the model would be extrapolating from cluster bounds for at least some pixels (see Figures 6 and 7) we needed to stabilize the regressions to eliminate wild extrapolation. We therefore developed a method of progressively dropping regression terms until none in the regression could extrapolate widely beyond the bounds of the fitted data. We used the relationship reported last year (CIAT 1997b, p. 27-30) to calculate rainfall event average.

We developed techniques for storing and retrieving data for these operations and developed images for Latin America and Africa showing the reliability of the estimations. Much remains to be done in completing the calibration set, but it is a viable product at present. It was sent out in CD form to 12 chosen referees involved in crop modeling, who are able to check it against their own data. Feedback from these referees will then be used to refine the model.

The method was successfully tested against historical records for three sites characteristic of different climate processes in the tropics and subtropics. Jones and Thornton (1998) fully describe the methods used.

Outputs

We now have a workable third-order Markov rainfall model that can be fitted to interpolated climate surfaces. This is the first such model for tropical climates. A user-friendly CD-ROM with manual will be available in December 1998, making the tool easily available and usable. With this tool the user can create input climate data for a series of crop models.

A simple way of assessing relationships, external validity, relative importance, and gaps among issues is arranging them across scales of reality and drawing influence connectors between issues. Figure 5 offers such an influence diagram for Ucayali. Only major connections have been drawn to facilitate the reading of the diagram, and important chains have been emphasized. In interpreting the diagram, keep in mind that higher hierarchies influence lower hierarchies, but lower hierarchies do not always influence higher hierarchies. Plus (+) signs in the connectors identify reinforcing interactions (the food of positive feedback loops); minus (-) signs identify dampening interactions (the food of negative feedback loops).

We find that:

- In political terms, the concentration of power in Lima (a national level phenomenon), mirrored by the concentration of power in Pucallpa City, directly or indirectly stimulates the economic outflow from Ucayali, the relatively low institutional development of the region, and urban immigration from the countryside.
- In economic terms the net outflow of capital from Ucayali (a regional level phenomenon) establishes strategic constraints for the infrastructural and institutional development of the region as a whole.
- In ideological terms, the extractive / productive bias in the production of goods (a global issue) has had a strong effect on deforestation and biodiversity loss (global issues), and wasteful exploitation of key regional resources such as timber and fish.
- Migration to the city from the countryside, although a global issue, has specific and dire consequences in Ucayali. Pucallpa City suffers a severe shortage of jobs and services, and serious health and pollution problems.
- A complex of issues including lack of access to credit and technical support, and unreliable markets establishes a low ceiling for agricultural productivity and development, and acts as an expeller of rural population.

Ráez-Luna et al (1998) give more detailed information on methods, analysis, and findings.

Applied research on agriculture and NRM will significantly contribute to the sustainable development of the benchmark site only if at least two key conditions are met in the determination of priorities and interventions. First, research must be explicitly oriented to empower regional actors. Second, effective research must efficiently integrate biophysical and socioeconomic disciplinary perspectives. Specific recommendations are given such as:

- Building a shared local database of national related initiatives, organizations, and individuals in the region, to be used it to identify expertise and strategic alliances in areas not supported by the CG centers.
- Developing initiatives specifically aimed to strengthen and create self-sufficient grassroots organizations such as producer cooperatives.

Outputs

The influence diagram for Ucayali allows quick identification of information gaps. The recommendations given for research should cut costs in that research would be more effectively focused.

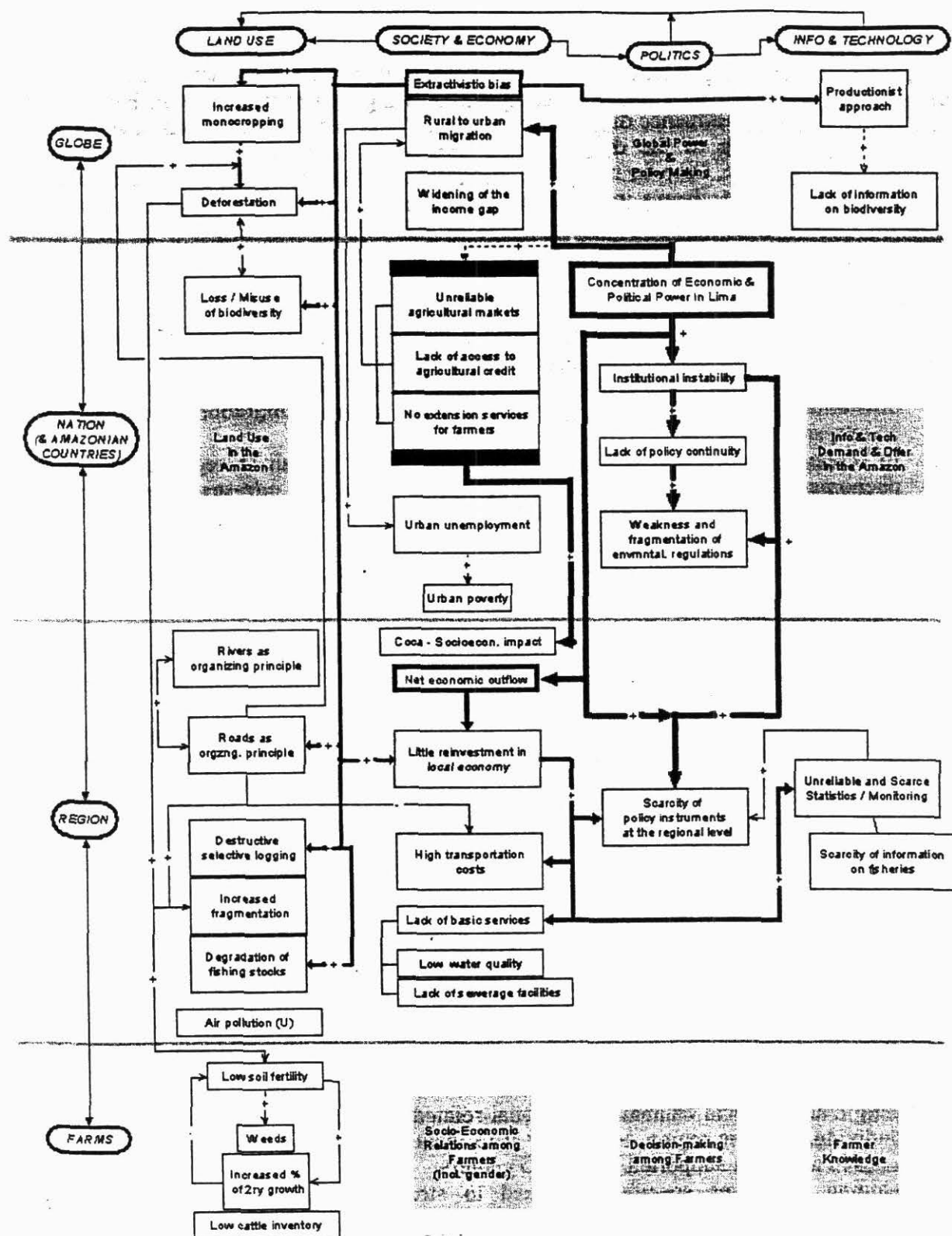


Figure 5. Influence diagram for Pucallpa, Ucayali, Peru.

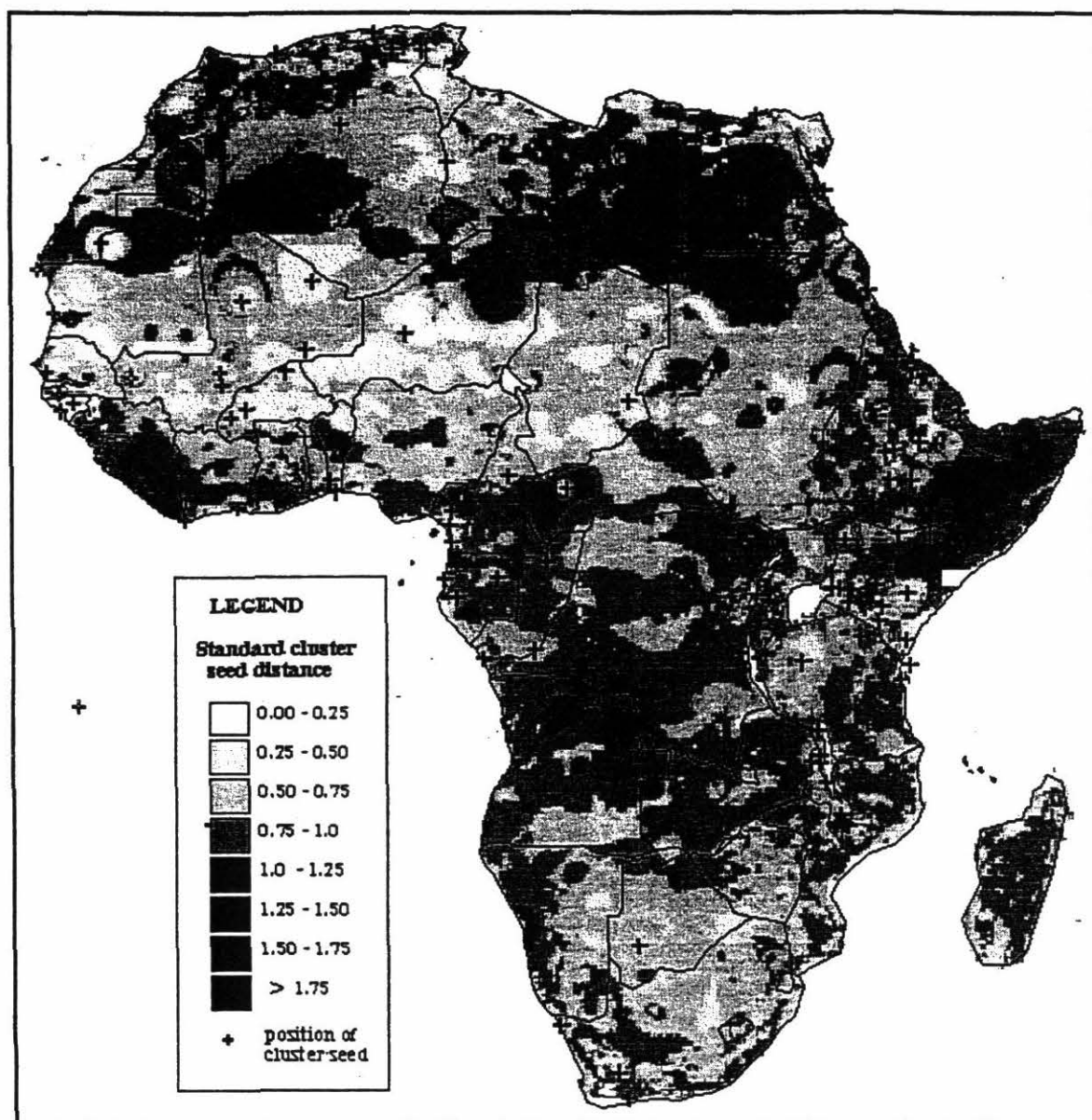


Figure 7. Africa standard climatic distances to cluster seeds.

Table 4. African and Latin American areas and a breakdown of the number of stations in the calibration set and as cluster seeds according to the Holdridge climate classification.

Holdridge class	Pixels in		Stations in	
	Latin America	Africa	Calibration set	Cluster seeds
Tropical desert	276	2721	41	23
Tropical desert scrub	108	1785	36	11
Tropical thorn woodland	687	3489	102	11
Tropical very dry forest	2992	7513	268	30
Tropical dry forest	10903	13131	629	55
Tropical moist forest	13018	1616	225	41
Tropical wet forest	130	28	23	11
Tropical rain forest	0	0	0	0
Premontane desert	168	4178	27	8
Premontane desert scrub	1168	3244	64	17
Premontane thorn woodland	826	7473	157	33
Premontane dry forest	4894	10716	661	58
Premontane moist forest	13477	12845	607	63
Premontane wet forest	2742	338	136	27
Premontane rain forest	57	0	9	4
Lower montane desert	562	14964	88	14
Lower montane desert scrub	1023	609	51	9
Lower montane thorn woodland	1191	211	114	23
Lower montane dry forest	1523	282	397	24
Lower montane moist forest	836	481	349	23
Lower montane wet forest	309	2	80	5
Lower montane rain forest	7	0	7	1
Montane desert	351	2006	56	9
Montane desert scrub	665	1022	91	7
Montane steppe	2481	716	312	29
Montane moist forest	1793	355	760	29
Montane wet forest	574	45	301	12
Montane rain forest	194	0	29	3
Subalpine desert	136	20	11	1
Subalpine desert scrub	279	268	41	3
Subalpine moist forest	365	423	202	7
Subalpine wet forest	486	100	322	7
Subalpine rain forest	105	9	158	11
Alpine dry tundra	89	0	8	3
Alpine moist tundra	70	22	59	3
Alpine wet tundra	95	50	180	5
Alpine rain tundra	91	21	201	5
Nival forms	66	15	2419	39

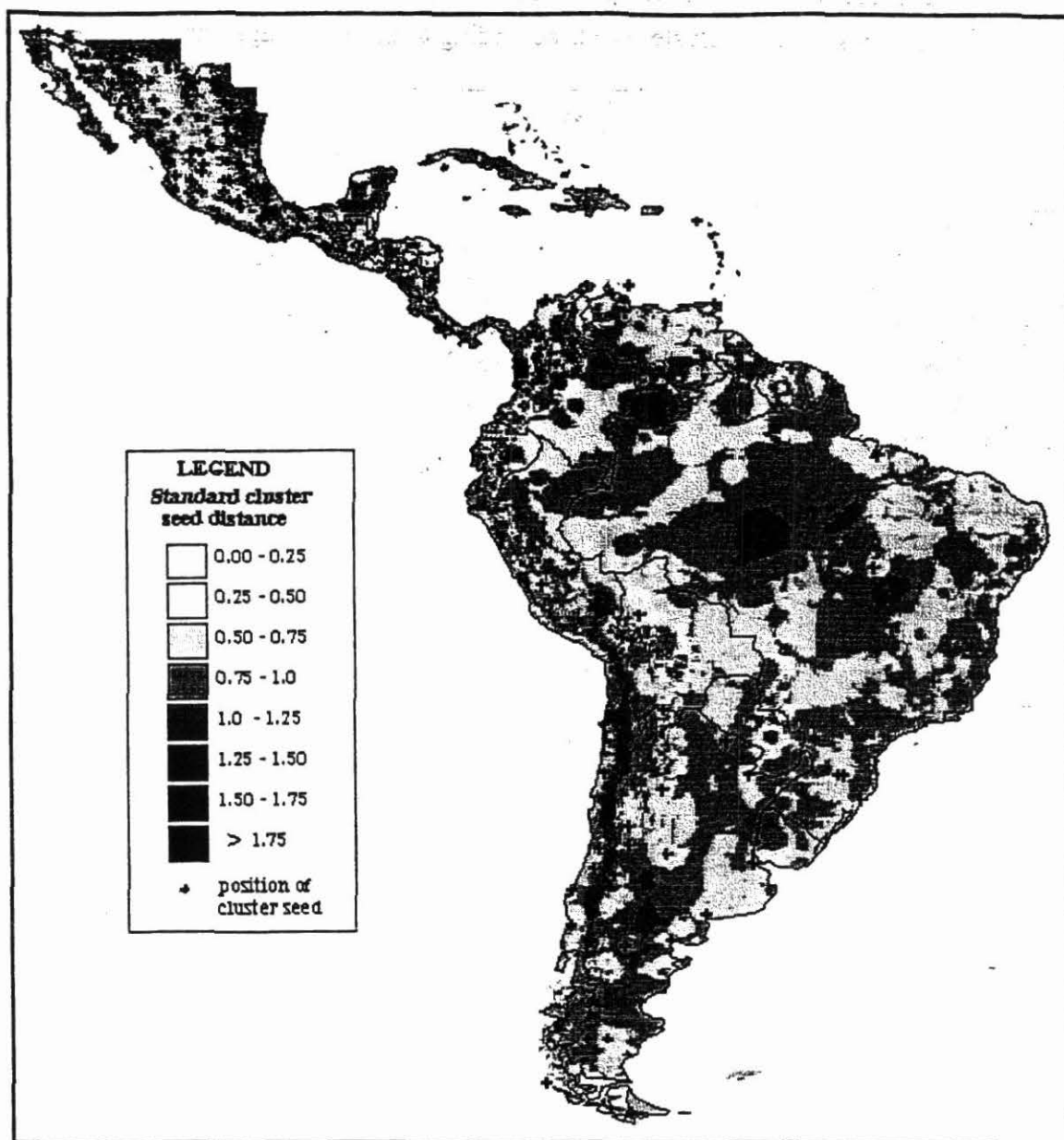


Figure 6. Latin America standard climatic distances to cluster seeds.

Output 2 Analysis of limitations and potential of land use in the hillsides, savannas, and forest margin agroecosystems

Activity 2.1 LAND USE OPTIONS AND CONSTRAINT SET FOR THE COLOMBIAN PORTIONS OF THE ORINOCO AND AMAZON BASINS.

Activity 2.1.1 The contribution of gallery forests to carbon sequestration in the Colombian llanos

Contributors: Erik Veneklaas, Sandra Obregon (Universidad del Valle), Adriana Fajardo (Universidad del Valle), Jaime Lozano, and Alix Ziebell

Highlights

- Data were collected and analyzed on the carbon stocks of the gallery forests of a representative part of the well-drained Colombian savanna, the *Altillanura*.
- The carbon estimates allow us to calculate regional-level changes in carbon stocks under different scenarios of future land use.

Objective

To assess how gallery forests contribute to carbon stocks and to find an environmentally acceptable management for the protection of the riparian vegetation.

Methods

Measurements of tree height and girth, and soil organic matter determinations were the basis of our carbon stock estimates. We sampled 80 plots (20x20 m) distributed over the watershed. Variation in a longitudinal sense (from small creeks to bigger rivers) and transversal sense (from stream to savanna) was provided for by laying out transects perpendicular to streams of all sizes. All trees with a diameter at breast height (DBH) wider than 5 cm were identified, their girth measured with tape and their height by clinometer. Based on their species composition, five forest types were distinguished (Table 5).

An increasing number of studies report allometric relationships between tree dimensions (diameter or basal area, and height) and tree biomass. Brown et al. (1989) and Brown (1997) analyze the available data for tropical forests and provide equations for forests of different life zones. The forests that Brown (1997) used for the allometric equation of the dry forest life zone are those that most resemble the structure of the gallery forests.

Table 5. Estimated biomass and other properties of five forest types in the Yucao watershed, Colombian Llanos. Means that share the same letter are not significantly different ($P < 0.05$) according to the Kruskal-Wallis test (Zar 1984).

Properties	Forest type and community					Mean
	I <i>Mauritia flexuosa</i> (n = 6)	II <i>Miconia multispicata</i> – <i>Oenocarpus mapora</i> (n = 12)	III <i>Syagrus inajai</i> – <i>Himatanthus articulatus</i> (n = 25)	IV <i>Caraipa llanorum</i> – <i>Hirtella elongata</i> (n = 18)	V <i>Licania</i> sp. – <i>Sclerolobium</i> cf. <i>odoratissimum</i> (n = 19)	
Basal area ($\text{m}^2 \text{ha}^{-1}$) [†]	50.7 ab	33.7 abc	29.0 c	33.1 c	48.2 a	48.2
Tree density (ha^{-1}) [†]	979.0 c	1700.0 ab	1690.0 a	1213 bc	1429.0 abc	1402.0
Canopy height (m) [‡]	9.3 ab	9.0 b	9.4 ab	10.6 a	10.1 ab	9.7
Tree biomass (t ha^{-1}) [†]						
Brown (1997)	283 a	161 ab	137 b	169 ab	254 a	201
Martinez et al. (1992)	281 a	119 bc	94 c	108 c	148 ab	150
Tanner (1980)	283 a	162 ab	138 b	170 ab	256 a	202
Palms (%)	99	28	13	2	0	28
Soil carbon (g g^{-1})						
0-15 cm	0.053 a	0.058 a	0.022 b	0.021 b	0.019 b	0.035
40 cm	-	0.042 a	0.007 b	0.005 b	0.009 b	0.023
Soil bulk density (g cm^{-3})						
0-15 cm	0.34 b	0.56 b	0.99 a	0.91 a	0.88 a	0.69
40 cm	-	0.67 b	1.10 a	1.08 a	1.07 a	0.86
Soil carbon (t ha^{-1})	136	226	111	92	99	133

† Basal area, tree density, and biomass refer to trees with diameter at breast height (DBH) > 5 cm.

‡ Canopy height was estimated as the average height of all trees with DBH > 10 cm.

In addition, we selected allometric equations from two studies of tropical forests that, like the gallery forests, have low stature and high stem density. These are a Mexican dry deciduous forest (Martinez-Yrizar et al 1992) and a Jamaican montane forest (Tanner 1980). Table 6 gives the equations. The Martinez-Yrizar et al. (1992) equation contains wood specific mass as a variable. We used a weighted mean of data that de Paula et al. (1993) presented for a Brazilian gallery forest. The value (0.76 g cm^{-3}) is a little higher than the mean of 0.69 g cm^{-3} that Fearnside (1997) calculated for Amazonian forests, but slightly lower than that of the Mexican dry forests for which the equation was established (0.78 g cm^{-3} ; Barajas-Morales 1987). The biomass of palms was estimated separately because they have cylindrical stems and no branches. Stem volume was estimated by multiplying stem height and basal area (Brown 1997). Specific mass of palm stems was estimated at 0.6 g cm^{-3} , and the biomass of leaves as 30% that of the stems, these being values about halfway between the extremes reported for palms (Brown 1997, Rich 1987).

Table 6. Biomass regression equations used to estimate aboveground tree mass (ATM, in kg) from tree diameter (DBH, in cm) or basal area (BA, in cm^2), height (H, in m) and wood specific mass (WSM, in g cm^{-3}).

Zone/site	Equation	Source
Dry life zone	$\text{ATM} = \exp[-1.996 + 2.32 \cdot \ln(\text{DBH})]$	Brown (1997)
Mexico	$\text{ATM} = 10^{[-0.759 + 0.9011 \cdot \log(\text{BA}) + 0.5715 \cdot \log(\text{WSM}) + 0.5654 \cdot \log(\text{H})]}$	Martinez-Yrizar et al. (1992)
Jamaica	$\text{ATM} = \exp[-1.71 + 1.16 \cdot \ln(\text{BA})]$	Tanner (1980)

The allometric relations yield an estimate of total aboveground biomass of trees with DBH > 5 cm. Trees with DBH < 5 cm, and understory, litter, and dead wood are other components of aboveground forest biomass. Brown (1997) suggests values of 3% for understory, 5% for litter, and 5%-40% for dead wood. Belowground biomass depends on forest type. We assume a value of 30%, which is between values reported for lowland moist and deciduous forests (Sanford and Cuevas, 1996). Together, these components add up to some 60% of the aboveground biomass of the trees with DBH > 5 cm. Carbon content of biomass was taken as 50% (Brown, 1997).

Soil carbon was determined on samples from each of the 80 plots. Samples of 50 cm^3 were taken at 0-3, 15-18, and 40-43 cm depth, but the first two were combined before analysis. Carbon contents were determined using the Walkley-Black method (Page et al 1982). Dry combustion of a subset of the samples yielded 6% higher carbon contents (assuming a 58% carbon content of soil organic matter), probably caused by more complete oxidation. The results of the Walkley-Black estimates were therefore multiplied by 1.06. Bulk densities were determined to calculate carbon contents in tons per hectare. The estimate refers to soils down to a depth of 1 m. Extrapolation to that depth was based on data from 11 selected profiles from two contrasting transects, in which samples were taken at depths of 0, 15, 40, 70, and 100 cm. The nonparametric Kruskal-Wallis test was used to test for statistical differences in properties comparing forest types (Zar 1984).

Not surprisingly, the gallery forests contain more carbon than do the native savanna and improved pastures. Spatial estimates, taking into account the proportion of the landscape that the different ecosystems occupy, suggest that before improved pastures were introduced, forests contributed one fifth to the carbon stocks of the landscape (Table 7).

Aboveground tree biomass amounted to 150-200 t ha⁻¹, depending on the equations used. An average carbon stock of the forest vegetation of 120 t ha⁻¹ was estimated. Soil carbon amounted to 133 t ha⁻¹ for the profile down to 1-m depth. Before the introduction of improved pastures, forests contributed some 20% to the regional carbon stocks. Conversion of half of the savanna to improved grassland could increase regional carbon stocks by 11% if forests were left untouched, or decrease them by 9% if at the same time all forests were destroyed.

Table 7. Estimated carbon stocks (t ha⁻¹) in the landscape of the Yucao watershed before and after the conversion of 50% of the savanna to improved grassland. Data for native savanna and improved pasture was taken from Fisher et al. (1994).

Agroecosystem	Landscape (%)	Carbon stocks (t ha ⁻¹)			Total landscape carbon (%)
		biomass	soil	total	
A Native savanna	84	3	187	190	78.9
Gallery forest	16	120	133	253	20.2
		Weighted mean 200			
B Native savanna	42	3	187	190	36.0
Improved pasture	42	5	237	242	45.8
Gallery forest	16	120	133	253	18.2
		Weighted mean 222			

Outputs

Increased pressure on the forests is likely, as several useful tree species have already been reported to be disappearing. Extracted wood is mainly used for fence posts and construction. On the other hand, the use of concrete fence posts is increasing, and excluding fire from the grasslands may allow the recovery of forests whose boundaries have retreated because of frequent burning. In the Colombian *Llanos*, establishing productive and sustainable pastures, accompanied by the protection of the riparian vegetation, seems to be an environmentally acceptable management.

Activity 2.1.2 Forests in the Colombian savanna: distribution, dynamics and conservation

Contributors: E Veneklaas, S Obregon (Universidad del Valle), A Fajardo (Universidad del Valle), J Lozano, and N Beaulieu

Highlights

- Information was gathered on the nature and value of gallery forests.
- The natural dynamics and current uses made of gallery forests were assessed.
- The possible threats from land use intensification were identified.

Objectives

The objective was to describe the composition, structure, and functioning of gallery forests in the Yucao watershed of the Colombian savannas, south of the Meta River.

Methods

The start of the project was reported last year (CIAT 1997b, p. 3-6.). The data collected in 1996-97 fieldwork were analyzed. Further data including surveys from 1997-98 were incorporated.

Composition

The gallery forests are low-statured forests with rather open canopies and high stem density (Table 5 of 2.1.1). Forest composition and structure vary along ecological gradients of which the most important is related to the hydrological regime. In eighty 20 x 20-m plots (3.2 ha), 147 tree species (DBH>5 cm) were found. The palm-dominated forest is the least diverse (1-4 species); the other forests contain an average of 20 species per 400-m² plot. The tree flora of this region is not exclusive to savanna forests. Zero to few endemics are found, and most species are broadly distributed geographically.

Most species of the Yucao forests occur in the humid forests of western South America, and many are distributed throughout tropical South America, or South and Central America. The affinity with the flora of dry tropical forests is relatively small. The gallery forests can therefore be considered as extensions of humid forest into the seasonally dry savanna environment. The relatively high species richness of gallery forests suggests that the current level of isolation is either too recent or not severe enough to have had a large deleterious effect on diversity.

Dynamics and maintenance

Gallery forests maintain their structure and species richness despite the fact that their habitats are highly dynamic (Brinson 1990) and to an important extent isolated from large continuous forests (Kellman et al. 1994). The forest strip in the Yucao watershed averages less than 100 m in width. Many ecological factors vary across the gradient between savanna and river. The presence of grassland affects the forest microclimate near the border with the savanna. Fire may destroy

parts of the forest and cattle may enter. Near the river, a permanent water surface affects the microclimate. The force of the water currents may damage the vegetation or erode the bank. Flooding influences nutrient and sediment balances.

Most trees have diameters under 20 cm. The overall tree diameter structure shows a typical decrease of tree numbers in the higher diameter classes, caused by the mortality of older individuals. More detailed observations of population structure, including seedlings and saplings, were made for four species. Juveniles of all four species abound, suggesting that reproduction has no important limitations. Seedlings and saplings (individuals with diameters < 1 cm) of the four species that were studied in detail, tend to be clustered. They sometimes occur in plots where adults (diameters > 8 cm) do not seem to be nearby (although there may have been adults just outside the transects, which were only 20 m wide). But, importantly, juvenile trees were never absent where adults were found. These observations suggest that, in the habitats where these species occur, reproduction is adequate and suitable regeneration sites are sufficient to support a continuous regeneration.

The coexistence of individuals of all sizes suggests that gap-phase regeneration, which is dependent on the creation of canopy gaps and is widely accepted as the principal regeneration mechanism in humid tropical forests (Whitmore 1991), does not have that role in the gallery forests. The fact that the presence of seedlings and saplings is not correlated with canopy cover estimates also supports this conclusion. The reason is probably the low mean canopy cover. Without light measurements and phenological observations one cannot conclude that canopy cover is low throughout the year. As some of the species are deciduous, and we made our cover estimates in the dry season, canopy cover may be higher in the rainy season. Nonetheless, a period of greater light transmission to the forest floor may be a reason for many seedlings and saplings being present in closed forest.

Small canopy gaps (or rather an irregular canopy) are frequent in these low statured and dynamic forests, but large gaps are not. The forest contains few or no species that behave like typical pioneers, with abundant regeneration after canopy opening. The rare occurrence of large gaps does not imply that levels of natural disturbance are low. Rather, the evidence suggests that riparian forests are highly dynamic. Floodplains are dynamic landforms, and flooding and fire represent additional disturbance factors that are important in riparian savanna forests (Brinson 1990). The generally low stature of forests despite high productivity suggests high mortality rates. In the five forest types, the basal area of dead trees still present in the forest varied between 8% and 21% that of the living trees, indicating a high turnover rate. Although in most cases the reasons for tree mortality could not be identified in the Yucao forests, evidence existed that damage caused by other trees and by wind was important.

With the available information, predictions cannot be made about the natural regrowth capacity of forests after clear cutting. The paucity of pioneer species suggests that no specialized tree flora exists that can respond to large-scale disturbances. Nonetheless, several gallery forest species may even colonize savanna land if protected from fire and grazing (Torrijos 1996). Protecting plantations is therefore essential if reforestation projects are undertaken.

Natural resources and environmental services

In 1995, many farmers in and around the Yucao watershed were asked to provide information on the availability of, and changes in, resources that the savannas and forests offered (J Smith and JV Cadavid, unpublished). Most of the species mentioned were trees and animals whose presence is limited to the gallery forests. The most frequent use of trees is for fence-posts. Some timber is harvested for construction or furniture (P Hoyos and D Molina, CIAT, personal communication, 1998). Large-scale timber extraction is unattractive because of the low densities of stems of high-quality and sufficient size. Nonetheless, some of the most valued species, like *cañafistol* (*Cassia moschata*), *dormidero* (*Enterolobium schomburgkii*), and *macano* (*Licania hypoleuca* and *Terminalia amazonica*) have become rare. In our survey, signs of low-intensity extraction were most often found in the periodically inundated forest. Indeed, the species about which farmers were most concerned, *cachicamo* (*Calophyllum brasiliense*), *saladillo* (*Caraipa llanorum*), and *aceite* (*Copaifera officinalis*), are those that are most abundant in this forest although not exclusively so. They are known to have hard and durable wood suitable for fence-posts.

Little information is available about non-wood uses of forest plants. Palm leaves (*Mauritia flexuosa*) are used for roof construction. Some trees produce edible fruit (e.g., *adriana* and wild pineapple, *Ananas ananasoides*, occurring in the understory of the dry forests). Chemical compounds in plants are unexploited. However, the flora contains many species of families with resins, latex, oils, phenolics, and alkaloids. The likeliness of finding substances that the pharmaceutical or cosmetics industry can exploit is probably high.

In the survey, farmers gave many names of animals that have apparently disappeared or are less abundant than before. These include 15 species (or species groups) of mammals, 7 of birds, and 12 of fish. Most of these animals live in the gallery forests. Particularly noteworthy is the concern about the population of game animals, especially mammals, but also birds, which by far dominate the list (Table 8). Although several fish species were mentioned, none was mentioned more than twice.

Threats and conservation

At present, the major threats to the extension and integrity of the gallery forests are the damage by burning of savanna and the continuing extraction of wood and animals. If colonizing and intensifying land use in the Colombian savanna follows the same course as in much of the *cerrado* area in Brazil, the future of the forests is endangered. As in Brazil, forests near watercourses are legally, but not effectively, protected.

Deforestation aimed at increasing the area of grassland is probably not the main threat to the forests. The risk of uncontrolled burning, a major menace for the forests is likely to decrease if improved pastures replace savannas, as pastures are not regularly burned. Yet the disappearance of natural savannas may affect wild animal populations and organisms of the savanna-forest boundary. The increasing number of households resulting from smaller farm sizes will probably stimulate uncontrolled extraction of resources. Moreover, floodplains now covered by forests may be increasingly used during the dry season for subsistence crops.

Table 8. Plant and animal species in and around the Yucac watershed that farmers most frequently mentioned as having disappeared^a.

Plant and animal species		No. ^b
Local name	Scientific name ^c	
Trees 2.1.2.1		
Cachicamo	<i>Calophyllum brasiliense</i>	25
Saladillo	<i>Caraipa llanorum</i>	18
Aceite	<i>Copaifera officinalis</i>	17
Cañafistol	<i>Cassia moschata</i>	17
Laurel	<i>Ocotea</i> sp.	15
Guatero	<i>Slerolobium odoratissimum</i>	15
Arrayán	<i>Eugenia</i> sp./ <i>Myrcia</i> sp.	10
Majaguillo	<i>Xylopia ligustrifolia</i>	7
Mammals		
Lapa	<i>Agouti paca</i>	19
Venado	<i>Mazama</i> sp., <i>Odocoileus virginianus</i>	19
Chigüiro	<i>Hydrochaeris hydrochaeris</i>	18
Cachicamo	<i>Dasyus sabanicola</i> , <i>D. novemcinctus</i>	13
Danta	<i>Tapirus terrestris</i>	5
Birds		
Paujil	<i>Crax alector</i> , <i>Mitu tomentosa</i>	6
Pava	<i>Penelope jacquacu</i> , <i>Aburria pipile</i>	4
Loros	<i>Psittacidae</i>	3

- a. Total number of farmers in 1995 survey = 98. J Smith and JV Cadavid kindly provided data.
- b. Number of times the species was mentioned.
- c. Scientific names of animal species according to INDERENA (1986).

Remote sensing allows us to identify discontinuities and size reductions of gallery forests (Beaulieu et al. 1997). In such places, restoration should be attempted (cf. Barbosa 1993). At the current, relatively early, stage of agricultural intensification it is recommendable to start monitoring the condition of riparian and stream ecosystems.

Outputs

A clearer picture of the natural dynamics and current uses made of gallery forests helps decision-makers with the overall management of savanna systems. The gallery forests are an important resource, and need protection. They come under pressure when other parts of the system intensify land use effects.

Activity 2.1.3 Support to the Colombian government's land use planning

Contributors: Nathalie Beaulieu, Ovidio Muñoz, Germán Escobar, Maryory Rodriguez, Manuel Winograd, and Germán Usma

Highlight

- The planning process for Meta Department and Puerto Lopez municipality was begun in support of the Colombian government's land use planning.

Objective

Our objective is to produce a DSS for the introduction of new agricultural alternatives in the area. The survey aims at clearly establishing the problems that each municipality would like to solve through land use planning, and at extracting common problems suffered by the municipalities located in the foothills, savannas, and forest margins agroecosystems.

Methods

In 1997, the Colombian congress passed law number 388 that establishes the framework for territorial planning (*ordenamiento territorial*) by the local governments. This law prescribes that the plans of *ordenamiento* at the municipal level should be submitted by January 1999. The planning process at the departmental level should take place during 1999. PE-4's contribution will be to develop planning support tools for the municipal and departmental levels, and to directly participate in the planning process for a pilot municipality, Puerto Lopez, and a pilot department, Meta.

In this support to the departmental governments, we will be collaborating with the Corporación Colombiana de Investigación Agropecuaria (CORPOICA), IGAC, the alternative development project of the United Nations (UNOPS), the Consejo Regional de Planificación Económica y Social (CORPES)-Orinoquia, CORPES-Amazonia, and local universities. To date, we have initiated a planning process for the department of Meta. Links have been made with the institutions noted above and a student in Agricultural Engineering (a joint program between the Universidad del Valle and the Universidad Nacional) has initiated her pre-graduate thesis on the subject. IGAC is presently finishing a detailed zonification of this department that PE-4 will help publish in digital format. This study, which includes soil classification and land use mapping, will provide a great part of the biophysical data needed for the DSS. The information will be complemented by climate and infrastructure information being generated in CIAT, and with satellite imagery.

In September, we visited various institutions in Villavicencio, capital of Meta Department. Especially strong bases for collaboration were established with the CORPES-Orinoquia, CORPOICA, and the Gobernación del Meta. The land-use planning support tools are being developed alongside the sustainability-indicators tool, jointly with the local institutions. The sustainability-indicators tool will be used to monitor the impact of any land use changes in the future.

In October, we visited and interviewed the decision-makers and decision influents in 10 of the Meta Department municipalities. These include the mayors and their cabinets, the Unidades Municipal de Asistencia Técnica Agropecuaria (UMATAs), local offices of CORPOICA and the Ministry of Agriculture, and representatives of the agro-industrial sector. A survey of interviews with farmers will be run at a later date.

Biophysical and socioeconomic data existing at CIAT for the Meta Department and the Puerto Lopez municipality were grouped into GISs in the ArcView software. We expect a preliminary version of a land-use-planning tool to be ready by December.

Output

We are providing data for the DSS for local governments.

Activity 2.2 ANALYSIS OF AGROECOSYSTEM ISSUES IN PUCALLPA-UCAYALI REGION AND SUBREGION

Contributors: Sam Fujisaka and German Escobar

Highlight

- An assessment was made of how colonist land-use affects plant community and biodiversity in the Peruvian Amazon. Farmer practices negatively affected number and types of species.

Objective

The main objective was to examine the changes in plant species, communities, and numbers as the cycle of slash-and-burn (S&B) agriculture proceeded from forest to fields to fallows of different ages, and again to cultivated fields in Pucallpa, Peru. We also sought to elicit colonists' perceptions of both useful and undesirable plant species in forests, cultivated fields, and fallows, and to compare the colonists' perceptions to the plant data sampled in the field.

Methods

We sampled vegetation in fields at the following stages:

- Forest,
- First year of cropping after forest clearing,
- Second year of cropping,
- Fallows of 1 to 2 years,
- Fallows of 3 to 5 years,
- Fallows of more than 5 years,
- First year of cropping after fallow, and
- Second year of cropping after fallow.

We sampled six transects per land use. In each transect we sampled 10 plots of 4m² with a 5-m distance between each, and identified species and recorded number of individuals per species. Each land use, as a result, provided 240 m² of sample area.

To understand the plant community changes, we used published sources to evaluate forest species not continuing in other uses and each of the most frequently appearing species per land use in terms of habitat and seed size, production, and means of dispersion.

We interviewed a sample of 71 farmers:

- 19 practicing S&B agriculture in the higher forested area away from the river,
- 19 S&B farmers who had also planted oil palm,
- 18 settlers along the Rio Aguaytia (where lands are seasonally flooded and soils are lighter and richer), and
- 15 colonists with small cattle ranches along the Lima-Pucallpa highway.

Respondents were asked about desirable forest plant species not slashed and allowed to grow in their crop fields, worst crop weeds, and desirable and undesirable species in fallow.

In the forest, 235 plant species were encountered of which 143 were not found in any successive land use. However, plants not found in the forest had colonized fields and fallow such that 580 species were identified across treatments. Plant species reflected replacement of shade-adapted plants (seed dispersed by bats, other mammals, ants, and larger birds) by pioneer plants adapted to open, drier, sunny conditions and producing larger numbers of small seed (dispersed by smaller birds and the wind). Each non-forest land use was hospitable to 7% - 25% of the forest species and 13 - 66 plant species exclusive to that land use.

As field conditions changed over time, different sets of more competitive weeds emerged in higher numbers. In response, farmers changed crops, fallowed fields, and cleared more forest. Farmers were most worried about *Rottboellia cochinchinensis*, which appeared in fields opened from fallows, and about *Imperata brasiliensis*, an indicator of land degradation (Table 9). Older fallowed fields were similar to forest in many respects, although species composition differed. Counts of farmer-named useful species across treatments were minimal, indicating high human intervention in the forest and heavy pressure on such species in all land uses.

Losses in plant biodiversity in areas subject to S&B agriculture were largely expected. Noteworthy, however, was that the forests of Pucallpa reflected substantial human intervention as evidenced by low frequencies of the desirable trees and other plants and high frequencies of gap pioneers. Although fallowed areas regained some of the forest properties, valued plants were largely shade-tolerant, slow-growing hardwood forest trees, which did not appear in fallows.

Outputs

The interaction of human activities and the natural system cannot be overemphasized. Colonist land use in the Pucallpa area reflects heavy human intervention. The plant community and biodiversity were strongly affected, many species being lost.

Table 9. Farmer-reported weeds of annual crops (% of subsample), Pucallpa, Peru.

Major weeds	Local name	FR (%) ^a	Numbers per type of field ^b			
			1fo	2fo	1fa	2fa
<i>Imperata brasiliensis</i>	Cashausha	51	0	18	4	53
<i>Homolepis/Paspalum/Axonopus</i>	Torourco	48	1	285	58	180
<i>Rottboellia cochinchinensis</i>	Arrocillo	45	0	8	371	245
<i>Baccharis latifolia</i>	Sashahuaca	39	545	355	615	513
<i>Killinga sesquiflora</i>	Cortadera	23	18	18	75	0
<i>Acacia paniculata</i>	Pashaquilla	21	4	1	0	0
<i>Vernonia baccharoides</i>	Ocuera	20	34	69	43	0
<i>Paspalum virgatum</i>	Remolina	20	0	3	0	0
<i>Davilla</i> sp.	Paujilchaqui	17	0	0	0	0
<i>Pueraria phaseoloides</i>	Kudzu	15	0	30	128	240
<i>Solanum grandiflorum</i>	Siucahuito	15	16	3	1	0
<i>Andropogon bicornis</i>	Rabo de zorro	15	0	25	17	1
<i>Croton trinitatus</i>	Sinchipichana	14	0	0	0	3
Farmers naming species (no)		97				
Total species named (no)		53				

a. FR = farmers reporting

b. 1fo = fields opened from forest after 1 year, 2fo = after 2 years; 1fa = first year after fallow, 2fa = second year after fallow.

Activity 2.3 STAKEHOLDER ANALYSIS FOR PUCALLPA-UCAYALI

To be reported in 1999.

Activity 2.4 SPATIAL EXTRAPOLATION METHODS DEVELOPED FOR HONDURAS

Contributors: Grégoire Leclerc, Hector Barreto, Nathalie Beaulieu

Highlights

- The method allows us to consider any categorical data by means of a euclidian distance measure of proportions, and its relevance estimated by a χ^2 test.
- Watersheds of Honduras have been ranked according to homology to Río Tascalapa hillsides pilot watershed according to selected biophysical factors.

Objective

Our objective is to quantify homologies of selected areas (i.e., watersheds) with respect to a benchmark site. This allows us to define the extrapolation domains of technologies and methods developed in benchmark sites, and allows a better selection of contrasting ones.

Method

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:

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

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 $\frac{1}{2}$ normalizes the distances in such a way that the maximum distance is 1. Figure 8 gives a graphical representation of Equation 1.

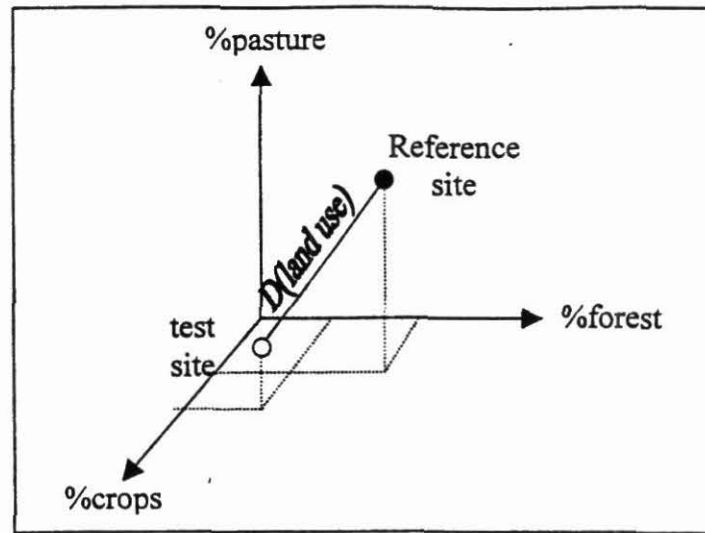


Figure 8. Graphical representation of Equation 1.

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) :

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

Where $W(x)$ is a weight to a particular factor x , and M is the number of factors. Again the factor $\frac{1}{2}$ normalizes the distance to a maximum value of 1. Figure 9 shows Equation 2 graphically.

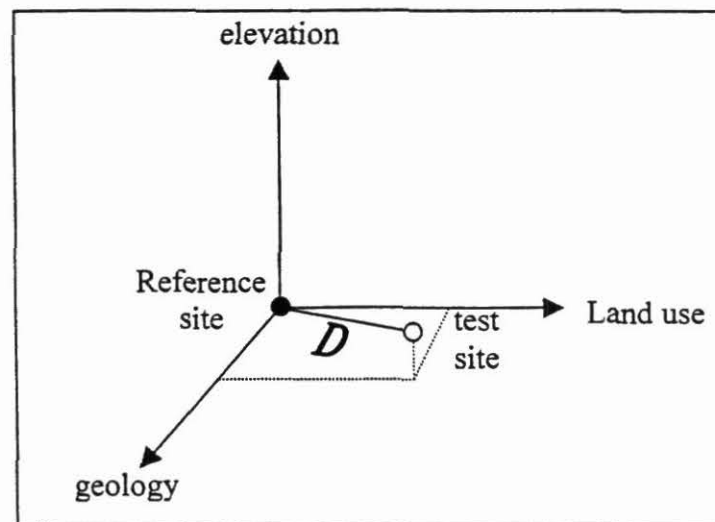


Figure 9. Graphical representation of Equation 2.

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 χ^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 χ^2 is computed as follows:

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

Where the sum runs on all the classes within a given factor (or for all classes and factors together if needed). O 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 O for that class and the two watersheds, and dividing by the total area (in pixels) of the two watersheds. For the χ^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 χ^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 0.826km² of the following factors:

Elevation –ETOPO30 DEM, 1998
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 – 1991 Instituto Geografico
Nacional (1:5000,000)

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 Hondureña
de Desarrollo Forestal (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 10 shows the proportions found for the Honduras benchmark site.

Based on these proportions, we can compare the benchmark sites to ensure they are contrasting enough. Table 11 shows the χ^2 obtained.

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

- Elevation ranges – There is a 5% probability that Saco and Cuero River watersheds are exactly the same.
- Land use – There is a 20% probability that the Cuero and Cuscateca River watersheds are exactly 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 exactly the same.

Figure 10 shows the distance to the Tascalapa River watershed for all watersheds, and χ^2 corresponding to 80%, 95%, and 99% confidence levels, according to elevation, geology, relief, and land use (maps shown at the top). Below are the histograms showing the distribution of distances for all watersheds. Arrows at the bottom depict the distance to the Tascalapa River watershed of the three other benchmark watersheds.

From Figure 10, 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 Rio Tascalapa benchmark site in Honduras and the watersheds found sufficiently contrasting. The method, here applied to watersheds, is a tool that allows us to answer the question “Where else can I apply the work that I am doing here?”

Table 10. 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

Table 11. Chi-squares and distances 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	21.100	0.070	-	-				
Cuero	81.400	0.770	38.600	0.790	-	-		
Saco	72.600	0.770	28.700	0.790	9.800**	0.004	-	-
Geology (n = 5):								
Tascalapa	-	-						
Cuscateca	89.500	0.940	-	-				
Cuero	92.800	0.970	48.900	0.950	-	-		
Sacor*	71.000	0.840	27.700	0.810	31.300	0.860	-	-
Land use (n = 5):								
Tascalapa	-	-						
Cuscateca	25.100	0.100	-	-				
Cuero	23.000	0.130	5.200*	0.170	-	-		
Saco	50.500	0.250	11.900**	0.280	10.800*	0.160	-	-
Relief (n = 4):								
Rio Tascalapa	-	-						
Rio Cuscateca	53.000	0.540	-	-				
Rio Cuero	94.500	0.970	50.500	0.840	-	-		
Rio Saco	75.500	0.940	30.600	0.780	11.000**	0.070	-	-

- a. * = Probability of 0.2 that watersheds are the same, ** = probability of 0.05 to 0.01 that watersheds are the same.

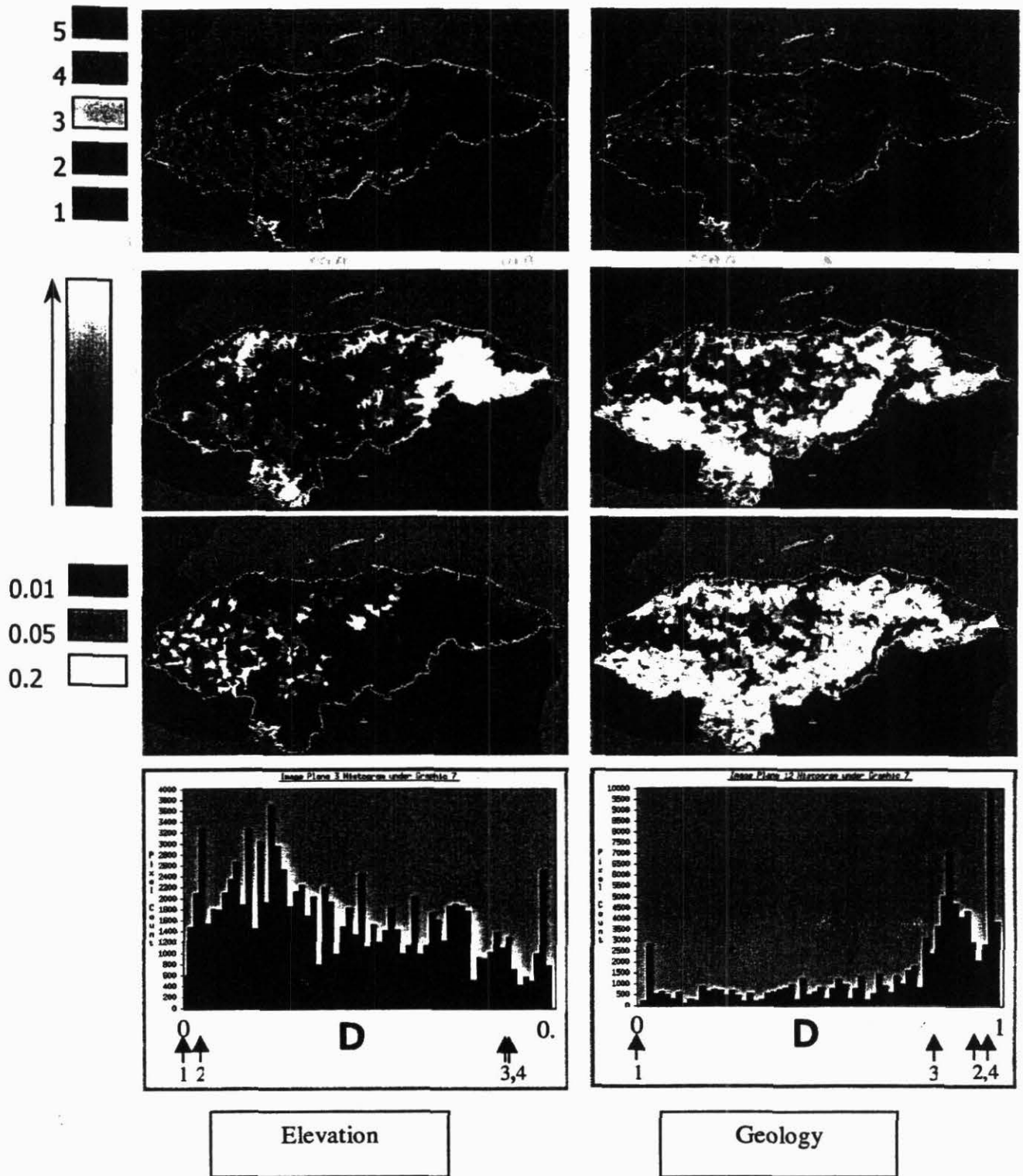


Figure 10. Maps showing distance to the Tascalapa watershed for all watersheds and χ^2 according to elevation, geology, relief, and land use; and histograms showing distribution of distances for all watersheds (1 – Tascalapa River, 2 – Cuscateca River, 3 – Cuero River, and 4 – Saco River).

Activity 2.5 RISK AND CONSTRAINT ANALYSIS OF SOIL DEGRADATION PROBLEMS IN THE CIAT AGROECOSYSTEMS

Activity 2.5.1 Contour hedgerows for soil erosion control

Contributor: Sam Fujisaka

Highlights

- The promotion of contour hedgerows as a means of controlling soil erosion can and should be limited to areas where certain conditions exist.

Objective

To research farmer adoption of contour hedgerows for soil erosion control and assess the promotion of the same.

Methods

Using results of work conducted in northern Mindanao, Philippines (1987-93) and more current work in other upland sites, a hypothesis was developed regarding adoption and the reasons for and against adopting contour hedgerows for soil erosion control.

Adoption of contour hedgerows has been poor at most sites where promoted, including in Honduras, Nicaragua, Vietnam, and Thailand where CIAT conducts collaborative research on improved crop and natural resource management. This does not imply that farmers do not practice soil conservation. The Central American farmers, for example, conserved soil by employing minimum tillage (adapted because herbicides were less expensive than hired animals and hired manual weeding) and contour planting.

Experiences and observations led to the following hypothesis. Farmers adopt conservation measures only under certain conditions. These are where soil erosion is a problem, where erosion affects most farmers and fields, and where soils are from moderately to highly productive. Another condition is where population has increased to the extent that shifting fields is no longer physically or economically feasible, and sufficient labor is available to invest in conservation measures.

The hypothesis can also be expressed in a four-cell matrix with sloping agricultural areas with lower population and open frontiers versus higher populations and closed frontiers on one axis and low versus high soil productivity potential on the other axis (Figure 11). Although contour hedgerows have been promoted worldwide as a means of reducing soil erosion, only a limited subset of upland areas may be available where farmers can and will adopt soil conservation measures. It makes sense to promote contour hedgerows and other soil conserving innovations only in the more favorable areas where erosion is a problem and population is reaching the point where extensive forms of land management are no longer possible.

This suggests that research and extension should cease promoting contour hedgerows where:

- Erosion is not a sufficiently serious problem,
- Farmers have already conserved soils using other measures,
- Local ability to invest is negligible in marginal, over-populated areas and soils remain poor even if not lost to erosion (and other structural changes are more urgently needed), and
- Low population and land availability in more favorable areas makes extensive practices sensible.

Instead, resources should be focused on favorable frontier areas experiencing a transition in which populations are rising and where farmers see new needs for soil conservation and contour hedgerows.

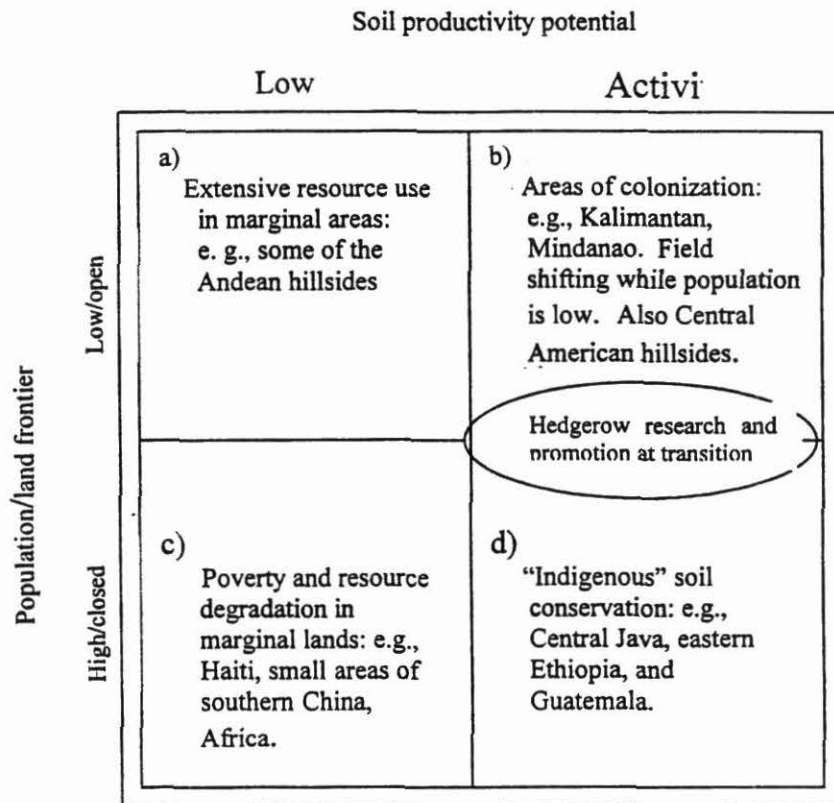


Figure 11. Sloping agricultural lands matrix.

Outputs

The hypothesis enables a clearer focusing on where to promote contour hedgerows as a means of soil conservation.

Activity 2.5.2 Micro-watershed classification: a guide to identifying similar catchments for field research and soil degradation analysis

Contributors: Koulla Pallaris, Jorge Rubiano (PE3), Glenn Hyman and Edmundo Barrios (PE2)

Objectives

Before investing money in our soil degradation field research, it is necessary to obtain an idea of the distribution of simple landscape characteristics. Evaluation of the characteristics of an area will help determine where to site monitoring stations in order to obtain measurements which are both representative of the area but which also cover the whole spectrum of heterogeneity of an area. Using simple biophysical/morphological parameters, geographical spatial analysis can be used to delineate "similar areas". This procedure is simple to carry out and useful for preliminary evaluation of a study area. The ultimate objective of this approach is to avoid measurement specificity, to make local results valid for wider regions based on the assumption that similar areas will behave in similar ways. The purpose is to scale up from site measurements to watershed impact assessment.

Methodology

Our approach has 3 main classification stages. The first step involves delineating the topographic boundaries of the watershed by deriving a digital elevation model (DEM). Secondly we delineate the micro-watersheds, in which sampling will be carried out and finally we carried out the classification analysis by overlaying map layers of different biophysical / morphological properties.

Delineation of watersheds is of fundamental importance because the characteristics of a drainage basin controls the paths and rates of movement of water to the outlet and the magnitude and timing of outputs via streamflow, groundwater flow and evapotranspiration (Dingman 1996). Further, using micro-watersheds as sampling units is useful because they have clearly defined boundaries which may help track the impact of landuse change and farm practices on the hydrological processes of a watershed. A previous study (Rubiano 1993) had manually chosen the microwatersheds which could potentially be used as sampling units, by defining the upstream contributing area from each tributary outlet which joined the main river. This was preferred over automatic raster based processing as it appears that the algorithms used in this process needs further development before widespread application.

Basic factors considered important in affecting productivity, soil erosion and water-balance were chosen. Biophysical classification was carried out using soil type, aspect and slope. The choice of morphological properties included area and coefficient of compactability of each micro-watershed. Morphological variables are important because even though two micro-watersheds may appear to be similar, the hydrological response may differ due to the geometry of the watershed. For example, stream discharge of circular catchments increases more rapidly in response to rainfall events compared to elongated catchments.

Reclassification of these basic factors was carried to group together areas with similar properties, by defining class boundaries considered important for the analysis. Each class was assigned a unique number identifier. The maps were overlaid to produce a classified image showing classes with unique combinations of biophysical properties. Further spatial analysis was performed on a micro-watershed basis, where the most frequent class within each micro-watershed was derived and overlaid to produce a map showing the distribution of similar micro-catchments (Figure 12). Although much cruder, this may be more useful in the initial determination of "similarity areas". The geometric characteristics of each micro-watershed were classed separately. For example, the size distributions were classed according to what was considered manageable working units.

Output

The first classification generated 28 classes, with 5 significant biophysical combinations. These classes can be considered areas where monitoring stations could be set up in order to obtain representative measurements, covering the most significant variability of the catchment. The definition of micro-watersheds and the classification of the area should ideally be validated with field observations before we can confidently use them for selecting monitoring sites. The methodology outlined here has great potential as a process for designing monitoring frameworks. These are needed for accurately defining baseline conditions which can then be used to assess the impacts of the adoption of alternative land management systems

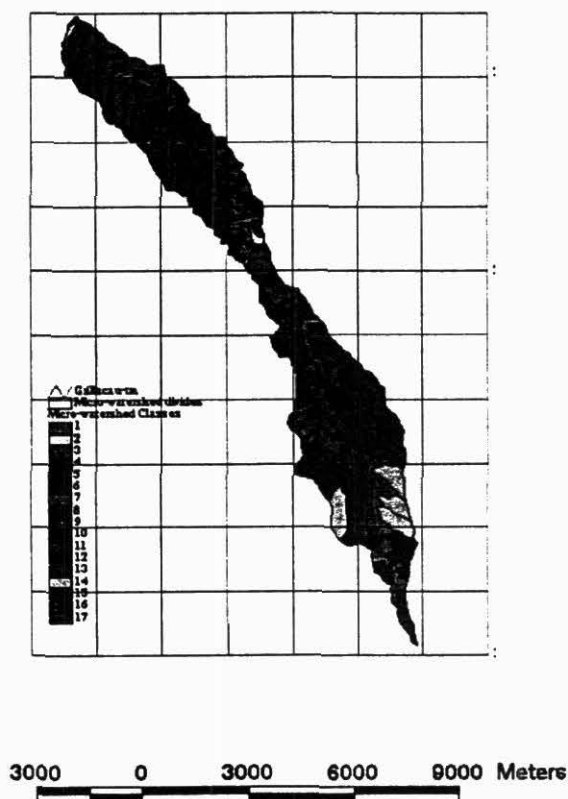


Figure 12. Micro-catchment classification of the Río Cabuyal Watershed

Activity 2.6 IMPROVEMENT OF AGRICULTURAL SYSTEMS, NORTHERN CAUCA

Contributors: Germán Escobar, Herman Usma, Otto Madrid and Sam Fujisaka

Highlight

- A 3-year participatory research project for a marginal traditional community in northern Cauca was initiated

Objective

The objective is to develop appropriate and sustainable technologies through participatory research for improving the well being of targeted indigenous communities in northern Cauca.

Background

The Asociación de Cabildos del Norte del Cauca (ACIN) coordinates the project which covers 13 indigenous reserves in seven municipalities. ACIN represents 68,000 people, of whom 65% are indigenous and 30% are smallholders. The project area covers 170,000 ha encompassing the Nevado del Huila. The area is about 85% forest, and includes watersheds such as the La Paila, Quinamayó, and El Ovejas. 70% of sloping lands are eroded and contribute to low agricultural productivity. The population has a life expectancy of only 37.5 years.

The project works in an indigenous reserve of 6000 ha. ACIN is seeking to develop sustainable agriculture that uses local knowledge and is less dependent on outside markets. CIAT was asked to help. Through PE-4 and PE-5, we are collaborating in working with small-scale farmers in the participatory development of sustainable productive systems. The project also strengthens the Colombia-CIAT agreement. Other collaborators are the Centro de Investigación y Servicios Comunitarias de Santander de Quilichao (CRISEC), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Centro de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)-CIAT, the Federación Nacional de Arroceros de Colombia (FEDEARROZ), and project PE-5.

The direct beneficiaries of the project are indigenous peoples of northern Cauca. The potential users are small-scale farmers belonging to the Corinth, Huellas, and Toez Reserves, and the Black community of Pilano.

Methods

Initially, trials were to be run on the producers' lands, but difficulty with the availability of seed meant redesigning the process. The ACIN approved the use of part of El Nilo farm to set up the Centro Alternativa de Investigación Agropecuaria "El Nilo".

Work began in May on seed multiplication under the direct responsibility of two indigenous technicians with collaboration from the agricultural anthropology team from CIAT. Seven

varieties of cassava and eight of beans were planted and evaluated by members of the community. ICRISAT has begun an experiment on sorghum and millet. Others have since become involved. The idea is to include further CIAT projects and/or NGOs in this participatory research process.

Outputs

The indigenous people of the flat areas of northern Cauca are working to produce crops in a sustainable manner. The project has sparked great interest and increasing collaboration.

Output 3 Frameworks for analyzing land use dynamics and for using indicators of sustainability in the CIAT priority agroecosystems

Activity 3.1 FRAMEWORK AND INTERFACES FOR COMMUNITY WATERSHED MANAGEMENT IN THE HILLSIDES BENCHMARK SITES

Contributors: Grégoire Leclerc, Ron Knapp (PE3), Brahm Verma (UGA), and Shree Nath (UGA)

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. Our vision calls for an interactive G/DSS as a technological tool to facilitate the mutual understanding of perspectives held by different stakeholders.

Method

CIAT has been working in collaboration with the DSS Center at the UGA since September 1997. Years of experience in using the Participatory Planning by Objectives (PPO) methodology revealed that in certain circumstances the methodology 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, 1998). 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. Some of the 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. G/DSSs 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 the problem
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 built around a RADIX, which is a graphical representation of a hierarchical structure of multiple criteria. The G/DSS allows us to design the RADIX suitable for a particular environment. Figure 13 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.

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 stimulate discussions among a group of stakeholders 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 Honduras decision makers 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. The methodology has been extremely well received: the participants provided valuable feedback and expressed their interest in contributing to future developments.

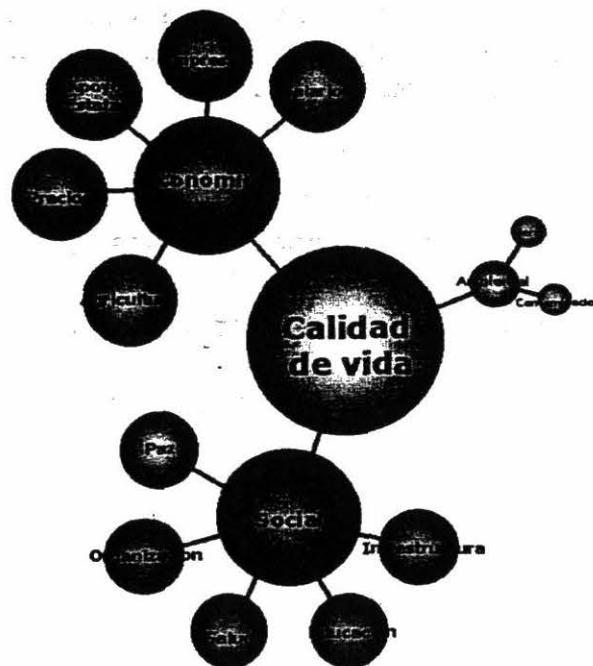


Figure 13. RADIX of objectives constructed based on the results of the Feb 1998 Participatory Planning by Objectives. The size of the spheres is proportional to the number of objectives identified. Subrepresentation of environmental objectives is obvious.

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, we and our collaborators 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 3.2 DEFINED AND HARMONIZED CONCEPTUAL FRAMEWORK FOR SUSTAINABILITY INDICATORS IN CENTRAL AMERICA.

Activity 3.2.1 Pressure-State-Impact-Response model

Contributors: Manuel Winograd, Andrew Farrow, and Marta Aguilar

Highlights

- The Pressure-State-Impact-Response model was defined and refined.
- Visits to institutions helped improve and train people in the use of the framework and the indicators.

Objectives

The main objective was to define and validate a conceptual framework allowing datasets to be organized and integrated for use in the decision-making process at different levels (administrative, ecological, and sectoral) and scales (local, national, and regional), facilitating the exchange and use of information required in decision-making and planning.

Methods

This conceptual framework will relate social, economic, and environmental data, socioeconomic and environmental statistics, and soil quality and land use information in a multiscale approach to meet policy-making and management needs. Conceptual frameworks and methods, and the routine production and update of data, need to be harmonized with the dissemination and adoption of the use of the information tools. This is the key issue regarding the use and production of indicators and information for policy-making, environmental management, and development planning.

For this reason, CIAT, the World Bank, and UNEP-Regional Office for LAC (ROLAC) implement the project, within the framework of the CIAT-UNEP project on Environmental and Sustainability Indicators; and with the collaboration of relevant international, regional, and national institutions and governments (Annex 1). Strong participation of relevant national level agencies and institutions was needed. With this in mind, a workshop was organized at the beginning of the project to harmonize the framework, issues, and the indicator sets, to identify major regional and national partners, and to obtain the formal participation of those institutions in the project.

The model was defined based on the development of four groups of indicators. The first observes the causes of rural, environmental, and land use problems (Pressure on the environment

and society). The second monitors the quality of the environment, land, and natural resources resulting from human activity and the state of the society (State of the environment and society). The third observes the impact of human activity on the environment and the land, and the effect of the environment on society and rural development (Impact on the environment and society). The fourth refers to the measures and responses of society on the environment, land, and rural development (Response to the environment and the society).

Outputs

A model was defined and refined (Pressure-State-Impact-Response [P-S-I-R]). The visits to institutions served to improve and train people in the use of the framework and indicators.

Activity 3.2.2 Indicator sets for rural sustainability in Central America

Contributors: Manuel Winograd, Marta Aguilar, and Andrew Farrow

Highlight

- Sets of indices, basic indicators, and complementary indicators to monitor rural development at different scales are now available (Winograd 1997).

Objectives

The main objective was to define a core set of rural sustainability indices and indicators for policy making at regional and national level, and complementary indicators at local and sectoral level. The goal of this study is related to the improvement of the use and exchange of indicators to policy and decision-making, and testing the usefulness of the indicator set.

Methods

For the conceptual framework, a general approach was taken to define and develop indicators and information tools adopted for the project.

1. A conceptual framework was selected and harmonized with partner institutions and users to organize the information.
2. Problems and themes were identified, and variables defined to select indicator sets with partner institutions and users.
3. Basic data and coverage (i.e., agroecological zones [AEZ], ecoregions, life zones, land use categories, and administrative boundaries-1st, 2nd, and 3rd order) were selected and defined.
4. A core set of related indicators (i.e., socioeconomic) was selected with partner institutions and users.
5. A core set of rural sustainability indicators (i.e., land quality and environment) were selected, developed, and harmonized.
6. Criteria and methods for the indicator sets were defined.

7. Data were searched for and acquired and databases developed to use and validate the proposed indicator sets in relation with partner institutions and users.
8. Capacities and tools were developed to identify and analyze cause-effect relationships related to land use, land quality, and rural development.
9. An interface was developed to use the indicator sets and other related tools (i.e., spatial land use models) at different scales (region, country, municipality, and watershed) in relation with end users.
10. The information was disseminated, validated, and distributed to partner institutions and users.

The countries of the region are becoming more integrated through, for example, the Comisión Centroamericana de Ambiente y Desarrollo (CCAD). They share resources such as drainage basins and biodiversity, and share problems of rural development and degradation of common lands (i.e., land tenure, urban migration, and erosion). Thus, we had to approximate at the regional scale to produce and use information for decision-making. However, not all the countries are in the same situation regarding information. For this reason, a common conceptual framework and a set of indicators were brought into line with methods, related data, and user needs.

To carry out this regional study, a basic set of rural development indicators and contextual indicators were defined and harmonized with respect to development issues (Winograd 1997). At the same time, a geographical stratification, for example by AEZ, was defined to obtain the general context and the scales for the development and use of the indicator sets. This implied closely collaborating and participating with producers and users of the information to take into account national and regional needs and characteristics.

Outputs

Two sets of indices (10), basic indicators (71), and complementary indicators (95) to monitor rural development at different scales are available. The indices were derived from issues previously defined with users. The indicator sets are in three super categories (economic, social, and environmental). These indicator sets are the base for searching for information, creating databases, and validating information tools with end users and institutions.

Activity 3.3 INTEGRATED CONCEPTUAL FRAMEWORK FOR RESEARCH IN SUSTAINABLE AGROECOSYSTEMS APPLIED TO PUCALLPA-UCAYALI

Contributors: Tamsyn Murray, James Kay (University of Waterloo, Ontario), David Waltner-Toews (University of Guelph, Ontario), and Ernesto Ráez-Luna

Highlights

- The research method provides a process for farmers, researchers, decision-makers, and all involved stakeholders to learn how to increase sustainability.

Objectives

The aim in developing the research guide was to take the most relevant and useful aspects from different methodologies and test them in Ucayali. This would then provide a coherent and practical research tool that could be applied to other forest margin areas in the Neotropics.

Methods

We use a specific research methodology that demonstrates the necessary steps to be taken to achieve greater insight into and understanding of complex socioecological systems. This research methodology is being developed and applied within the context of a case study, the Ucayali region of the Peruvian Amazon. It involves an iterative process of establishing and modifying theory, developing, testing and retesting hypotheses, and acquiring and analyzing data.

There are four basic underlying assumptions.

1. Multiple perspectives exist of any given "reality" and questions of sustainability or health are necessarily value judgments, expressed as the goals defined by the stakeholders of the system.
2. Systems have a hierarchical and emergent nature.
3. Relationships characterized by positive and negative feedback loops as opposed to linear causation are emphasized.
4. Multiple steady states exist, the transition between which can be non-linear, discontinuous and catastrophic.

The four underlying assumptions have led to three guiding principles. They are: multiple stakeholders, multiple modes of inquiry, and negotiation among multiple goals; multi-level and cross-scale investigation; and unpredictability and inherent uncertainty.

At each stage in the research process a series of guiding questions are posed. They represent a starting point, the key questions from which other more specific and applied questions can be derived. They are based on early hypotheses that are first generated and iteratively modified

throughout the entire research process. The research activities that result from the guiding questions within each step will produce one or more tangible outcome. Figure 14 identifies these outcomes within a learning process, as each step results in greater insight and knowledge that is passed on to the next step. Murray et al (1998) give a more detailed explanation.

Outputs

A research method has been developed that is better able to explain and anticipate events. The data is more relevant and applicable to other forest margin regions. Three key insights have emerged:

- The impact of cross-scale interactions,
- The effect of the dynamic nature of many processes within Ucayali on the abilities of institutions to address pertinent issues and design interventions in a timely and effective fashion, and
- The impact of multiple versions of the same reality on defining pertinent issues, setting research priorities, and coordinating research activities

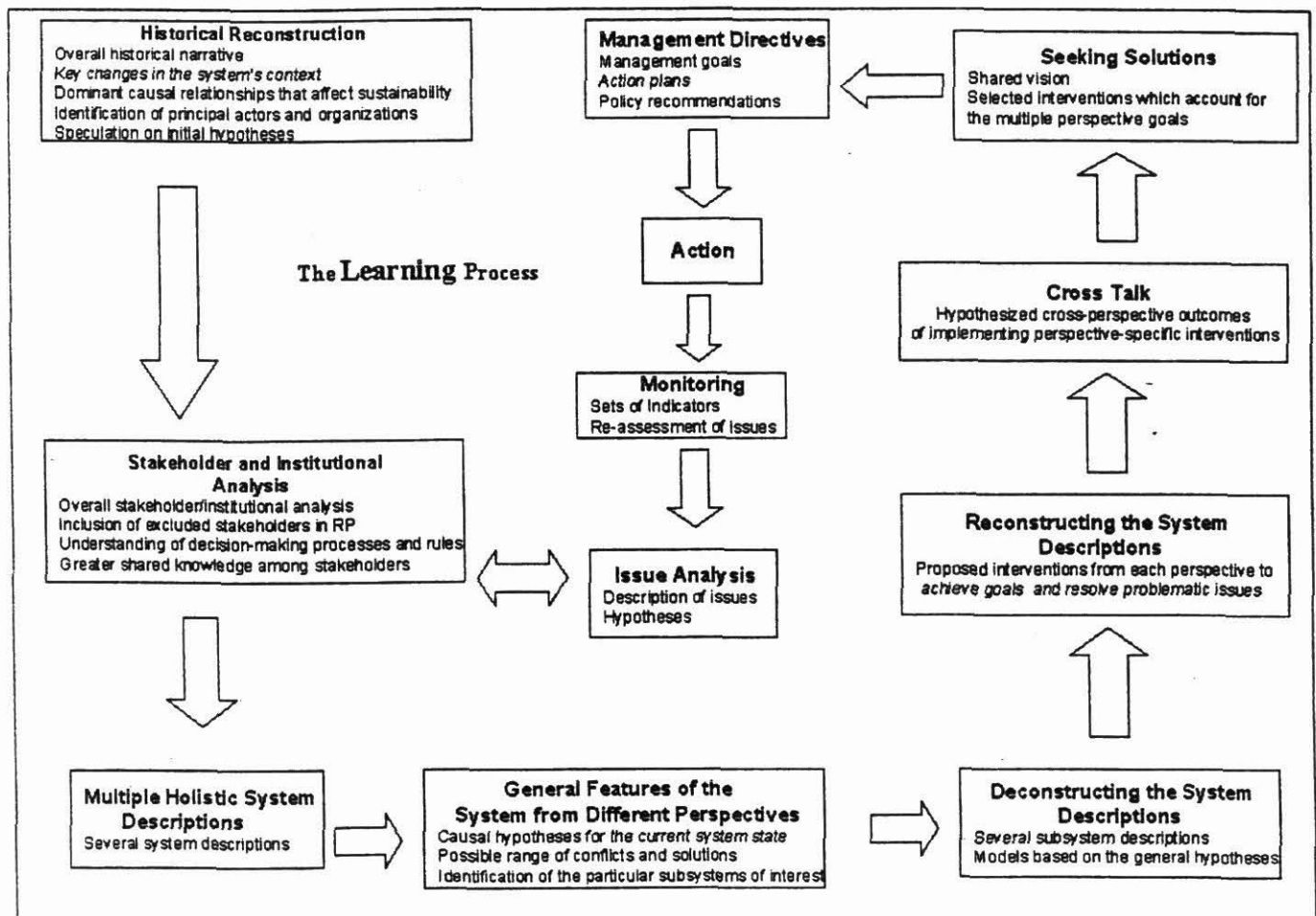


Figure 14. Outcomes identified within a learning process for Ucayali region, Peru.

Activity 3.4 NEW TOOLS AND METHODS TO ANALYZE CAUSE-EFFECT RELATIONSHIPS OF LAND USE CHANGES

Contributors: Manuel Winograd, Andrew Farrow, Kasper Kok (WAU) and Marta Aguilar

Highlights

- An agreement was reached with Wageningen Agricultural University to work with the CLUE land use models.
- Visits to institutions in the Netherlands promoted work already done and the promise of future collaboration.
- A new user interface was derived from issues for the economic, social, and environment categories, allowing the use of indicators in different ways.

Objectives

The tools and how the different users synthesize, aggregate, visualize, and disseminate the information are an important output of the project. Tools are needed that make it possible to explore the dynamics and impacts of the policies, actions, and strategies in rural development, and to identify and analyze cause-effect relationships. Two types of tools must be developed for this: first, land use models to explore the impact and changes in land use; and second, an interface allowing users to view and overlap information (i.e., indicators and models) needed for policy-making and planning at different scales.

Methods

Spatial models make it possible to explore the changes in land use by analyzing and exploring the trends, impact, and potential of agroecological zones and ecoregions. A simple existing model of compartments was used to explore the changes of land used (see under 1.3 Methods). However, this model is not spatial, making it impossible to analyze where these changes occur. For this reason, the model must be adapted to a georeferenced basis. To do this, a spatial land use model (CLUE) developed by Wageningen Agricultural University (WAU), and applied for example in Costa Rica, will be used. The CLUE model makes it possible to obtain maps on the changes of land and their effect in an integrated multiscale approach. This model is used with a resolution in pixels of 10 km x 10 km. To apply the methodology proposed in CLUE, data for the six categories of the land use model and maps on the driving forces (i.e., population, soils, and climate) should be prepared. The relationship between land use and the driving forces should be analyzed based on multiple regression techniques on the changes of land use. With this information, spatial changes can be allocated and the maps developed on possible land uses to carry out multiple scale analysis.

Besides the land use models, capabilities must be created to use the information and to identify and analyze cause-effect relationships regarding rural development, land use changes, and land quality. Cause-effect relationships must be identified and analyzed by overlapping and using different types of information (i.e., models and indicators). To create these capabilities, an interface allowing users to overlap and visualize indicators and models was defined and developed based on the interface developed for the CIAT-UNEP project CD-ROM. Where the cause-effect relationship is well understood, algorithms can be used to create indices that operate

spatially. These indices have to be accurate, detailed (i.e., relevant to the scale at which they are viewed), and transparent (i.e., well documented and potentially repeatable). These indices were only created where it was felt that the user did not have the ability (computer processing power or expertise in the subject) to analyze the cause-effect relationship within the interface. The goal of the interface is to enable users to explore, identify, and analyze development trends and cause-effect relationships regarding rural development and land use in a dynamic way. The interface is related with the transformation of land (Pressure), the state of land (State), the degradation of land (Impact), and the intensification of land use/protection of land (Response).

During the visit to the Netherlands, other institutions working with models at regional level were visited. This opened up the possibility of future collaboration. It was useful to see the different approaches being used and receive helpful comments on our work.

The source code for the CLUE model (and an explanation of how it works) was obtained as well as useful comments and input from the CLUE team regarding our work. An agreement with WAU to work during 1999 with the CLUE model was reached. This primarily concerned the obtaining of results that will be incorporated in the Central American indicators CD to explore trends in land use indicators. A pre-requisite for this contract was the development during 1998 of the database for the CLUE model (see Activity 1.3).

Outputs

The visit to WAU allowed us to explore and understand the possible use of the CLUE model, and the amount and type of data required for applying the model in Central America. Regarding the interface to use information, a new interface was defined, derived from issues for the economic, social, and environmental categories allowing the use of indicators in different ways. Users and donors were consulted for the design specifications of the final interface to develop the CD-ROM for Central America and the updated version of the CD-ROM for LAC.

Activity 3.5 INDICATOR SETS FOR RURAL SUSTAINABILITY IN CIAT'S AGROECOSYSTEMS AND BENCHMARK SITES

Activity 3.5.1 Indicator sets

Contributors: Manuel Winograd, Marta Aguilar, Nathalie Beaulieu, Ron Knapp (PE-3), Glenn Hyman, Douglas White (PE-5), Peter Kerridge (PE-5), Ruben Estrada (PE-3), Ernesto Ráez-Luna, Tamsyn Murray, Sam Fujisaka, and Federico Holmann (PE-5)

Highlights

- A beta version of an information system with 45 indicators was developed for Meta Department, Colombia.
- A proposal of rural sustainability indicator sets was distributed to CIAT's agroecosystem Programs for discussion.

Objective

The objective was to help improve the selection of benchmark sites and impact assessment in CIAT's agroecosystems.

Methods

A series of meeting was organized with CIAT's agroecosystem Programs to identify issues and variables to develop indicator sets. A proposal for a set of indicators was sent to each program to validate them and to explore the development of the database to use indicators.

Outputs

In the case of the Meta Department in Colombia, a beta version of an information system with 45 indicators was developed with the goal of exploring data availability and to develop and apply the P-S-I-R framework at local level. For other cases in CIAT's agroecosystems, a series of meetings was organized to define the final set of indicators for each agroecosystem and to develop the database and the interface to use the indicators.

Activity 3.5.2 Indicators of sustainability defined and mapped for Meta Department, Colombia

Contributors: Manuel Winograd, Marta Aguilar, Ovidio Muñoz, German Escobar, and Nathalie Beaulieu

Highlights

- Indicators of sustainability were defined and mapped at a more detailed geographic scale for Meta Department, Colombia.
- The resulting tool is available at the CIAT website.

Objective

To provide sustainable indicators for the Meta Department of Colombia that can be used as a tool to support land use planning.

Methods

A preliminary version of a sustainability indicators tool was completed for the Meta Department. We used the same methodology and framework as the indicators of sustainability for Latin America (CIAT 1997b, p 53) to define indicators at a more detailed geographic scale for the Meta Department, Colombia. The data and algebraic relationships for the calculation of the indicators were integrated in the ArcView 3 program with a user-friendly interface. The tool is available on our website <http://gis.ciat.cgiar.org/>. In collaboration with government institutions and NGOs, it will be periodically updated. In the scope of the agreement with the Colombian government,

similar tools will be developed for each of the departments included in the Orinoco and Amazon regions of the country

A basis was established to jointly extend this tool for the entire Orinoco area with the CORPES-Orinoquía in Villavicencio. This institution has already started to group georeferenced data. In the process of developing this joint tool, CIAT will help strengthen the CORPES's GIS capacity.

Outputs

We have developed a tool that can be used as support for land use planning by the local government of Meta Department.

Activity 3.5.3 Identifying field level soil indicators

Contributors: Patrick Hill and Peter Wenzl (Biotech)

Highlights

- The ratio between particulate organic matter and total organic matter shows as a promising indicator of soil microbial activity
- We measured soil carbon at the Puerto Lopez-Puerto Gaitan study site
- We have developed a method that is capable of extracting amplifiable DNA from soils that are high in organic carbon.

Objective

Our objective was to verify if the soil carbon increase that has been associated with the cultivation of improved pastures occurs in the different landscapes and soil types found in the Colombian savannas.

Methods

To estimate net carbon changes in our study area, we must extrapolate changes in soil carbon measured at experiment sites over the landscape. The two most important landscapes in the Puerto Lopez-Puerto Gaitan area are the *serrania* and *altillanura* (Fletcher and Lombana 1978). The *altillanura* consists of old river terraces with rolling topography; slopes range from 0% to 7%, and soils are heavy textured Haplorthoxes. The *serrania* is made up of dissected older river terraces; soils are lighter, and slopes are up to 50%. Where slopes are gentle, soils are Haplorthoxes and Ustorthoxes; steeply sloping areas are mapped as Entisols and Inceptisols.

CIAT has maintained a research station in the study area at Matazul in the *altillanura* for 9 years. Several studies at Matazul have found that when native savanna is converted to improved pasture an increase in soil carbon occurs (Fisher et al 1994, Gijsman 1996). Most of the study area (80%) is *serrania*, where soils are much sandier, so it is unclear how well these results can be extrapolated.

In June 1997, surface soil at eight sites between Puerto Lopez and Puerto Gaitan were sampled. One site (no. 2) was at Matazul and a second site was at a nearby farm in the *altillanura*. Six sites were in the *serrania*. Each site was at a fence line between native savanna and improved pasture. Samples were taken from both native savanna and improved pasture. Soils were sampled at 0-5 cm and 5-10 cm depth. Table 12 gives site descriptions.

Soils were air dried and analyzed for: total organic carbon (T.O.C.); -carbon as measured by oxidation with a 33-mmol solution of KMnO_4 ; carbon and nitrogen in the sand size fractions of 2000-250 and 250-53 μm , or particulate organic matter (P.O.M.).

Table 12. Description of eight sampled sites between Puerto Lopez and Puerto Gaitan.

Site	no.	Vegetation under		% sand	% clay	Soil series	% slope
		Native savanna	Pasture				
<i>Altillanura</i> :	1	<i>Trachipogon vestitus</i>	<i>Brachiara decumbens</i>	30	45	Ptab	6
	2	<i>T. vestitus</i>	<i>B. brizantha</i>	31	41	Ptab	0
<i>Serrania</i> :	3	<i>Rhynchospora barbata</i>	<i>B. decumbens</i>	62	18	EDde	0
	4	<i>R. barbata</i>	<i>B. humidicola</i>	63	19	EEbc	4
	5	<i>T. vestitus</i>	<i>B. decumbens</i>	71	17	EEbc	10
	6	<i>T. vestitus</i>	<i>B. humidicola</i>	69	18	EEbc	0
	7	<i>T. vestitus</i>	<i>B. dictionebra/ B. humidicola</i>	58	20	Abbc	15
	8	<i>T. vestitus</i>	<i>B. dictionebra/ B. humidicola</i>	60	20	Abbc	3

Results from the two sites in the *altillanura* were clear. At both sites, soils under pasture contained more total carbon, P.O.M., and oxidizable carbon than soils under native savanna. Using only the 0-5 cm surface layer gave statistically significant differences for 2000-250 P.O.M. at 5% for both sites, and for 250-53 P.O.M. at site no. 1. However, when results were combined for 0-5 and 5-10 cm, the only statistically significant results were for coarse P.O.M. (2000-250 μm), which were significant at 5% for site one and 10% at site two (Figure 15).

Results from the six *serrania* soils are harder to interpret (Figure 16). In two of the soils, soil organic carbon seemed to clearly increase with conversion to cultivated pasture, in two others it measurably decreased, and in the other two no change occurred. This variability cannot be explained either by native vegetation, soil texture, or soil series (see Table 13). At site no. 3, T.O.C., 250-125 P.O.M., and ox C. showed statistically significant decreases under pasture, and 2000-250 P.O.M. indicated a statistically insignificant increase. At site no. 6, although carbon increased with pasture installation, 2000-250 P.O.M. levels were lower at 5-10 cm for pasture soils.

More research is needed on *serrania* soils to determine if the decrease of carbon observed in some soils on conversion to pasture is permanent or temporary; and if this decrease is controlled by soil or management factors.

The rough order of sensitivity of the four indices is: P.O.M. 2000-250 > P.O.M. 250-125 > ox C. = T.O.C.

Little benefit came from using oxidizable carbon as measured by the KMnO_4 method compared to T.O.C. Earlier work (CIAT 1997a, 1997b) on sites at Mondomo and Santander de Quilichao, Cauca found that this method was much more sensitive than total carbon. This is less so for these soils from the Colombian savannas, probably because sites in Cauca contain a considerable amount of volcanic material, which fixes carbon in inactive forms.

Altillanura and *serrania* soils showed clear differences in P.O.M.:T.O.C. ratios. The two in the *altillanura* had ratios between 8% and 15% at 0-5 cm depth and for soils in the *serrania*, ratios ranged from 17% to 35%. Absolute values of 2000-250 P.O.M. under native savanna were also statistically significantly lower in soils of the *altillanura* compared to the *serrania* (Table 13).

Table 13. Total organic carbon (T.O.C.) and two fractions of particulate organic matter (P.O.M.) for savanna soils.

Site	no.	T.O.C. (%)	P.O.M. (2000-53) mg C/g soil	Ratio	P.O.M. (2000-250) mg C/g soil	Ratio
<i>Altillanura</i>	1	2.293	1.80	0.079	0.400	0.018
	2	2.296	2.15	0.094	0.370	0.016
<i>Serrania</i>	3	0.927	2.29	0.247	1.130	0.122
	4	0.860	1.60	0.186	0.671	0.078
	5	0.774	1.29	0.167	0.760	0.084
	6	0.809	1.44	0.136	0.673	0.083
	7	1.281	3.07	0.240	1.014	0.080
	8	0.964	1.58	0.164	0.400	0.041

These results disagree with much of the published literature in three respects:

1. The large differences in P.O.M. levels between native savanna and improved pasture for the two *altillanura* sites: nos. 1 and 2 (Matazul).
2. Absolute P.O.M. levels are low for all eight sites, as are the P.O. M.:T.O.C. ratios for the two *altillanura* sites.
3. The large differences in (2000-250) P.O.M. content and overall P.O.M. ratios between the heavier textured soils of the *altillanura* and the sandy soils of the *serrania*.

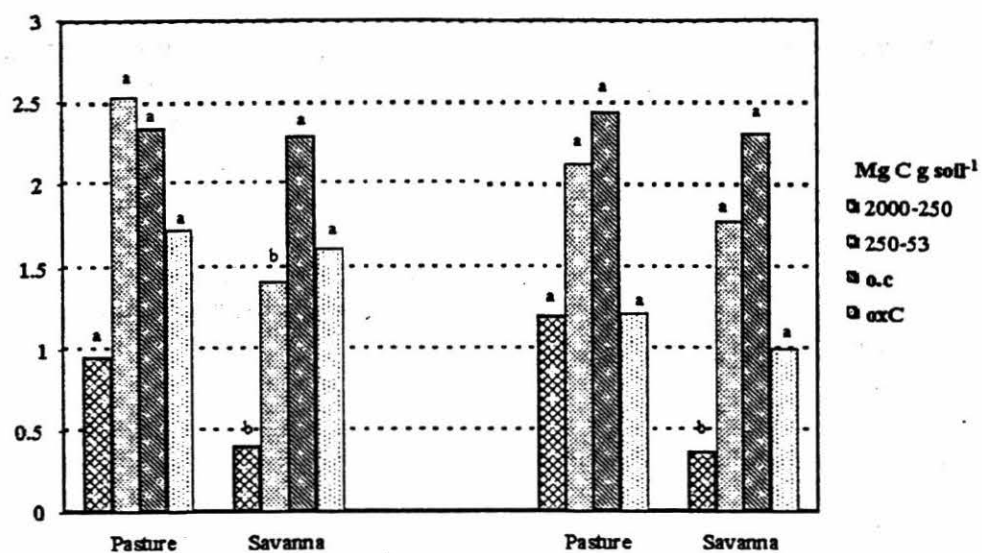


Figure 15. Carbon measured in *altillanura* soils.

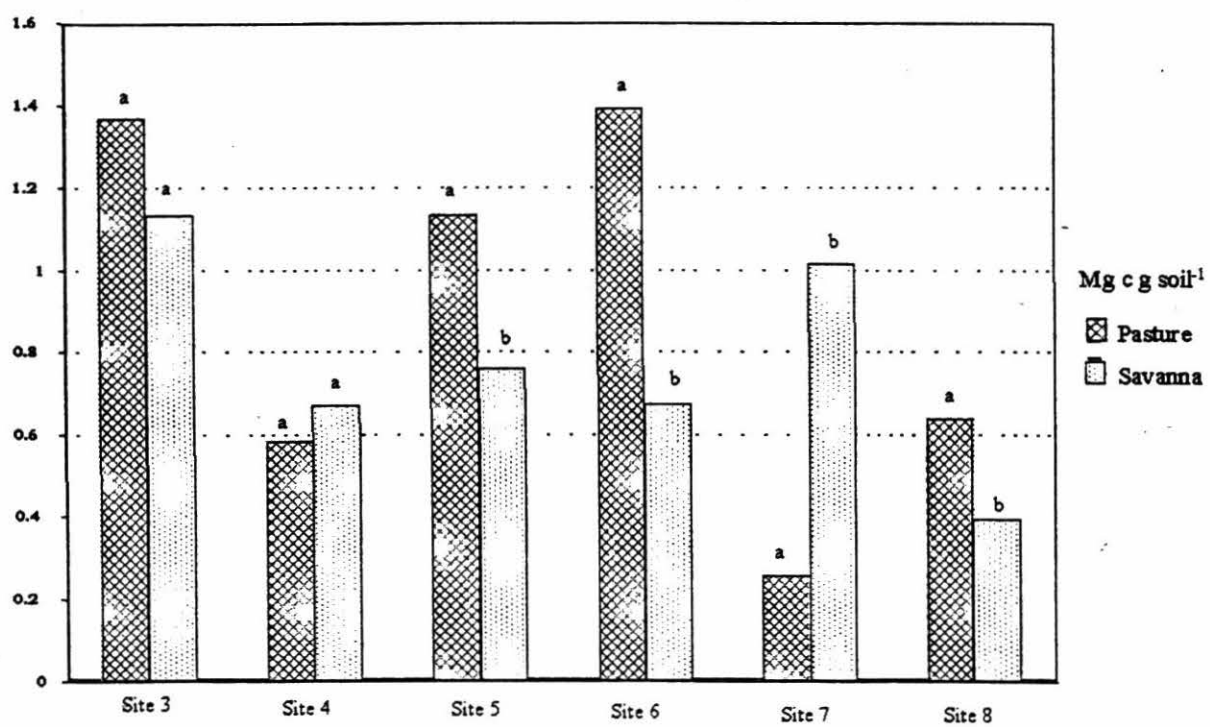


Figure 16. Carbon measured in *serrania* soils.

The most probable reason for the high levels of 2000-250 P.O.M in soils of the *serrania* is that they have low biological activity, which limits the breakdown of the largest fraction of P.O.M. Finer P.O.M. fractions do not seem to be affected. Franzluebbers and Arshad (1997) have found that in cultivated soils of northern Alberta, low temperature and precipitation result in P.O.M. levels and P.O.M.:T.O.C. ratios well above literature values. Several sources (e.g., Jenkinson 1977, Amato and Ladd 1992) have described how litter breakdown is slower in soils of low pH. It is probable then that the low pH and sandy texture of these soils slows P.O.M. breakdown. Comparison of the C:N ratios of P.O.M. from *serrania* and *altillanura* soils supports this interpretation for the soils of the *serrania*.

In these soils a high P.O.M.:T.O.C. ratio indicates low biological activity. The P.O.M.:T.O.C. ratio under savanna weakly predicts how much carbon soils will gain or lose when converted to pasture (r^2 0.69). We cannot draw any conclusions from this as the relationship is only based on eight sites; however these sites were planted to pasture at different times. It would be worth investigating if the P.O.M.:T.O.C. ratio is a useful local indicator of soil quality for soils of the *serrania*; this assumes that carbon inputs under native savanna are roughly equal over the landscape.

Work has continued on the development of a direct extraction method for bacterial DNA from soils (CIAT 1997b). This method was developed on soils that are high in organic matter. Soils that have a lot of organic matter also contain a lot of microbes and thus yield more DNA than more typical soils do. A potential problem is that any method that extracts clean amplifiable DNA from these soils may lose a lot of DNA during cleaning steps. To ensure that this was not the case, our extraction method is being tested on a range of soils close to CIAT-Palmira and CIAT-Carimagua. All soils extracted so far have yielded quantities of clean DNA that correspond to literature values (Table 14). Any further modifications to the method will be on the removal of unnecessary steps or shortening of the processing times to simplify the method.

Once the extraction method has been thoroughly tested, it will be used to extract DNA for fingerprinting of bacterial populations. Community fingerprinting is a new area of research; no consensus exists on which methods work the best. We will try denaturing gel electrophoresis (DGGE) (Muyzer and Smalla 1998) and RISA (Borneman and Triplett 1997) and compare both methods to the reassociation method. Links have been established with Dr van Elsas at Wageningen who has agreed to supervise the thesis of the PhD student involved in this project. Dr van Elsas also has provided advice with the extraction method.

The Humbolt institute will also begin work on soil bacterial diversity. In late 1998, a student will arrive to begin work on a survey of soils of the coffee region near Armenia. The Humbolt institute has also planned work on the soils of the Colombian Amazon. We are discussing coordination of methods and purchases to produce comparable results and reduce costs.

Table 14. Some characteristics of soil samples taken to date.

Soil order ^a	Parent material	Land use	Texture	Organic carbon (%)	Slope (%)	pH
Haplic Kastanozem	Levees, splay material	Tobacco	Sandy loam	4.0	0	6.3
Humic Cambisol	Sandy conglomerate	Secondary forest	Sandy loam	3.2	30	4.6
Lithosol	Diabase	Natural fallow	Loam	3.5	50	6.8
Haplic Kastanozem	Flood plain sediments	Bamboo (Guadual)	Loamy clay	17	0	5.8
Anthrosol	Artificial amendments, sand	Garden	Loamy sand	25	0	7.5
Ferralsol	Old river terraces	Native savanna	Clay	2.3	0	4.5

a. According to Food and Agriculture Organization (FAO) classification.

Output

A method that is capable of extracting amplifiable DNA from soils that are high in organic carbon is now available and being thoroughly tested in the field. Our work on indicators makes it possible to characterize and identify soil bacterial flora, which will be a very useful indicator of soil health and biodiversity. Final results on carbon changes in our study area will be ready in 1999.

Activity 3.6 MULTISCALE MODELING METHODOLOGY FOR ANALYZING LAND USE AND AGRICULTURAL DYNAMICS

Activity 3.6.1 Classifier system prototype

Contributors: Euan Crawford (University of Edinburgh), Grégoire Leclerc (PE-4/PE-3), William Bell (IS), and William Mackaness (University of Edinburgh)

Highlight

- We developed a Classifier System Prototype for the exploratory analysis of spatial data.

Objective

Current spatial analysis techniques, whether conceptual or widely used, are not powerful enough to allow us to release the empirical regularities that exist amongst the noise in large spatial datasets. This study details the development and implementation of a prototype classifier system that searches for rules and relationships among spatial data.

Methods

The technique was built on work by Crawford (1997). Holland classifiers (Holland 1975) are essentially expert systems that incorporate elements of inductive learning and rule creation, and are particularly adept at producing solutions to highly complex problems that cannot be solved analytically. They comprise three main elements:

- A standard classifier system: a rule base and message board,
- A learning and induction system: bucket brigade algorithm, and
- A rule discovery system: genetic algorithm.

A system prototype was developed to test the applicability of the classifier system to the exploration of spatial data. The system incorporates elements from both the standard Holland classifier and Wilson's (1987) Animat classifier, with a number of modifications.

The use of a ternary alphabet (0,1,#) to represent rules and environmental input has the advantage of allowing the standardisation of many, potentially diverse, datasets. Coupled with the ability to use fixed length registers in the CPU for simple string-matching, rapid processing is possible. However the system was designed for use with a decimal alphabet to easily represent and interpret results. System trials used rules and environmental input represented by the alphabet {0,1,2,3,4,5,6} with '6' acting as a wild card (#).

The system searches for rules by scanning the study area from upper left to bottom right. At each grid cell the values in the corresponding datasets are recorded and mapped to a single chromosome of the form described earlier (Figure 17). Comparisons are then made between each rule in the rule base and the input string. The number of matches, including wild-card matches, is recorded for each rule. The remaining steps in the algorithm are carried out before proceeding to the next cell.

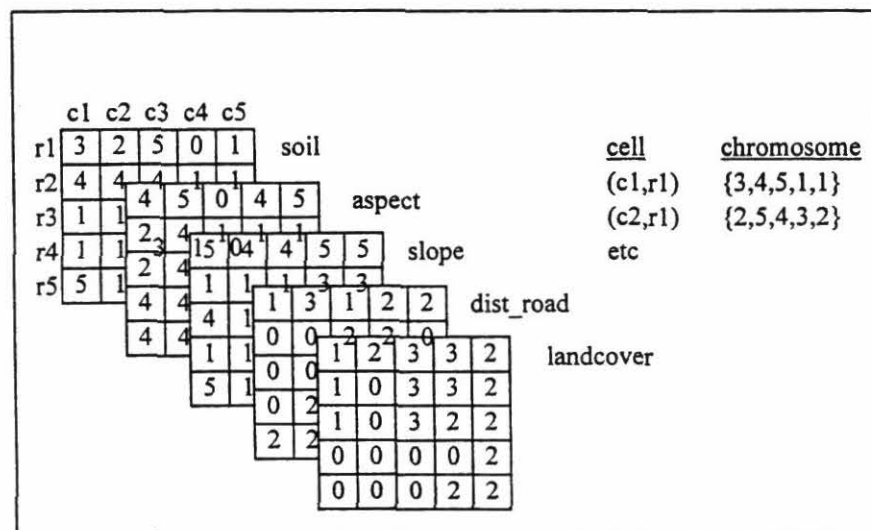


Figure 17. Environmental input (five 5*5 rasters).

The algorithm builds a condition set (rules that fully match the condition part of the input data), then a decision set (the rule with the greatest strength plus all rules with same outcome), which is tested against the input data to establish whether the system provided the correct decision. Depending on the decision, each rule from the decision set receives a pay-off, which depends on the number of matches with the input data. The system also includes the capability to levy taxes on rules to control the way the system learns. Finally, after the rule base has been matched with the input string and rewarded accordingly, genetic operators' crossover and mutation are employed to speed-up solution discovery.

Testing was carried out using five artificially generated spatial datasets corresponding arbitrarily to soil, aspect, slope, distance from road, and land-cover data. The latter is treated as the outcome and the preceding four layers form the condition. Each dataset is stored as an ASCII raster.

The datasets were generated containing known regularities or rules. The system was tested by incorporating a performance algorithm to monitor the percentage of rules in the rule base that corresponded to one of the known rules. This, in effect, measures the ability of the system to learn by recognizing regularities and adapting the rule base accordingly.

For each trial the rule base was populated with 250 randomly generated rules. Rules were generated by setting each allele (except those in the outcome part) to either # or a value from the set {0-5}, each with a probability of 0.5. Each trial was run for 45 generations (one generation is equivalent to every rule being matched once with every cell in the input data) over rasters of size 8*8. Payoff was set to 1000, g to 2, and $1/cr$ to 0.5 after initial experimentation. All tax values were set to zero to limit the number of variables for testing.

Results

Figure 18 shows results from a simple trial where the input data contained only three randomly placed rules and no random noise ('non-rules') with $1/mt$ set to 0.015. The upper series (total) represents the percentage of the rule base that corresponds to any one of the three known rules, and the other three series (rule 1-3) correspond to the discovery of individual rules as a percentage of the entire rule base. As the total shows, the system rapidly recognizes, learns, and populates itself with known rules. Although the total reaches close to 100% after six generations, the population is initially dominated by rule 1 and, to a lesser extent, rule 2. The system only 'discovers' rule 3 after eight generations. Thereafter rule 3 becomes more widely represented, at the expense of rules 1 and 2. After 25 generations, the system appears to reach a stage of equilibrium with only minor changes in the composition of the rule base.

The randomly populated rule base (zero generations) contains solution matches. Although the theoretical probability of random generation of any one of the known rules is low, the high percentage of wildcards in the initial population (50%) increases the probability greatly (the performance algorithm includes rules with up to three wildcard matches). The graph shows that the initial rule base did not contain any rules matching rule 3. The system required time to search the solution space and adjust itself to present a successful system decision.

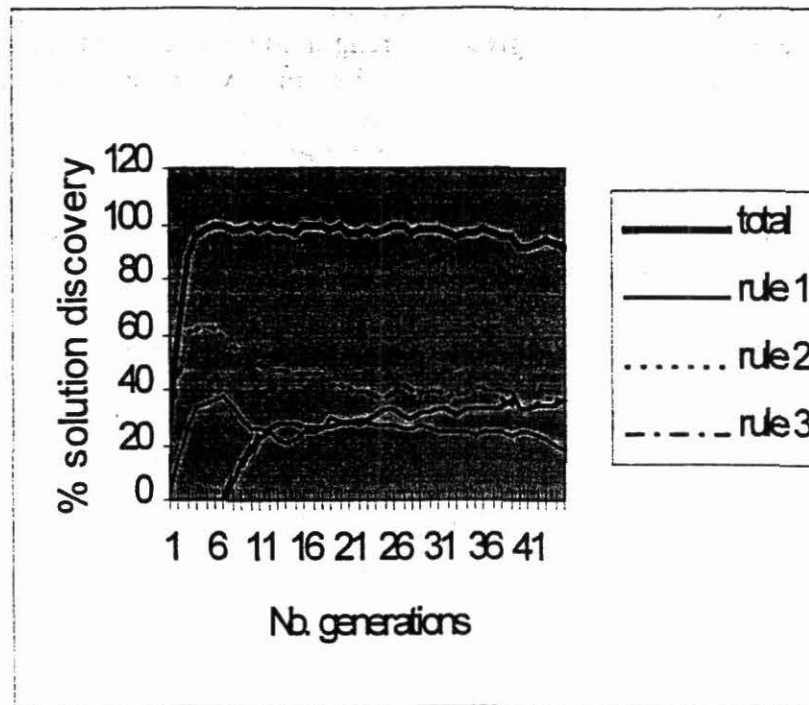


Figure 18. Results of a simple trial.

A number of trials were run to explore the performance and robustness of the algorithm:

1. Trials on a dataset with no regularities (no more than one occurrence of a rule) showed that sometimes rules that did not exist were "discovered".
2. Mutation rates had marked effect on learning, which stressed the need for a strategy that uses accumulated knowledge of the rule base.
3. Trials on noisy input data (data containing both known rules and random noise) showed that the system found the rules, although with less success than for clean data (90% instead of 97%).

The system was coded in C (csp.cpp and csp.h) using the Borland C compiler (V 4.5) under Windows 3.1. Although written for a 16-bit operating system (OS) it is anticipated that few changes would be required for porting to a different OS.

The system was designed to explore the applicability of the classifier system rather than achieve high performance levels. With limited attention paid to program optimization processing speed can be slow. For a trial with a rule base of size 300 and five 8*8 input raster processing time on an RM PC-466 (486) is 34 m and on an RM PC-575 (75 Mhz Pentium) is 21 m. For trials with real, significantly larger, datasets some form of optimization would clearly be required. The use of a more restricted alphabet to represent rules and data input may help in this respect.

Datasets must be stored as ASCII rasters of equal dimensions. The system can, theoretically, handle any number of datasets, of any size. However, limitations are imposed by the memory capacity of the hardware running the system.

The algorithm includes a bounds checking function. The rules are coded as integer arrays and this function makes period checks for rules with strengths approaching INT_MAX to avoid system crashes. Although unnecessary for most trials, it avoids problems where large datasets are processed over many generations.

An immediate advantage of the technique over statistical methods is the ability to incorporate both interval and categorical data. This would allow analysis of the conditions giving rise to low income and poverty by incorporating biophysical (soil, slope etc.) and socioeconomic (land tenure, farming practices etc.) data. Analysis should aim to incorporate as many factors as possible, with little a priori concern for which data might be relevant. If the system is run over a sufficiently large number of generations it will identify particular sets of conditions that give rise to particular outcomes with irrelevant data simply represented by wild cards in the rule base.

Where a priori theories or hypotheses about the nature of regularities in the data are held, they can be incorporated as rules, seeded in the rule base. Over a number of generations, the proliferation or extinction of these rules should help determine their validity.

Outputs

The system provides, at the least, the basis for a technique that can be used for the exploratory analysis of 'real world' spatial data. The system has a large number of potential applications. As the arbitrary naming of the test datasets implies, the system could be used to look for evidence regarding the causes of soil erosion, marginal cropping, and other unsustainable practices

Activity 3.6.2 Multiscale characterization of Honduran agroeconomic systems

Contributors: Andrew Nelson, Gregoire Leclerc, Ron Kanpp (PE3), and Stan Openshaw (University of Leeds)

Highlight

- A model was developed for the interactive exploration of spatial point patterns across geographic scales.

Objective

The aim was to make a multiscale characterization of Honduran agroeconomic systems for targeting problems, priority areas, and beneficiaries.

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 15 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 15. 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 19 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 to 4.
6. When all points have been examined, map results.

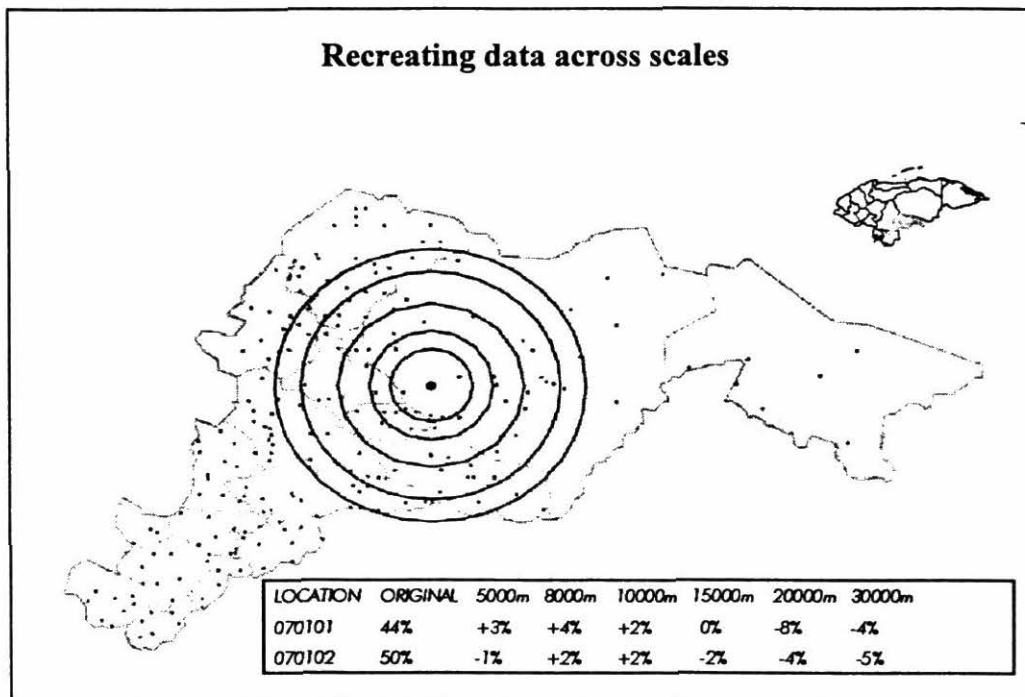


Figure 19. Illustration of the concept of point-centered aggregation.

In Figure 20 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 two scales are shown in Figures 21 and 22. 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.

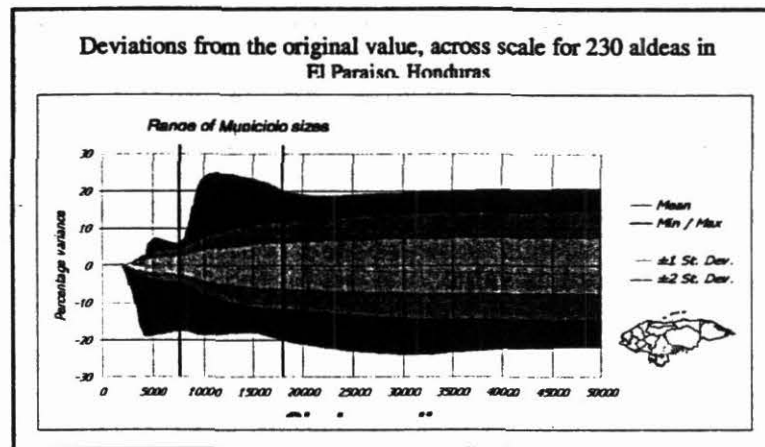


Figure 20. The change in a variable across scale shown by highlighting the averaging out process that occurs through aggregation.

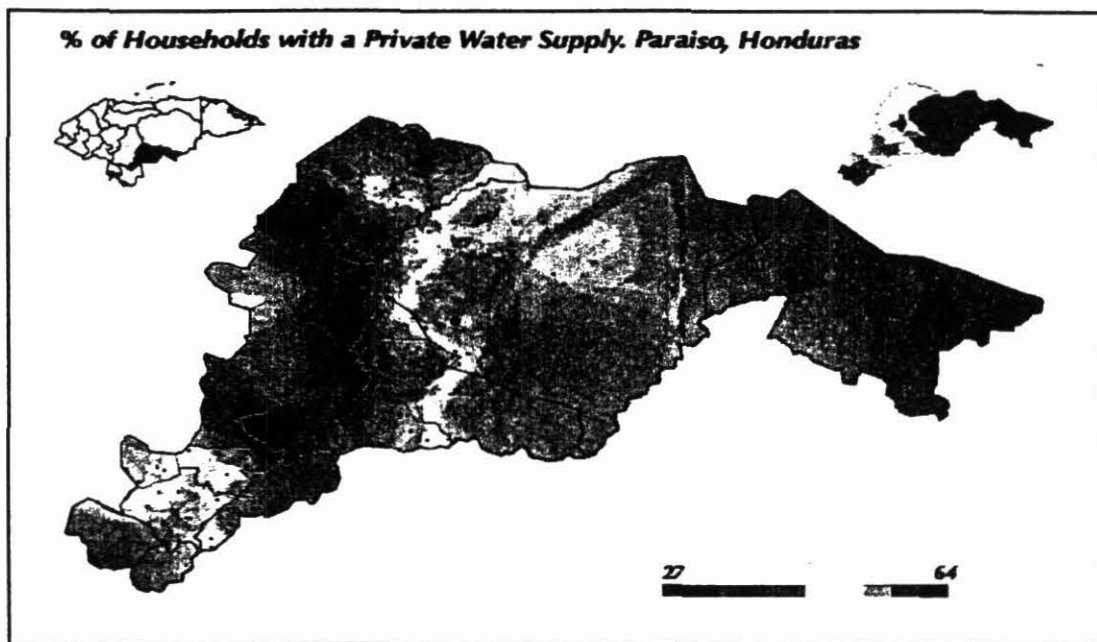


Figure 21. A Kriged surface of the original village (point) data.

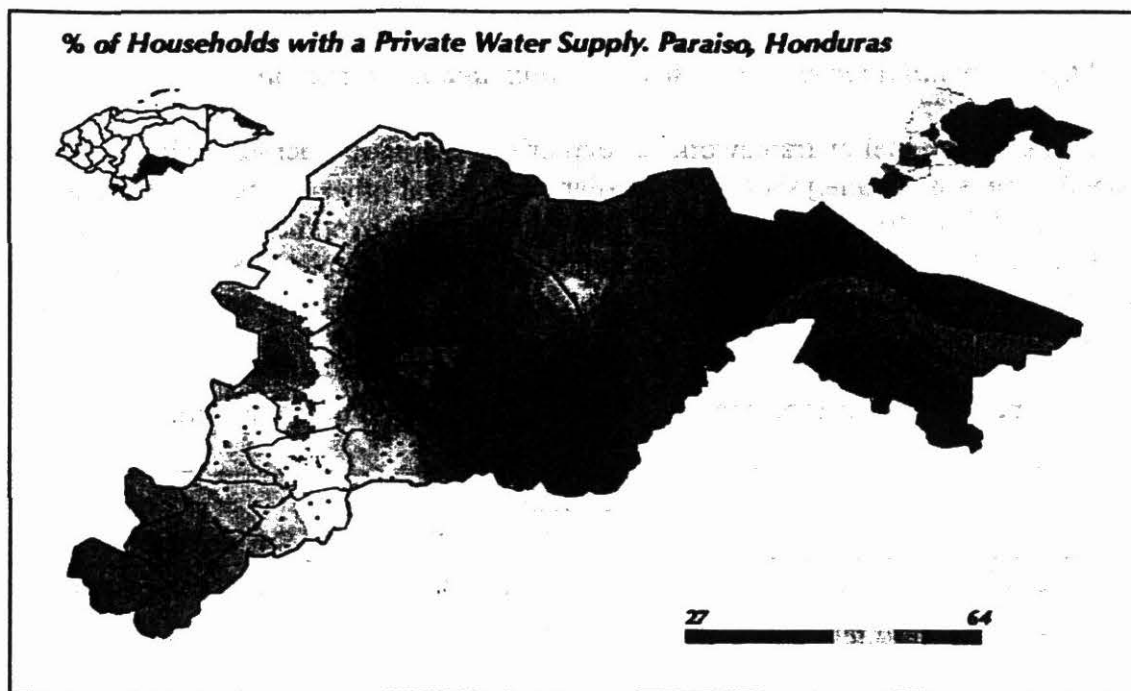


Figure 22. A Kriged surface of the data aggregated with a circle radius of 20,000 meters. This circle size gives an area equivalent to the average Honduran municipality area. The municipality map is shown (top right) as comparison. Clearly the municipality map does not give a fair representation of household water supply.

It is easy to relate the artificial scale (circle size) to real geographical entities, such as villages, municipalities, watersheds, micro-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 rule-base 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 16 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 16. Spatial analysis tools that will be incorporated into the framework.

Point data	<u>Analyses</u>	
	Areal pattern	Surface data
<i>Point centered aggregation</i>	<i>Zone design</i>	<i>Smart interpolation</i>
<i>Geographical analysis machine</i>	Spatial lag plots	<i>Pycnophylactic interpolation</i>
Geographical explanation machine		<i>Dasymetric interpolation</i>
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.

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.

Outputs

We have developed a tool kit for exploratory spatial data analysis (Figure 23). 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.



Figure 23. The user interface for aggregating and visualizing agroeconomic census data.

Activity 3.6.3 Comparison of areas obtained from census with areas from land use mapping from remote sensing imagery.

Contributors: Julie Cox.

Highlight

- Satellite and air photo imagery processed and land cover classified for the Honduran Departments of Atlantida, Yoro, and El Paraiso.

Objective

To georeference national demographic data and compare with mapping from remote sensing sources at various scales of geographical aggregation. This allows communities to visualize current and past land use and plan future land use.

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. More details can be found in Cox, 1998. (ref to Julie's technical report).

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.

Output 4 Developed and defined policy relevant environmental and sustainable indicators

Activity 4.1 ENVIRONMENTAL AND SUSTAINABILITY INDICATORS CD-ROM

Contributors: Manuel Winograd and Andrew Farrow

Highlights

- Version 1 of the Environmental and Sustainability Indicators CD-ROM ("Atlas CD") was distributed, in particular to Central American countries.
- A press conference was held in Washington, USA to promote the use of the Atlas CD.

Objectives

For indicators and information tools to be useful, they need to be distributed to the users and kept updated. Based on the products of the first phase of the UNEP-CIAT project (Atlas CD), the indicators CD-ROM will be continually updated to develop a second version in 1999 for LAC. The updating activities will also be useful for testing and refining the indicators for the test studies in Central America.

Methods

The first steps in improving policy-making and creating capacity building in the use of information tools are related to the production and distribution of the information tool. Thus the Atlas CD was broadly distributed in the region to help policy-makers in using information tools. During the visits to the regional and national institutions in Central America, the Atlas CD was distributed free and installed in all institutions to obtain feedback from users, show the use of indicators, and to obtain new data and indicators. Three hundred and twenty copies of the Atlas CD have been distributed to date (Figure 24).

Outputs

The agreements of cooperation with national and regional institutions should be based on the exchange of information. The distribution of the Atlas CD fulfilled the first goal of the project, related with producing and distributing information. A series of comments to improve the new version of the Atlas CD was received. At the same time, the usefulness of the production of information is related with the use made of the information. For this reason, the press conference and all of the activities related with the diffusion of the tools were great successes for the project (i.e., bilingual flyer distributed via e-mail, newspaper articles etc.).

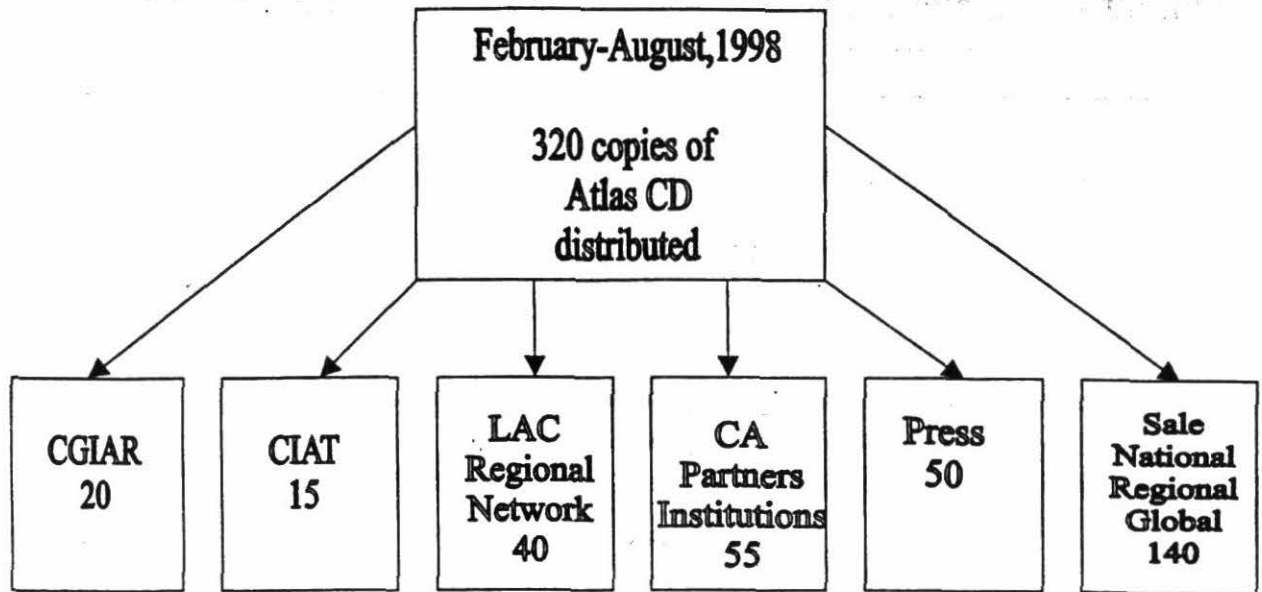


Figure 24. Distribution of Atlas CD.

Activity 4.2 BIODIVERSITY QUANTIFIED AND MAPPED AT LOCAL, NATIONAL, AND REGIONAL SCALES

Activity 4.2.1 Gradient analysis

Contributor: Grégoire Leclerc

Highlights

- The parametric method developed is an application of known image processing algorithm Maximum Likelihood.
- The non-parametric method developed is a multiscale probability estimate performed on fuzzy clusters.

Objective

All living organisms are adapted to specific environments; a way to understand this adaptation is Gradient Analysis, or the analysis of the response of a system to environmental gradients. Our objective is to be able to quantify and predict this response, considering any number of environmental dimensions.

Methods

We developed two methods: a parametric one to apply for the Gaussian response of the system; and a non-parametric one to apply in the case where we cannot assume any functional. When properly field-tested, these methods will be integrated into a biodiversity mapping toolbox. More details can be found in Leclerc et al. (1998)

Parametric method

The Maximum Likelihood Classifier (MLC), a well-established technique used for the classification of remote sensing images, is fundamentally simple. From ground-truth training sites (areas on an image where the interpreter knows what is on the ground), basic statistics are computed (such as mean and standard deviation) for each spectral band, and the correlation matrix between bands. The assumption is that a given class has a normal probability distribution in the N-dimensional space of surface reflectivity, and that this probability distribution can be computed from the training sites statistics. All the work is therefore contained in the delineation of training sites of adequate meaning and size.

This approach is so similar to Gradient Analysis that we can use the highly efficient tools that have been developed for RS image classifications to perform such analysis. We here briefly describe the underlying mathematics of MLC and show how it can be applied to gradient analysis.

Let X be a vector corresponding to a single pixel in an N-dimensional space image (it can be surface reflectivity, monthly temperature, solar radiation, soil pH, etc.). For each training site for class c , one can compute a mean vector M_c , and a covariance matrix V_c for all the bands, and a probability distribution can be derived (i.e., each band contributes differently to each class according to a Gaussian probability distribution). Class c will be assigned to an unknown pixel with vector X if the probability $P(X|c)$ of being a member of c is greater than for any other class. To speed computer processing time, the decision is generally done based on $\ln [P(X|c)]$:

$$P(X|c) > P_i, i=1, 2, \dots, m \text{ possible classes} \\ \ln(P_i) = \{-0.5 \ln(|V_c|)\} - [0.5 (X-M_c)^T V_c^{-1} (X-M_c)] \quad (1)$$

where $|V_c|$ is the determinant of covariance matrix V_c . This approach is largely based on the statistical technique of discriminant analysis. The matrix notation greatly simplifies the expression of a normalized N-dimensional Gaussian probability distribution and matrix algebra greatly speeds up computation. Using a covariance matrix gives a result equivalent to a regression of an N-dimensional Gaussian through a cloud of points in N-space defined by the training sites.

In effect, for the one-dimensional case we have:

$$V_c = \frac{1}{N} \sum (x - \bar{x})^2 = \sigma^2 \quad (2) \\ |V_c| = \sigma^2$$

and

$$\ln(P_i) = -0.5 \ln(\sigma^2) - 0.5(x - \bar{x})^2 / \sigma^2 \quad (3)$$

therefore:

$$P_i = \frac{1}{\sigma} e^{-\frac{(x - \bar{x})^2}{\sigma^2}} \quad (4)$$

which is a one-dimensional Gaussian of half width σ . From this example one can see that the probability distribution is normalized in such a way that the total probability (the integral of P_i from $-\infty$ to $+\infty$, or the surface under P_i) is equal to one.

For a given pixel with vector X , P_i is computed for each class i , and the pixel is assigned the most probable class (i. e., the one with greater P_i). Therefore, partition of N-space is achieved based on all the $P(X|c)$. Note that P_i is normalized by $|V_c|$, to have a total probability (the volume within P_i) equal to one. Class membership $L(X|c)$, the relative probability that a pixel X has been classified in class c , gives a mean to evaluate how well a pixel has been classified, and is exactly the output needed for Gradient Analysis. It can be computed as follows:

$$L(X|c) = \frac{P(X|c)}{\sum_{r=1}^m P(X|r)} \quad (5)$$

where r is the number of classes.

The parametric method has been developed using the image processing software PCI 6.2. Through the use of this software, hundreds of functions (statistical, display, and import/export) are then available to support exploratory gradient analysis. For testing, we chose the *Phaseolus vulgaris* locational data and the 36 rotated climate surfaces at 30 arc-second resolution (Jones et al 1997). First we produced surfaces of the first four principal components (PCs) from the 36 climate surfaces (program PCA). By analyzing the scatterplot of the distribution data with respect to the PC (Figure 25), we found two well-defined clusters. Using a fuzzy clustering algorithm (program FUZCLUS) we grouped the accessions in two clusters (ellipses of 3σ are drawn on Figure 25). We then computed the signatures for each cluster and ran the ML classifier (program MLC – figure 25). The method is straightforward, and efficiently implemented through commercial image processing software.

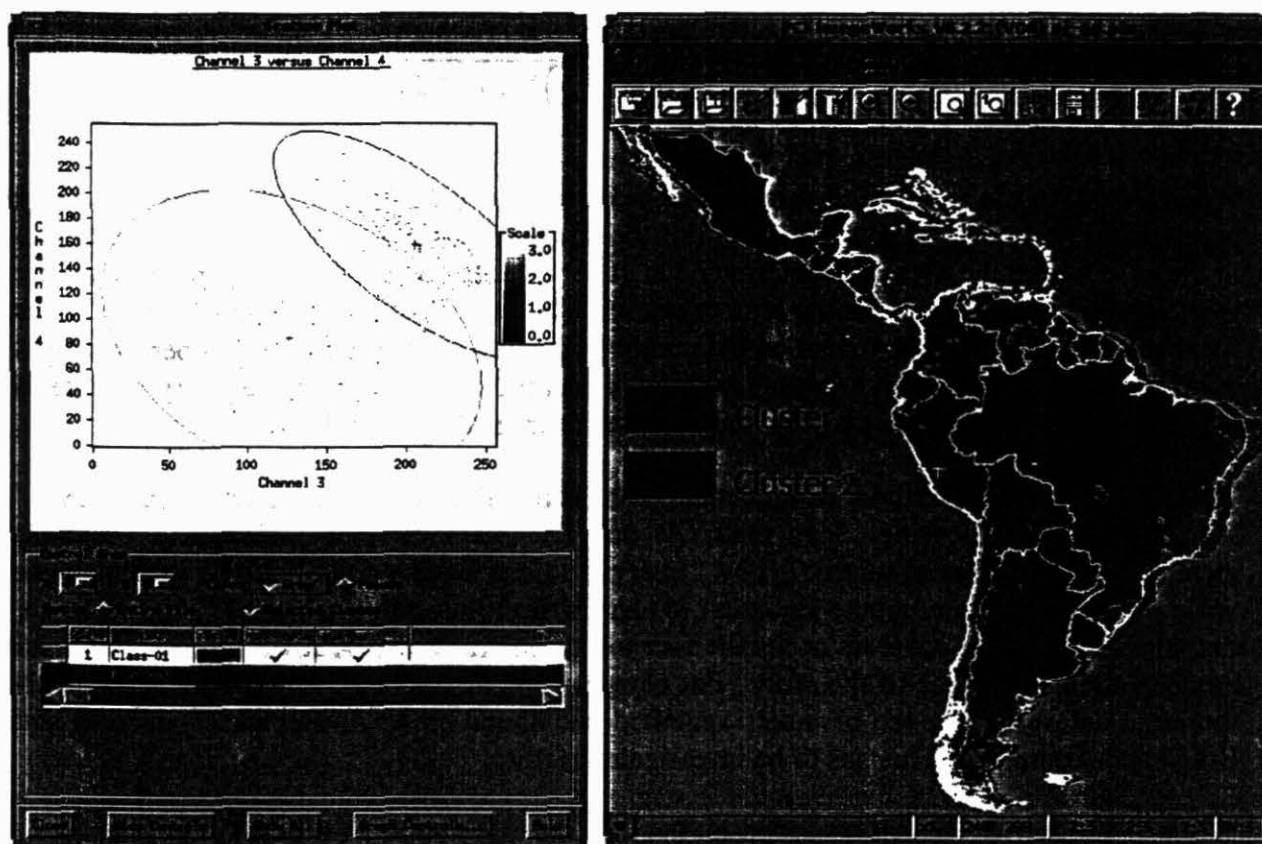


Figure 25. Left: Scatterplot of the distribution data with respect to the first and second principal components. Right: MLC classification into 2 clusters ($P > 0.5$).

Non-parametric method

This method is inspired by Skidmore (1998), with additional considerations on random sampling.

We simplify Skidmore's approach by converting multidimensional data to one dimension by means of Unsupervised Fuzzy Clustering (an unsupervised implementation of the MLC). This allows us to calculate only on one variable (cluster number). In addition, we take into account the random case, i.e., that if presence areas are drawn at random, the probability of presence is zero.

All calculations are based on two maps, A and B. Map A, a theme map, has two classes. The first represents the unsampled area where we want to restrict the analysis (for example bean-growing areas), and the second represents the sampled areas (for example where bean golden mosaic virus [BGMV] occurs). The sum of the area of the two classes gives the total area of interest. Map B, a cluster map, is obtained by fuzzy clustering of climate variable, and eventually crossed with other categorical data.

$P(i)$, the probability of finding the sample in cluster i not due to chance is given by:

$$P(i) = \frac{N(i,2)}{\sum_i N(i,2)} \cdot \frac{N(i,1)+N(i,2)}{\sum_i [N(i,1)+N(i,2)]} \quad (6)$$

Where $N(i,2)$ is the number of sample pixels within cluster i , and $N(i,1)$ number of unsampled pixels within cluster i . The second term of the equation corresponds to the probability obtained in the case where the areas are determined at random, i.e., proportion of cluster i cells compared to the total number of cells in the area of interest. Negative values of $P(i)$ are set to 0. Because the results depend to some extent on the number of clusters chosen and the number of samples, a multiscale approach gives a better solution. We produce a set of probability surfaces (for example 8, 16, 32, 64, 128, and 256 clusters), then average the probabilities.

The non-parametric method is implemented with the EASI+ script PROPPROB.EAS. The sequence is the following: Scan map (A) and (B) pixel by pixel, and fill a matrix(i,j) by incrementing the value of matrix(i,j) by 1 every time one finds a cell of cluster i within an area of value $j=1$ or 2. Then compute Equation (6) and write to an output channel (*100 to fit an 8-bit output channel). The program needs the user to set the parameter VALU to the maximum cluster number, to limit the size of the array. For comparison, we applied the non-parametric method to the same dataset as for the parametric method and found small discrepancies in areas south of Brazil and Argentina. This has to be investigated further.

We also applied the non-parametric method to the distribution of BGMV in Nicaragua (see Activity 5.1.2). Figure 26 shows the average of the probabilities obtained from 16, 32, 64, 128, and 256 fuzzy clustering. This map shows areas of high risk that have not been affected yet by the BGMV and therefore need immediate attention.

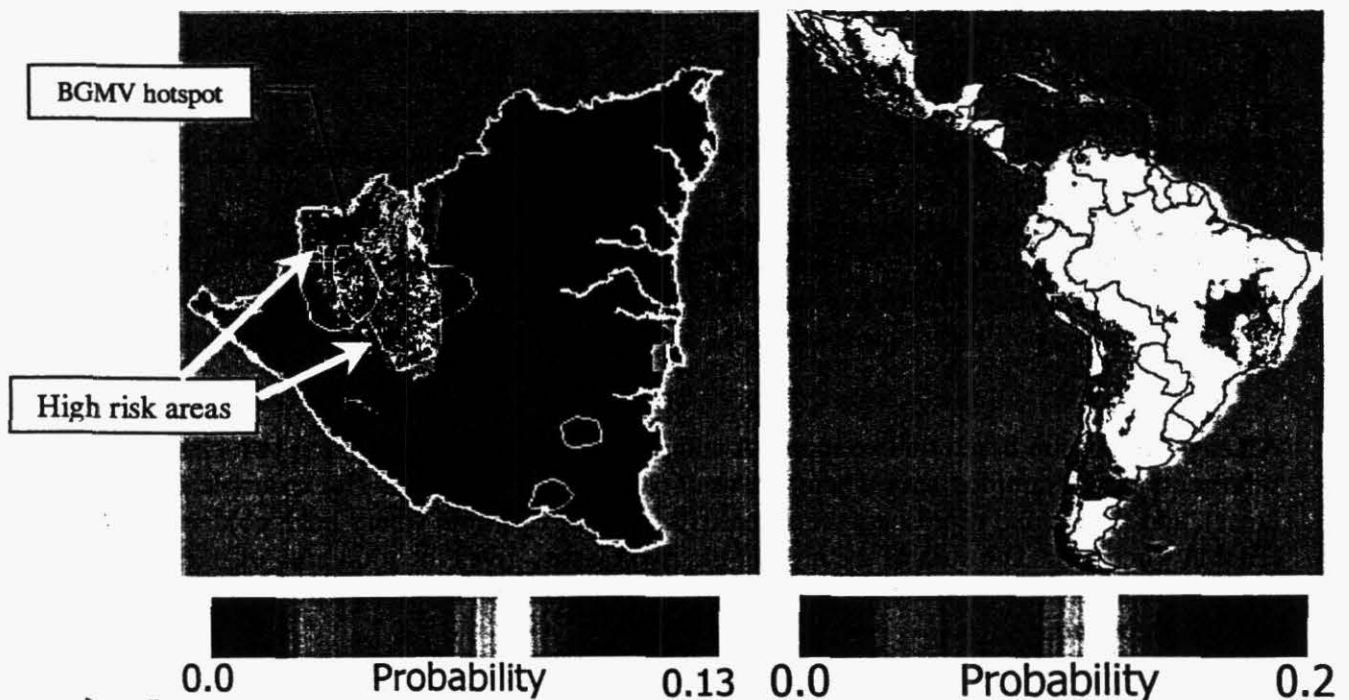


Figure 26. The average of probabilities obtained from 16, 32, 64, 128, and 256 fuzzy clustering. Left: BGMV; Right: *Phaseolus vulgaris*

Outputs

Examples of applications are:

- To predict where the probability of finding a particular specie is maximum,
- To predict where we are more likely to find a hot spot of pests similar to the ones already detected, and
- To find the growth response of a plant, so we can fine-tune breeding programs.

When properly tested, these methods will be integrated into a diversity analysis toolbox.

Activity 4.2.2 Spatial analysis of intraspecific diversity

Contributors: Andy Nelson, Grégoire Leclerc, Mikkel Grum (International Plant Genetic Resources Institute [IPGRI]), and Ian Dawson (IPGRI)

Highlight

- A new method for computing intraspecific diversity based on genetic distances has been developed and applied to *Irvingia* distribution in West Africa.

Objective

The focus of this work is the analysis of within-species diversity based on a combination of quantitative and qualitative characterization data. This is used to create a diversity index for each individual by calculating a distance-weighted mean of the dissimilarity values of all its neighbors. When properly field-tested, this method is to be integrated into a biodiversity mapping toolbox.

Method

The differences between individuals for one or more traits are used as an estimate of, or surrogate for, the genetic distance between the individuals. The idea is to find the best metric measure for the data available.

We subjected the quantitative characterization unstandardized data to a principal components analysis to reduce the effects of colinearity. The principal component scores with Eigen values over 1 were selected for further analysis. The qualitative characterization data were analyzed using a correspondence analysis, which basically analyzes the frequency of responses. The results provide information, which is similar in nature to that produced by factor analysis techniques, and allows one to explore the structure of categorical and binary variables.

The computation of the coordinates is based on the generalized singular value decomposition of P , as:

$$P = A D_u B',$$

so that

$$A \text{ inverse}(D_r)A = B' \text{ inverse}(D_c)B = I$$

Where P is the matrix of relative frequencies (i.e., each element of P is computed as the respective frequency from the input table divided by the grand total of all values); A is the matrix of the left-side generalized singular vectors; B is the matrix of the right-side generalized singular vectors; D_u is a diagonal matrix with the diagonal elements equal to the generalized singular values; and I stands for the identity matrix (a diagonal matrix with 1s in the diagonal).

The column coordinates are computed based on the column profile matrix. Specifically, the principal column coordinates are computed as

$$F = \text{inverse}(D_c)BD_u.$$

The resulting principal component scores and correspondence analysis coordinates are then standardized so that all values of selected variables are replaced by standardized values computed as follows: $\text{Std. Score} = (\text{raw score} - \text{mean}) / \text{std. deviation}$. The standardized variables are then used to calculate Euclidean 'genetic' distances between individuals in the population. To produce a spatial representation of diversity, the standardized 'genetic' distances are then used in the calculation of a spatial diversity index. It involves the calculation of the dissimilarity of the individual from all other individuals as proposed here:

$$G_i = \sum_{j=1}^N g_{ij}^2 \exp\left(\frac{d_{ij}^2}{R^2}\right) \quad (1)$$

Where G_i is the dissimilarity index for observation i , g_{ij} is the genetic or morphological distance or dissimilarity from observation i to observation j , d_{ij} is the equivalent geographical distance, and R the search radius. As a refinement to the analysis a DEM can be used to calculate the geographical distances considering friction.

We used data from field studies of *Irvingia*, a West African fruit tree species, for testing the method (Figure 27). The principal components, the correspondence analysis, and the standardization of the respective scores were done in Statistica 5.1 for WINDOWS 95. The matrix of Euclidean distances was then calculated in SAS version 6.12 for UNIX using a macro that also performs a cluster analysis. This macro also uses a bootstrap procedure to calculate standard error and intervals of confidence on a specified number of nodes. This can be used to compare qualitative and quantitative characterization data taken separately or together. We wrote spatial intraspecific diversity (SID) in C and Visualizing Diversity (vid) in Tcl/Tk under Unix to compute the dissimilarity indices. We also have the results of the Shannon-Weaver index for comparison. These were obtained using the point-centered method developed in 1997 (CIAT 1997b).

Output

The method successfully produced a diversity index for *Irvingia*, a West African fruit tree species, and can now be used for other species.

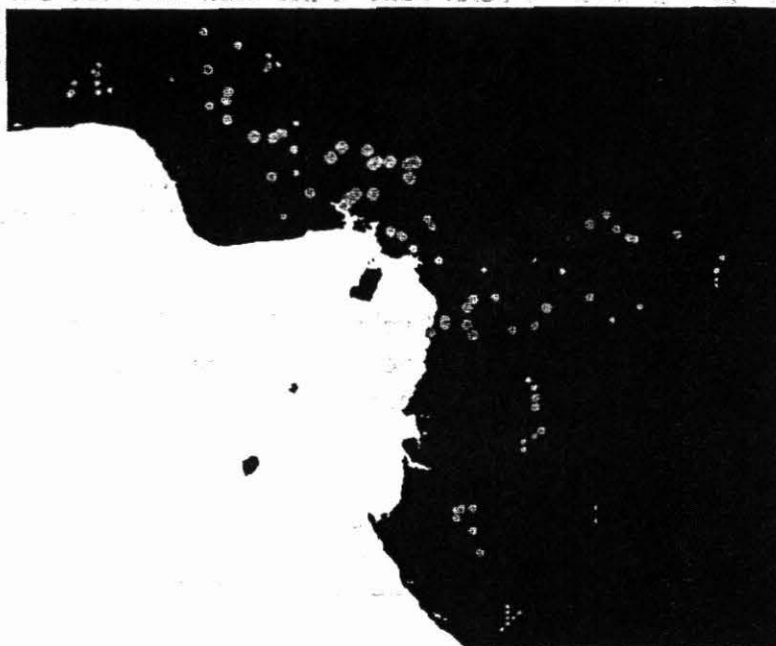


Figure 27. Circle plots of Genetic-Index for *Irvingia* distribution in West Africa (1 degree search radius).

Activity 4.2.3 An assessment of the spatial distribution of neotropical food crop diversity in Peru

Contributors: Ernesto F. Ráez-Luna, Glenn Hyman, and Germán Lema

Objective

Understanding the factors that are related to the high diversity of crops in agricultural systems would advance conservation of cultivated species. This activity is an attempt to discover relationships between the number and diversity of crops cultivated and some socioeconomic and environmental characteristics in different districts of Peru.

Methods

We used data from the 1994 Agricultural Census of Peru (INEI 1995) to obtain a snapshot assessment of the distribution of Neotropical food crop biodiversity in Peru at the *distrito* level (fourth administrative division). We used the census report of hectares cultivated by food crop

species and by *distrito* to calculate richness (number of species) and overall diversity (Shannon-Weiner index, H'). We explored the association of food crop diversity to **sample size** (total agricultural surface), **ecological diversity** (altitude range), **rural economic inequity** (slope of the cumulative distribution of people with 0 to 5 unsatisfied basic needs), **age of the rural population** (percentage under 15 years old), and **food security** (occurrence of chronic malnutrition among children in the first year of primary school) per *distrito*. Finally, we assessed threats to the most diverse areas in terms of percentage of non-cultivated land due to ecological degradation (water scarcity and soil erosion), socio-economic factors (lack of credit, labor scarcity, and lack of seed), and political violence per *distrito*. This exercise allowed us to obtain a preliminary identification of conservation priority hotspots.

We used a sample of 1739 *distritos* (96.5%) and 90 Neotropical species (out of 285 species and varieties recorded in the census), representing 116,864.2 hectares of cultivated land in 1994 (out of 2'576,791.7 cultivated hectares).

Figure 28 identifies the *distritos* with a calculated value of H' within the upper 5, 10 and 15 percent most diverse *distritos*. Three patterns are worth mentioning. First, there are important concentrations of high-diversity *distritos* in the Andean valleys of the departments of Cajamarca and Piura (Northern Peru), and in the departments of Lima and Ancash (West-Central Peru). These appear as the most important concentrations of food crop diversity in Peru. Second, the most diverse *distritos* of Peru arrange themselves along the Western and Eastern slopes of the Andes, largely between 600 and 3500 m of altitude, in the Yungas biogeographic region and along the Western agricultural valleys. Third, the Amazon lowlands seem to have relatively low diversity.

Outputs

Next year, we will conduct a more detailed analysis of the information. Further efforts along this research track will include at least five main lines of inquiry: (1) exploration of diversity patterns at less aggregated scales, and their relation with aggregated patterns; (2) exploration of spatial relations between inter-specific diversity, intra-specific diversity, and wild relatives of crop species; (3) identification and ecological-economic characterization of farming systems associated with high diversity; (4) study of agriculturally-significant organisms associated to high-diversity agroecosystems (soil microbia and macrofauna, insects, small vertebrates); and (5) study of the ecological and socio-economic factors and dynamics that determine the existence and enhancement of highly diverse agroecosystems.

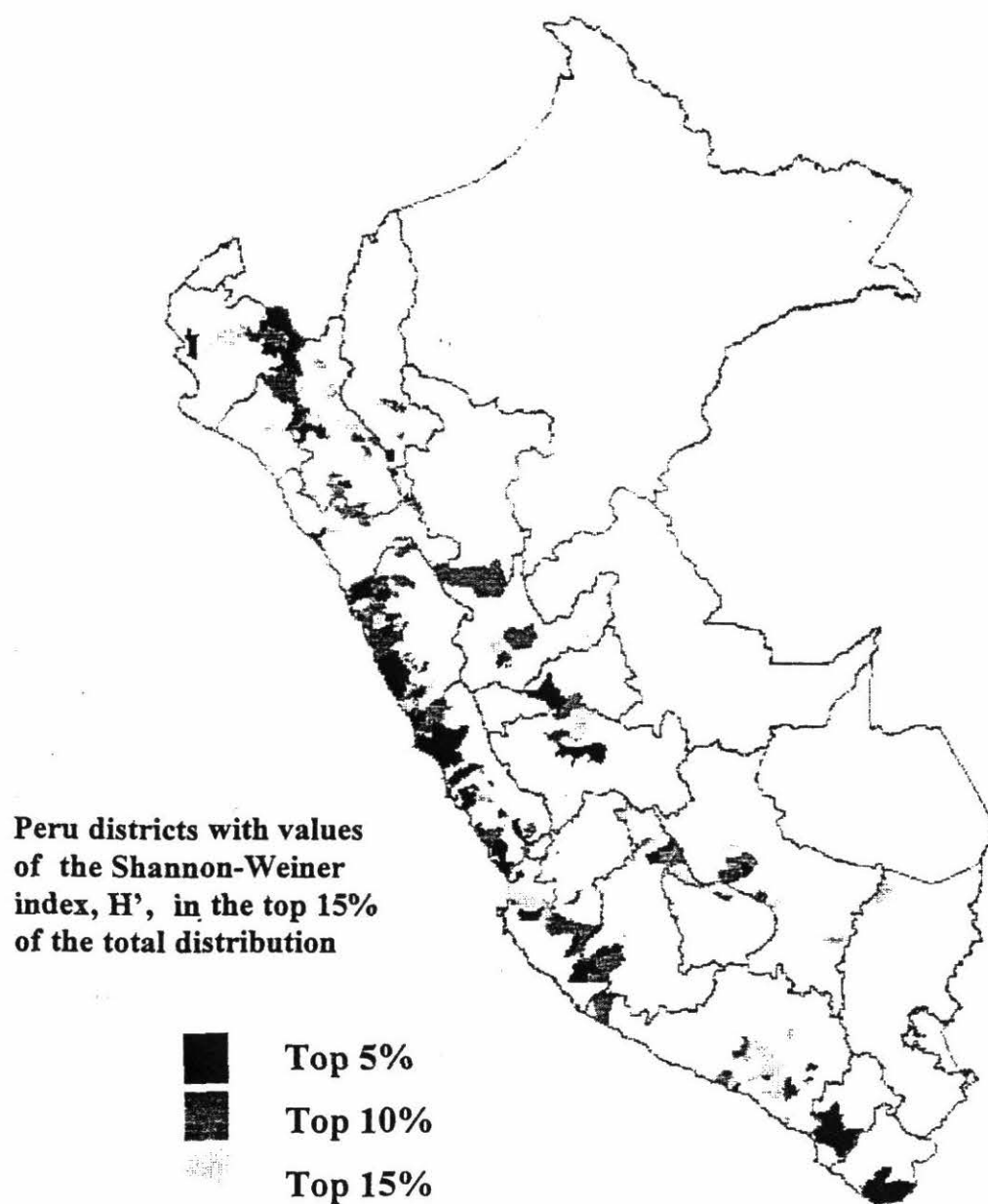


Figure 28. Peruvian districts with the highest agricultural diversity

Activity 4.3 GEOGRAPHICAL, SOCIOECONOMIC, AND ENVIRONMENTAL DATA FOR RURAL DEVELOPMENT INDICATORS, POVERTY, AND BIODIVERSITY PUCALLPA-UCUYALI

Contributors: Glenn Hyman, Ernesto Ruez, German Lema, Silvia Elena Castaño, Douglas White (PE5)

Highlight

- Agreement signed with INEI for work in the Peruvian Amazon

Objectives

The objectives are to investigate socioeconomic aspects and environment in Peruvian Amazon and to establish the relationships between environment and poverty so that policies of sustainable development can be made for this region.

Methods

As part of our collaboration with partners at the Pucallpa benchmark site, we are developing information datasets that will serve our indicators technology project, poverty studies, and our studies of how farmers manage biodiversity in the Peruvian Amazon.

This year we extended our relationship with INEI to include studies of poverty, socioeconomics, and agriculture at the level of *centros poblados* in our Pucallpa reference site. The median number of households that corresponds to a *centro poblado*, or community, in the benchmark site study area is 34. In July we completed a field campaign to georeference the 1993 population census and the 1994 agricultural census for eight districts in the vicinity of Pucallpa. GPS points were taken for over 250 *centros poblados*. Because of privacy considerations, INEI does not make available information at the household level. We aggregated the census information to the *centro poblado* level and included some information on the variability of data within communities.

In 1999, we expect to report the results of many of the poverty, sustainability indicators, and agricultural biodiversity studies for which this data development project was initiated. These databases for the benchmark site will be used by the consortium of local partners that will participate in the sustainability indicators technology project. We are working with IPGRI to study the diversity of agricultural crops that farmers report in the census questionnaire. This preliminary study will permit us to plan detailed fieldwork for in-situ conservation studies. The poverty work will be reported during the Poverty workshop that CIAT is hosting in September 1999. An example of the types of information that are being analyzed is that of the percentage of cultivated plantain consumed on-farm. Relative to rice and cassava, plantain appears to have greater market potential. This indicator may suggest the subsistence level of farmers or their ability to market the crop. At the *centro poblado* level, we have combined information from the agricultural census with poverty indicators from the population census.

Output

The information datasets and cross tabulation analysis will be used to help us target our research and development efforts in the benchmark site.

Activity 4.4 SOIL QUALITY INDICATORS MAPS SHOWING AGRICULTURAL CONSTRAINTS IN COLOMBIAN STUDY SITES.

To be reported in 1999.

Output 5 Analyses, scenarios, and options for sustainable land use in Latin America in general and in the CIAT priority agroecosystems

Activity 5.1 INTEGRATED PEST MANAGEMENT AND GIS: SPATIAL ANALYSIS OF THE WHITEFLY PROBLEM IN LATIN AMERICA

Activity 5.1.1 GIS interface for the whitefly project

Contributors: Justine Klass, Grégoire Leclerc, Francisco Morales (PE1), and Pamela Anderson (PE1)

Highlight

- For the whitefly project, we have constructed a database with a user-friendly interface (whitefly v1.0) that integrates all the biophysical and epidemiological information available.

Objective

To create an interface that integrates all the information collected by the whitefly project and other biophysical data relevant to the analysis of the whitefly transmitted viruses, that enables end-users to update the database, query areas of interest, and perform site characterization.

Method

The on-going project "Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics" is funded by the Danish International Development Agency (DANIDA). A main output for Phase 1 of the project is the creation of a GIS, which integrates both spatial and non-spatial information about the whitefly and viruses in Central America and the Caribbean. The GIS consists of a series of biophysical and socioeconomic GIS layers, as well as census databases and other data files. All datasets were processed with ArcInfo 7.1 running on UNIX workstations. To make all data available to the end-user, we developed and customized an ArcView 3.0 /spatial analyst project using Avenue, which integrates all components of the UNIX GIS database. This is an open system that allows a user to introduce external data to the GIS for immediate visualization. All coverages were converted to geographic projection referenced to the Clarke1866 ellipsoid. It can be immediately ported to a PC/WINDOWS environment.

Outputs

The ArcView 3.0 project (Figure 29) integrates the following information:

- Areas affected by whitefly-transmitted viruses,
- Crop production by municipality,
- Base information, such as rivers, roads, towns, land-use cover, and DEM,

- Climate (rainfall, mean minimum temperature, mean maximum temperature, evaporation, number of dry months), 3-km pixel size, and
- Economic loss.

The functionalities implemented are:

- Site characterization under the cursor,
- Tab-delimited text file containing information at any administrative level linked dynamically to existing administrative boundary coverages to enable real time visualization of external tabular data. Edition is done through Excel,
- Characterization of climate for areal units, and
- Procedures to generate point coverages from Excel files.

Data to be integrated before December 1998 are:

- Whitefly specie distribution (biotype, and reproductive and target crop host distribution), and
- Socioeconomic impact (pesticide use, yield loss, and insecticide resistance).

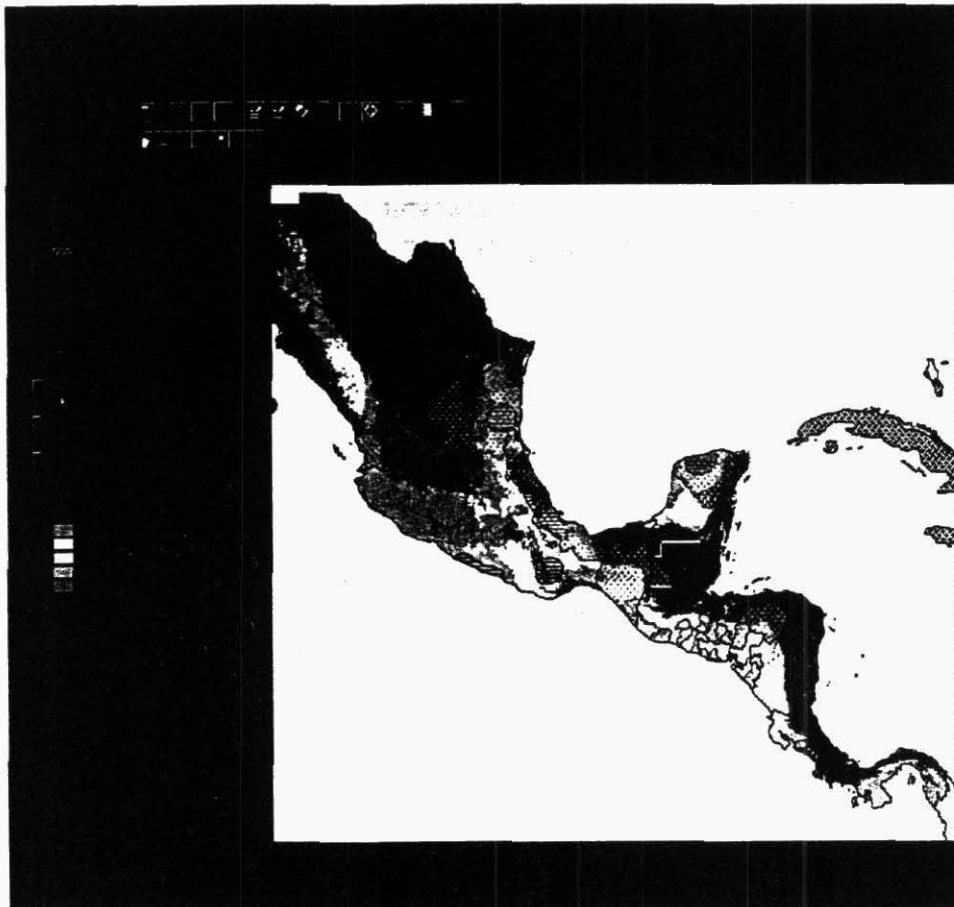


Figure 29. ArcView interface illustrating areas with bean golden mosaic virus and pepper huasteco begomovirus with number of dry months.

Activity 5.1.2 GIS analysis of presence-absence data for the whitefly project

Contributors: Justine Klass and Gregoire Leclerc

Highlight

- We have tested several methods to analyze presence-absence and biophysical data of poor resolution or spatial accuracy.
- A subregional study on occurrence of BGMV was carried out to test methods of analysis.

Objective

The main objective of this research is to characterize the environmental response of the virus disease system and of the whitefly vector, and assess areas of high risk of infestation (or critical areas) using GIS.

Methods

To start testing methods of analysis to be applied to Integrated Pest Management (IPM), a subregional study on the occurrence of BGMV was carried out. The data used to complete this analysis was based upon the known location of bean-growing areas within Nicaragua. Of these, the critically affected BGMV areas were identified. In the case of Nicaragua, one main region was identified.

A grid representing the presence (value = 1) and absence (value = 0) of the virus and whitefly for all bean-growing areas within Nicaragua was created. This was used as a mask to try to identify all the high-risk virus areas within the bean-growing areas.

Three methods were used and compared to estimate the location and probability of BGMV occurrence:

- The single-dimensional logistic regression analysis (MATHCAD, PCI),
- The multi-dimensional logistic regression analysis (ESRI, ArcInfo), and
- Fuzzy clustering (PCI).

According to Arnez (1997), the occurrence of *Bemisia tabaci* is related to elevation, temperature, humidity, and the number of consecutive dry months. Thus, based on the study in Costa Rica, it can be assumed that *B. tabaci* can be found at an elevation ranging from 0 - 1500 m with a temperature range from 19 - 30 °C. Because of climate variations, the critical environmental factors required for *B. tabaci* to exist will differ by country and by region. Some of the reasons for this include variation in topography and regional climate, and available host plants for *B. tabaci*.

We only used the climate variables to depict possible *B. tabaci* areas, because we are still collecting crop information. JD Corbett and RF O'Brien of Blackland Research Center, created the 3 arc-minute climate surfaces using ANUSPLIN (Centre for Research and Environmental

Studies [CRES], Australia National University [ANU], Canberra). The climate variables of mean annual minimum and maximum temperatures, annual rainfall, mean annual evapotranspiration, and number of dry months with rainfall < 60 mm per month were produced from monthly surfaces.

For the Nicaraguan sites (Esteli, Matagalpa, and Jinotega) we found the following ranges:

Elevation	545-1436 m
Maximum mean temperature	25-30 °C
Mean diurnal temperature	10.6 °C
Number of dry months	3-6
Annual rainfall	923-1321 mm
Minimum mean temperature	15-20 °C
Mean annual evaporation	1464-1716 mm

Single-dimensional logistic regression analysis

The single-dimensional logistic regression probability $P(x)$ was computed using a MATHCAD template. The logistic equation used is:

$$P(x) = \frac{\exp(\beta_0 + \beta_1 \cdot x)}{1 + \exp(\beta_0 + \beta_1 \cdot x)} \quad (1)$$

Where x represents an independent variable such as temperature.

The MATHCAD procedure uses a maximum likelihood rule to find the best-fit coefficients. This is more robust than a simple least-square regression, in the case of presence-absence data. A sample file containing the climate values was created for each climate surface and used to compute the coefficients in MATHCAD. For each case, a scatterplot of the data is plotted against the presence and absence of the virus. 1 represents the presence of the virus and 0 represents its absence. The logistic curve is fitted through the scattergraph (Figure 30). From the graphs it should be noted that a bias in the regression curve might exist since both the presence and absence of the virus have similar climate values. This will make it difficult to determine where one exists and one does not, and justifies our use of a robust regression method.

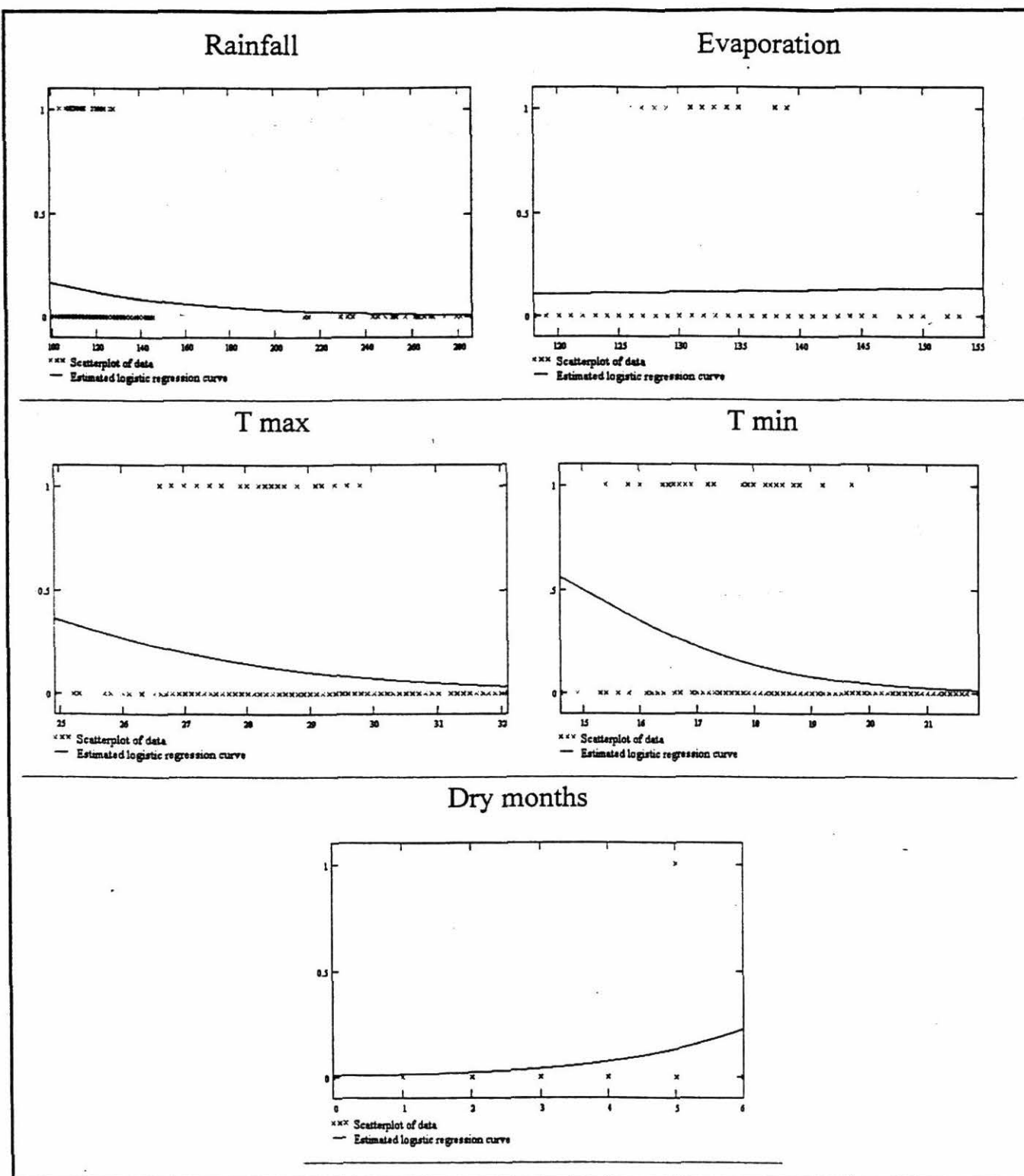


Figure 30. Estimated logistic regression curve for each variable tested.

Table 17 gives the regression coefficients and goodness of fit. The goodness of fit indicates the importance of the individual parameters being tested. From the table, the most critical factor is minimum temperature; evapotranspiration has little to no effect.

Table 17. Coefficients and goodness of fit for the climate variables chosen^a.

Parameters tested	Coefficients and goodness of fit		
	β_0	β_1	Goodness of fit
Dry	-5.204	0.661	0.0380
Evapotranspiration	-3.045	0.008	0.0005
Maximum temperature	9.217	-0.393	0.0480
Minimum temperature	9.251	-0.618	0.1320
Rainfall	0.169	-0.018	0.0290

a. Maximum temperature limited to < 32 °C.

Individual probabilities are then combined using a weighted sum:

$$P(x_1, x_2, \dots, x_N) = \sum_{i=1}^N P(x_i) \frac{W(x_i)}{\sum_{i=1}^N W(x_i)} \quad (2)$$

Where the $W(x_i)$ are given by the goodness of fit (Figure 31).

Figure 31. Map of P based on single-dimensional logistic regression.

Multi-dimensional logistic regression analysis

Multiple regression allows us to examine the relationship between the known value of a dependent variable with the known values of a set of independent variables. Instead of fitting each variable individually we do a multiple regression using a least square minimization criteria of a multidimensional logistic equation:

$$P(x_1, x_2, \dots, x_N) = \frac{1}{1 + \exp(-\sum_{i=1}^N \beta_i x_i)} \quad (3)$$

Where β_i are the regression coefficients and x_i are the independent variables.

A sample file containing the value for each cell of each variable was created from the GIS layers and then the logistic regression was fitted using an ArcInfo aml. The coefficients were:

Constant (β_0):	-4.381	Max temp.:	-1.294	Monthly evap:	0.273
Annual rainfall:	-0.009	Min temp.:	-0.399	No Dry month:	0.400

with RMS = 0.29 and Chi-square = 461.

These were substituted in the equation above to produce a grid of P . If we compare these results with the other two methods used, they are different. The cause of this is unclear and needs to be investigated further.

Based on the coefficients returned we can deduce that the most important contributing factors are the maximum temperature and the number of dry months; the effects of minimum temperature and evapotranspiration are less important; and annual rainfall appears to have the least influence of all.

Fuzzy clustering

Fuzzy clustering is a technique used for classifying remotely sensed data with little user intervention. We define a number of clusters, representing the regions we are trying to identify and then the algorithm looks for natural groupings in the data and determines cluster membership using a maximum likelihood decision rule.

Fuzzy clustering was used to partition the space defined by the five climate variables into 16 and 32 clusters. We visually identified the clusters within the BGMV-infected areas. This allows us to map areas having characteristics that favor the infestation, and are therefore at high risk. Table 18 reports the characteristics of the 3 clusters that appear to favor infestations for the 32 clusters classification.

Table 18. Characteristics of clusters (32 clusters map) that appear to favor infestations.

Characteristics	Mean			Standard deviation		
	Cluster 2	Cluster 3	Cluster 4	Cluster 2	Cluster 3	Cluster 4
Minimum temperature (°C)	18.8	17.7	17.2	1.0	1.2	1.6
Maximum temperature (°C)	28.9	27.7	26.9	1.3	1.4	2.2
Evaporation (mm yr ⁻¹)	1656	1560	1502	42	43	43
Dry days (no.)	5.5	5.0	3.9	0.4	0.2	0.2
Rain (mm yr ⁻¹)	1658	1560	2685	1294	1360	1360

The climate that exists within the virus hot spot area is highly similar to that found in the surrounding bean growing area. The number of fuzzy clusters should be increased to see if additional climate differences could be delineated within the same region. If no additional differences occur then we can continue to use the 32-fuzzy classes, because these depict additional areas not visible with the 16-fuzzy classes. A multiscale approach similar to that described under Activity 4.2.2 might be more appropriate in this case (see Activity 4.2.2 for preliminary results).

To fine tune the prediction models we will need to add more data from other regions to try to obtain an accurate site characterization of the location of BGMV. It is also important to obtain exact locations of this virus so that proper classifications can be made. Ground-truthing the data and collecting GPS points for each region in question will allow for greater accuracy in the delineation of training areas.

Outputs

We developed parametric and non-parametric methods to analyze data of uneven spatial accuracy, that can be used to characterize critical areas for IPM. The data used represents an approximation of the areas affected by the virus. Because of the semi-quantitative field data, we found fuzzy approaches to be more appropriate than simple-linear regressions.

Activity 5.2 REGIONAL, NATIONAL, AND LOCAL POVERTY ASSESSMENT FOR LATIN AMERICA, HONDURAS, AND BENCHMARK SITES

Activity 5.2.1 Human welfare indicators related to agricultural land use for Honduras

Contributors: Tonny Oyana, Patrice Couillaud, Gregoire Leclerc, and E. Bronson Knapp (PE-3)

Highlights

- Several indicators of poverty were derived from unit level census data, at household, village, municipio, department and country scale, and presented graphically for Honduras
- These indicators are compared to “official” indicators, and found to be highly correlated.

Objective

The general objective is to understand the link between poverty and environmental degradation, using Honduras as a case study. Specific objective is to demonstrate the feasibility of deriving poverty indicators from unit level population and housing census data.

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, ArcInfo, 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_3: Unsatisfied basic needs; and NBI_4: UBN + lack of education) six classes were defined (Table 19):

Table 19. Household poverty classes in Honduras.

Stratum number	Definition	NBI_3 or NBI_4 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 education and/or 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.

For spatial analysis purposes, the relationship between the village codes in Oracle and ArcInfo coverages was 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 that becomes the unique identifier between ArcInfo 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 20). The 1974 and 1988 census data are compared to establish the spatial changes that have occurred over time.

Table 20. 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

Outputs.

At national level, this method shows that of the total Honduras population, 55.11% as measured by the derived composite indicator *NBI_3* and 58.74% by *NBI_4* do not meet the defined satisfaction criteria (Table 21 and Figure 32). The hardest hit Departments are Intibuca and Lempira, where over 80% of the population are classified as poor.

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 21). Results show a strong correlation between indicators (Table 22). However our results show systematically higher proportions of poor. This is explained by the fact that we defined the norm of a given parameter as the average value for the country, and therefore *NBI_3* and *NBI_4* represent more a measure of equity than an absolute measure of poverty.

Table 21. The percentage of poor (averaged) as assessed by this study and others.

Department	Other studies ^a		This study ^b	
	FHIS (1993)	SECPLAN (1992)	<i>NBI_3</i> (1988)	<i>NBI_4</i> (1988)
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

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

Table 22. Correlation between the results of this study and other studies..

	NBI_3 (1988)	NBI_4 (1988)
FHIS (1993)	0.87	0.78
SECPLAN (1992)	0.94	0.95

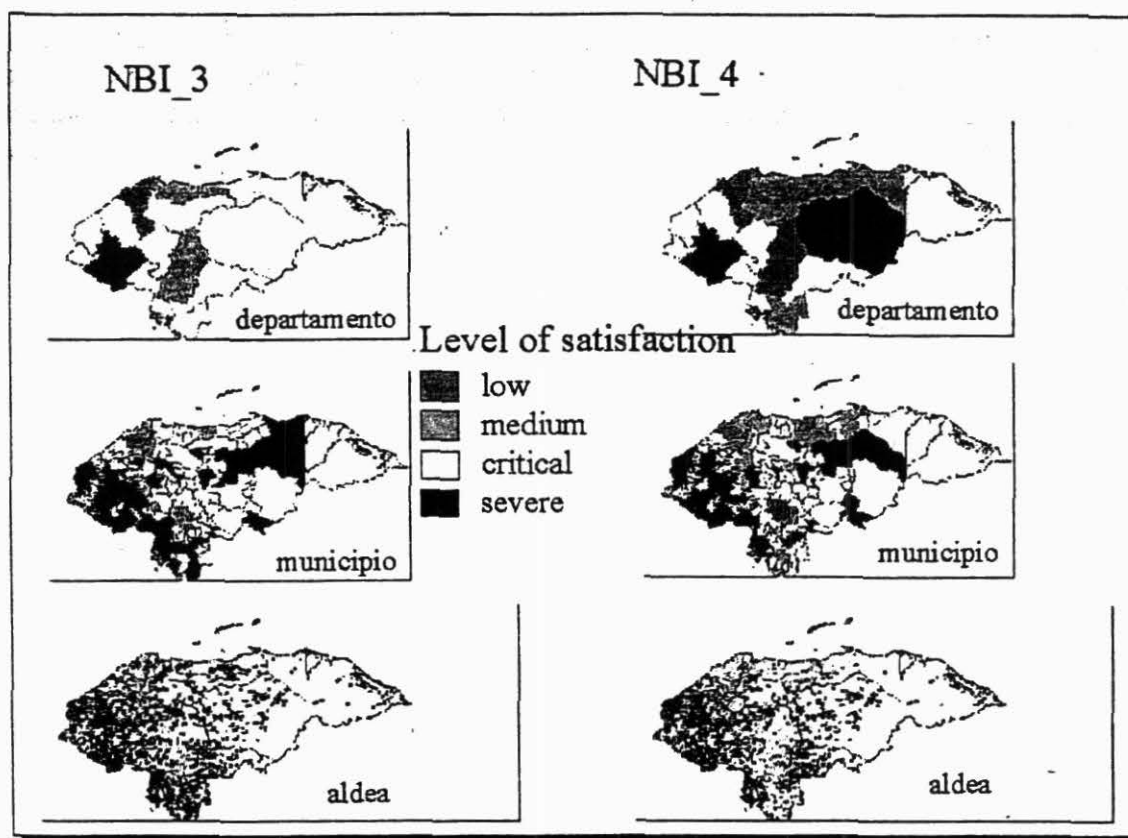


Figure 32. Poverty indicators aggregated at 3 administrative levels. One can see that the choice of the indicator matters as the maps are significantly different.

Activity 5.2.2 First estimates of Urban and rural population density for Honduras.

Contributors: Gregoire Leclerc, Andy Nelson, Julie Cox, Glenn Hyman and Helle Ravnborg

Highlights

- Urban population density is being computed using Night Light imagery and Landsat TM land cover maps.
- Urban and rural population density is being modeled using an accessibility map.

Objective

Accurate mapping of population density will help improve the sampling and extrapolation domains for the well-being ranking methodology (Ravnborg et al, 1998), and will allow us to quantify population/natural resources interactions.

Method

Spatially contiguous clusters from night light imagery (Hyman et al. 1997) and bare soil/urban maps from Landsat TM imagery classifications (Cox 1998) are being crossed with 1988 village population census data from Honduras (Couillaud 1998). When several villages fall within the same cluster, the total population for these villages is used for this cluster. Because only a fraction of the villages appear in the remote sensing images, we needed to develop a model to derive population density for the other villages. Strong correlation is found between village population and the areas obtained from these two remote sensing sources (urban extension areas). However, the areas from the night light imagery are significantly larger than the ones obtained from TM imagery, which leads to two different models. The equation relating urban area to total population is given by:

-Night light imagery ($R^2=0.84$; very low population density villages (<0.9) have been excluded):

$$Area(ha) = 0.305 \cdot Population + 555$$

-Landsat TM classification ($R^2=0.73$; we used population density between 4.5 and 35):

$$Area(ha) = 0.03 \cdot Population + 129$$

For the estimate of rural and urban population density, we used a different approach. We assumed that the area of influence of a village is given by the distance covered within an hour walk from the center of the village. We computed an accessibility surface (Knapp et al. 1998) using the night light imagery and villages point coverage as source data. Land use and slope were combined to make a friction surface. It was assumed that the transportation network was sufficiently developed to allow a 4km/hour walking speed on a flat surface. This allowed us to delineate an area of influence around a village or group of villages (Figure 33). When several villages were included in a cluster, the total area for the cluster was distributed to the villages according to their population (i.e. area is assumed to be proportional to population).

Output

Urban and rural population density have been computed for Honduras villages using different methods. These results are now being validated for better targeting and analysis of the interaction of population with natural resources.

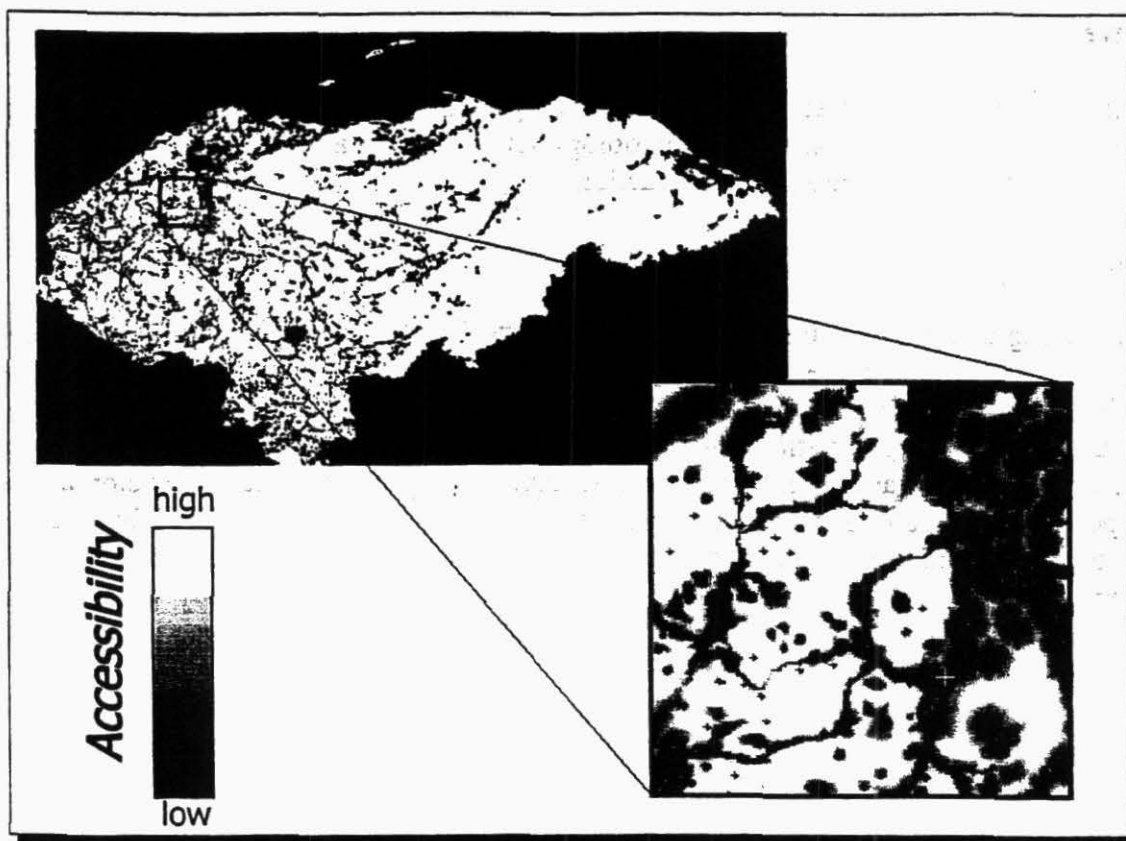


Figure 33: Area of influence of a village: 1 hour walking distance from the center of the village.

Activity 5.2.3 Poverty analysis in Pucallpa

Contributors – Clarisa Sanchez, Carlos Santur, Hector Savedra (INEI) Glenn Hyman, Ernesto Ruez, Tamsyn Murray, Edgar Amezcuita, Sam Fujisaki, Douglas White

Objective

CIAT and the National Statistics and Census Institute (INEI) of Peru signed a new agreement in July 1998 to continue collaboration on the use of census data for agricultural research. PE4 and INEI researchers are using census data for 275 communities at the Pucallpa benchmark site to study poverty in the context of land use and smallholder farming systems. Our aim is to understand relationships between farming systems and human well being.

Methods

We aggregated household level information (over 5000 households) to the level of *centro poblado* for 275 communities in the benchmark site study area. We used the Population and Household Census to calculate poverty indicators. The method replicates INEI's district level approach, but at the community level. The method is based on a selected set of minimum socially

acceptable standards for housing, education and economic dependence. The poverty indicators make up a set of unsatisfied basic needs (NBI is the Spanish acronym), which are:

- Inadequate physical structure of the house
- Number of persons per room in the house
- Availability of a system to discard human waste
- School attendance of children in the household
- Economic dependence in the household

The data for this project is organized in a relational database management system. Any information in the Population census can be compared with information in the Agricultural Census. For example, Figure 34 plots the percentage of households in each community with 5 basic needs unmet against cattle per person in the community. As expected, those communities in which livestock is a part of the farming system have lower percentages of their households with basic needs unmet. These are the types of comparisons that will be made in order to better understand relationships between human well-being and farming systems.

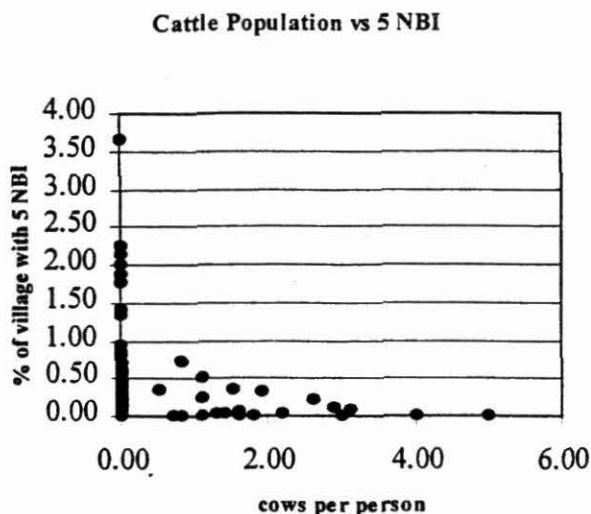


Figure 34. Plot showing the relationship between cows per person in the benchmark site communities and the percentage of households within the community that have 5 basic needs unmet.

Outputs

The analysis for the work will take place between January 1999 and July 1999. We expect to have a full fledged report by the end of next year. The analysis will provide an understanding of human well-being – farming systems relationships and will include recommendations for research, development and policy.

Activity 5.3 INDICATOR SET FOR WATER RESOURCES IN CENTRAL AMERICA

Contributors: Manuel Winograd and Marta Aguilar

Highlight

- The indicator set has been defined.

Objective

Given that the management of some resources remain sectoral (i.e., water) in Central American countries, carrying out a short study at the scale of the water sector is appropriate. The aim of the study is to develop appropriate indicators for decision-making at that level and to report on how these differ to those at other levels or scales.

Methods

A series of indicators for the categories P-S-I-R was developed and applied. The use, quality, and availability of water at national and regional level concerns many countries in the region. At the same time, Central American countries share water resources in some cases. Nonetheless, policy-makers make decisions without having access to reliable information on the sector. For this reason, developing a set of indicators for the water sector is useful for testing the information tools at the regional, national, and local level. Winograd (1997) reports a set of indicators for the water sector.

Outputs

The indicator set for the sector is available and the search for data was begun during the visits to institutions. This activity will be further developed during 1999.

Activity 5.4 INDICATORS OF ENVIRONMENTAL SUSTAINABILITY: WATERSHED, STATE, AND NATIONAL CASE STUDY FOR TASCALPA, YORO, HONDURAS

Contributors: Manuel Winograd, Marta Aguilar, and France Lamy (CIAT Hillside Project, Honduras)

Highlights

- The indicator set for Honduras has been defined following visits made to Honduras in collaboration with the Hillside Program.

Objectives

Although many of the problems of rural development and environment do not respect political borders, decision-making, and definition of strategies of development and land use, the necessary actions are carried out at national level. For this reason, we proposed to carry out a case study in a country where good data are available. The study would prove and test the use and application of the proposed indicators as a way of looking at usefulness and effectiveness in decision-making. Honduras was chosen as the site for the national case study, given the extensive work carried out by CIAT in the country. The objective of this national study is to identify and define the mechanisms and the stakeholders involved in the production and use of information at the national level, and create capacity building in the national institutions.

Methods

The aim of the study implies the identification of stakeholders at national level producing and using information for rural and land use decision-making. The study requires the search for other data sources and the definition of other indicators according to the scales and end-user needs. The validation and testing process of information needs the participation of the national institutions related with rural development and land management.

A series of visits was made to Honduras in collaboration with CIAT's Hillside Program to obtain data and particularly to harmonize methodology and the indicator sets at national and local levels.

Outputs

As a result of the visits to Honduras, indicator sets can be applied for decision-taking at different levels and scales (national, local administrative e.g., province, and local ecology e.g., watershed) in the case of Honduras to test and use the methodology applied to Latin and Central America.

Activity 5.5 ANALYSIS OF LAND USE SCENARIOS FOR THE COLOMBIAN PORTIONS OF THE ORINOCO AND AMAZON BASINS.

To be reported in 1999.

Output 6 Stakeholder networks at multiple scales within the CIAT priority agroecosystems for dialogue about land use options and scenarios

Activity 6.1 SURVEY REGIONAL AND NATIONAL USERS AND DATABASES IN CENTRAL AMERICA

Contributors: Manuel Winograd, Marta Aguilar, and Andrew Farrow

Highlights

- 50 institutions were visited to seek cooperation in the project.
- The visits allowed the search for and acquisition of data and the identifying of needs at the national level.

Objective

The objective of the project went beyond the simple acquisition of data from the institutions of the region although this is, in itself, of value. What was sought, in addition to improving the databases, was to bring into line and promote the use and preparation of indicators and other tools with regard to land use and quality, and rural development.

Methods

An initial profile was extracted from the workshop (see under 6.2) where participators indicated which institutions in their countries provided centralized information that was important for the system of indicators. Those to be visited were then selected, emphasizing Ministries of Agriculture, Ministries of Environment, and Institutes of Statistics plus some others coinciding with the area under study. Visits to selected institutions were then carried out (Annex 1). These institutions produce and utilize information and, as potential users of tools, are actors in the decision-making process.

A presentation personalized to the specific area was presented at each visit. The idea was to make known what has been achieved to date and what is planned for the future, seeking cooperation. The aim also was to find out what information each institution had available and gain access to the information or acquire it more formally at a later date.

Outputs

The visits allowed the search for data, and helped identify needs at national level, understand the policy-making process at national level, and know the capacity to produce and use information tools. We obtained a series of agreements of cooperation to work with indicators, exchange information, and help national institutions create the capacity to develop and use information tools.

Activity 6.2 CONSOLIDATE REGIONAL NETWORK IN CENTRAL AMERICA

Contributors: Manuel Winograd, Marta Aguilar, and Andrew Farrow

Highlights

- Visits to 44 national, six regional, and four international institutions brought about agreements, active participation, and cooperation.
- An Internet homepage was updated for the first phase of the project.

Objective

Agreements must be made with national and regional institutions to establish and participate in a regional network for rural sustainability indicators.

Methods

Government and national institutions and regional bodies were contacted to determine regional concerns regarding rural sustainability to assess interest in and obtain commitments to participation in this regional project and networking.

A launching workshop was organized to present the project and obtain the broad participation of national and regional institutions. The goal of the workshop was to harmonize frameworks, methods, and procedures; identify key and priority issues to develop indicators for rural development; define a set of indicators for rural development at different scales; and to obtain the active participation of the regional and national institutions in the project. Three people per country participated, from the Ministry/Secretary of Agriculture, the Ministry/Secretary of the Environment, the Ministry/Secretary of Planning, and the Census Bureau. People from regional institutions working with rural development, and environmental management and planning were also invited (e.g., the Instituto Interamericano de Cooperación para la Agricultura [IICA], and CCAD). During the workshop, the coordinating mechanism was identified and defined (i.e., steering committee and partner institutions).

Outputs

The institutions were visited and cooperation established in the area of data, use of information, and training and capacity building. Activities were established with those visited to cooperate in developing and using rural sustainability indicators and testing and improving an indicator set and framework.

At the same time, an Internet homepage for the first phase of the project was updated to promote networking activities and disseminate project activities. The homepage address is: [Http://www.ciat.cgiar.org/indicators/project.html](http://www.ciat.cgiar.org/indicators/project.html)

Activity 6.3 BIOPHYSICAL AND SOCIOECONOMIC DATABASES ON CD-ROM DISTRIBUTED WITH A USER-FRIENDLY INTERFACE.

Contributors: Elisabeth Barona, Gregoire Leclerc, France Lamy, Rafael Hoyos

Highlights

- Honduras atlas on CD-ROM available, incorporating socioeconomic and biophysical information for use as a Decision Support tool.
- Training material for the use of the CD-ROM.

Objective

Decision makers need geographic information for informed policy making. We created a detailed database of socioeconomic and biophysical information, as well as gray literature and training material, in a georeferenced framework and user friendly interface.

Output

We developed an atlas CD-ROM with more than 90 maps, a detailed description of all maps through a help system, "gray literature" references for conservation technologies, and training exercises from beginner to advanced. It is based on ArcView data publisher v.2.1, a very complete toolbox that allows advanced GIS analysis. It will be released for sale by National collaborators in December 1998. 25 experienced GIS users have been trained in advanced GIS techniques with the Atlas. A network of collaborators is being formed to update, improve and disseminate the Atlas in 1999.

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Output 7 Trained professionals in the use of Decision Support tools and scenario building methods

Activity 7.1 TRAINING AND CAPACITY BUILDING FOR LATIN AMERICAN COUNTRIES AND INSTITUTIONS, COURSES, WORKSHOPS, ETC

Activity 7.1.1 Launching workshop for Central American Sustainability Indicators Project

Contributors: Manuel Winograd, Marta Aguilar, and Andrew Farrow

Highlights

- The project-launching workshop was held.
- A series of activities were undertaken to disseminate and train people in the region. These included visits to institutions, organization of two regional workshops, and visits from institutions and individuals to CIAT.

Objective

Information tools are useful if they are disseminated and tested by the end users (policy-makers, planners, and technicians). To this end, two training and capacity building workshops are needed to harmonize, validate, refine, test, and diffuse the use of indicators and information tools.

Methods

The launching workshop was held at CIAT in March 1998, with 15 national and regional institutions participating. The framework was defined, the indicator set discussed, and the mechanism of cooperation and coordination of the project defined. Visits to and from institutions allowed ways of cooperation to be identified, helping to create capacity building and to test and diffuse the use of indicator tools.

Outputs

The launching workshop was highly successful, leading to better relations and intercommunication with other institutions. Visits to and from institutions furthered this cooperation and helped create capacity building.

Activity 7.1.2 Participation in the Canadian GLOBESAR-II Workshops and Training.

Contributor: Nathalie Beaulieu

We are participating in a development project on the use of images from the Canadian RADARSAT satellite. This project is called GLOBESAR-II, is principally funded by the Canadian International Development Agency (CIDA) and IDRC, and executed by the Canadian Centre for Remote Sensing (CCRS). Our involvement is at the research level, but we have also participated in the training of research teams under a contract issued to CIAT by AERDE Environmental Research.

We gave training on radar remote sensing to participants of the GLOBESAR-II project in Honduras, Costa Rica, Panama, and Colombia, in collaboration with scientists from CCRS as listed below.

Oct 6-10, 1997. Workshop organized and held at IGAC, Bogotá, Colombia.

Dec 1-5, 1997. Workshop held at the Escuela Nacional de Estudios Forestales (ESNACIFOR) and organized by COHDEFOR, Siguatepeque, Honduras.

Dec 6-14, 1997. Workshop held at the Universidad Nacional (UNA), and organized by the Instituto Geográfico Nacional (IGN), Heredia, Costa Rica.

Jan 19-22, 1998. Workshop held at the Contraloría General, census and statistics office, and organized by the Departamento de recursos minerales, Ministerio de Comercio e Industria, Panama.

Feb 2-3, 1998. Customized training at IGAC, Bogotá, Colombia.

Feb 4-6, 1998. Customized training at the Centro de Estudios Cafeteros y Empresariales Manizales, Colombia.

The first four events were 5-day workshops entitled "Radar image processing and extraction of information". The training material was prepared by CCRS. The last two events consisted of customized training, where Nathalie Beaulieu assisted the participants in their projects, addressing specific problems they were having with image processing. No training material was prepared for these events.

In the scope of the GLOBESAR project, we participated in a 2-day workshop on the extraction of DEMs from stereo RADARSAT images held at IGAC on February 13-14.

We also hosted the national Colombian seminar for the GLOBESAR project, where the nine Colombian research teams came to present their preliminary results on February 26-27.

We have participated in the GLOBESAR-II mid-term symposium "Radarsat applications in Latin America" from April 20-24 in Cartagena, Colombia, where researchers from the 11 participating countries presented their results. We presented a paper (Beaulieu et al. 1998).

Activity 7.1.3 GIS Workshops and GIS support to workshops.

Contributors: France Lamy, Elisabeth Barona, Gregoire Leclerc.

Highlight

- 136 participants from NARS, NGOs, and local, international, and regional organizations in Central American Hillside Project training and workshops, 1998. In addition to GIS specific training (see below), GIS has provided base material essential for all activities (orthophotomosaics, Atlases on CD-ROM, DEMs and slope maps).
- 3 one week training sessions in Arcview 3.0 have been offered to CIAT staff.
- 2 days G/DSS workshop held with key Honduras decision-makers.
- 1 day course on advanced Arcview using Atlas CD-ROM of Honduras.
- 1 seminar for the RENASIG GIS network.

Objective

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

Methods

Members of the Hillside project 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 Decision Support tools, and to evaluate their utility with several different types of stakeholders, including development practitioners from NGOs, farmers, and technical professionals. Table 23 shows participation by different types of institution in these events.

Outputs

Stronger links were formed or maintained with participating organizations and individuals. The project's interactive digital information system for Honduras (Atlas on CD-ROM) and associated DS tools were test-taught and evaluated successfully. Users Network and CIAT position consolidated in Central America. 20 non-GIS CIAT staff trained in the use of Arcview 3.0. Training material has been assembled into "guias", and is being solicited for use by other institutions (Ex. ESNACIFOR).

Table 23. Participant organizations in Central American Hillside 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.

Activity 7.2 INFORMATION PRODUCTS FOR THE AGRICULTURAL NRM SECTOR: INFODEV PROJECT FOR CENTRAL AMERICA AND THE CARIBBEAN

Contributors: Glenn Hyman, Manuel Winograd, and Marta Aguilar

Highlights

- The *InfoDev* project was approved by the World Bank.
- The basis is laid for the *InfoDev* project to begin in 1999.

Objective

The project aims to help data providers get information to their clients in a more efficient and useful way. It will help census agencies present this information in a geographic format that will allow users to more easily visualize data.

Methods

Our *InfoDev* proposal was approved by the World Bank and is funded for US\$241,000 over 2 years. This is a new project that will help six Central American countries develop user-friendly products for disseminating agricultural information and will begin in 1999. It is funded by a new World Bank program called *InfoDev*. This year we established the foundation for the network and organized the seminars for 1999, which will include CIAT and Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) information specialists.

Output

The basis is laid for the project to begin in 1999.

Activity 7.3 USER-FRIENDLY PACKAGE FOR BIODIVERSITY MAPPING

Contributors: Peter Jones (Consultant), Alexander Gradkov, Luz Amira Clavijo and Joe Tohme (Biotechnology).

Highlights

- Basic algorithms for package are completed.
- Beta release for group of users to check will be available December 1998 or early 1999.

Objective

The objective is to produce a user-friendly package applying the technique for mapping germplasm and biodiversity.

Methods

Starting in 1994 we worked with collaborators around the globe to develop a method of mapping the probable distribution of wild species from a calibration set of germplasm bank passport records or from herbarium species lists. A few years ago we were sure that we had a versatile and accurate method to do just this. Nevertheless, we persevered in applying it to a wide range of species of different types to make sure that we understood its strengths and weaknesses. We did not want to produce an end user tool applying the technique until we had determined where it might go wrong when put in the hands of naive users.

In the course of these studies we applied the technique to wild *Phaseolus* beans, six species of *Stylosanthes*, five wild *Manihot* species, cassava green mites, and root damaging pests of cassava, among others. These investigations have been reported in previous annual reports. With this experience to draw upon we felt that this year we were ready to produce a package of software and datasets that would allow germplasm and agricultural scientists to apply the method themselves in their own fields of investigation.

We decided to bring out a user-friendly package, drawing on the interpolated climate files produced by CIAT in the early 1990s for Latin America and Africa. The present interpolated climate surfaces are at a precision of 10 minutes of arc for latitude and longitude, giving pixels about 18 km on a side at the equator. We have worked with much more precise surfaces for studies in Honduras that used a pixel size of about 900 m. Production of climate surfaces at this scale is a long process, because much more precision is needed both in the climate normals data and the underlying DEM. It is hoped that higher precision surfaces will gradually be incorporated in the package, as they become available.

To produce the package we needed to hide the programming complexity from users, while making sure that the implications of choices and interpretations of intermediate results were brought to their attention. We had to translate the statistical and mapping operations from the mixture of GENSTAT, FORTRAN, IDRISI, and ArcInfo source code into a transparent package using C++ and Map Objects from ESRI. We have employed an expert Windows Interface

programmer to help with this work. He arrived from the Ukraine in March this year and is already well into the translation task and production of an appropriate user interface.

We cannot implement a program that takes all the decisions and runs as a black box from start to finish. The users need to make decisions based on their knowledge of the germplasm and geography. The package will try to guide users as to when these decisions are necessary and to this end we are implementing a form of on-line help or 'advice' to tell users what to look for at each stage of the analysis. We have started to produce a series of overlays of critical geographic features, i.e., towns, roads, rivers, and topography, which will always be presented in an appropriate density depending on the scale or 'zoom level' at which users are viewing the maps. Map views are used both for output and at various stages of data verification.

We are implementing a set of clustering techniques for users to create subsets of data depending on climatic criteria, viewed in the principal components plots, or as independent clustering algorithms.

A major advance on previous techniques is that we can now plot the actual probability of a pixel or accession belonging to a climate group. Previously, we plotted the probability density as a non-calibrated index, and map analysis was constrained to plotting population data calculated in a space with a constant number of dimensions. This is because of the nature of space as the number of dimensions is increased. The volume of the unit sphere changes from space to space and hence as dimensions increase the probability density falls drastically.

We have investigated the behavior of the normal probability integral in spaces with different dimensions and now have a simple coded subroutine to give us the value of the integral for any space we care to use. For even dimensions the integral is:

$$p = 1 - e^{-r^2/2} \left(\frac{1}{(n-2)} r^2 + 1 \right) \left(\frac{1}{(n-4)} r^2 + 1 \right) \left(\frac{1}{(n-6)} r^2 + 1 \right) \cdots \left(\frac{1}{(n-(n-2))} r^2 + 1 \right)$$

For odd dimensions it is:

$$p = \text{ERF}\left(\frac{\sqrt{2} \cdot r}{2}\right) - \frac{\sqrt{2} \cdot r \cdot e^{-r^2/2}}{\sqrt{\pi}} \left(\frac{1}{(n-2)} r^2 + 1 \right) \left(\frac{1}{(n-4)} r^2 + 1 \right) \left(\frac{1}{(n-6)} r^2 + 1 \right) \cdots \left(\frac{1}{(n-(n-2))} r^2 + 1 \right)$$

where r is the distance to the center of the distribution.

Figure 35 shows the plotted probability integrals for a selection of dimensions up to 40. These are the probabilities of observing a point between the origin (0) and radius r for multivariate normal population set in spaces with the designated dimensions. For one-dimensioned space this of course reduces to the familiar $N(0,1)$ where the probability q equals 1 minus the normal probability as used for a two-tailed test.

Because the probability is now independent of dimension, we can directly compare maps made by incorporating different numbers of principal components. Another important result is that we can now plot maps showing the probability of a pixel belonging to any of a number of climate groups by simply plotting $p=1-(1-p_1)(1-p_2) \dots (1-p_n)$. This will greatly enhance the interpretive powers of the mappings.

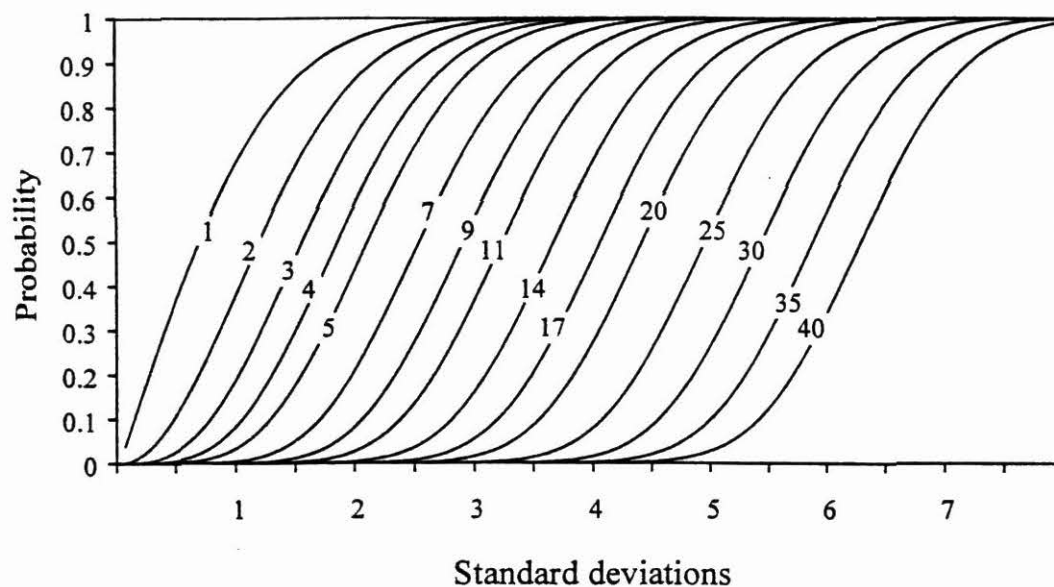


Figure 35. Plotted probability integrals for a selection of dimensions up to 40.

Although the basic algorithms are complete, we still have much to do in developing the software tools, both the on-line help and advice system and the scale-specific overlays. Work is proceeding on these. In parallel with work on the Markov weather generator, new climate data are being worked up with the eventual aim of providing new interpolated climate surfaces. Once in a rudimentary, but usable, form we will send the system to a group of scientists for a preliminary testing and review. This, together with our own in-house testing, will determine when the package is ready for release to the general public. A beta release is usually made at this point to a group of users who are prepared to take the package without a full guarantee that no errors remain and who promise to report such errors as they find. This version is due to go into

beta release either towards the end of 1998 or in early 1999. The final release of a commercial package will depend on the user response from the beta release, but we hope that it will be in 1999.

Outputs

The user-friendly package on mapping biodiversity, which will be available Dec 1998, will help predict areas with climatic similarity to existing germplasm collections. The tool has several uses that include targeting areas for future collection and identifying potentially new populations based on geographic dissimilarity. The work will aid scientists and conservationists in the global effort to find wild relatives of modern crops before they are lost to genetic erosion.

Activity 7.4 COLOMBIAN GOVERNMENT AND NATIONAL AGRICULTURAL RESEARCH SYSTEMS PERSONNEL TRAINED IN THE USE OF DSS AND SCENARIO / CONSTRAINTS ANALYSIS.

Contributors: Nathalie Beaulieu, Maryory Rodriguez, Ovidio Muñoz, Marta Aguilar

Objective

The activity will strengthen the planning capacity of local governments through the use of land use planning tools.

Outputs

Informal training of planning office personell in the Department of Meta and the Puerto Lopez Municipality starts in November 1998. We are jointly developing decision support tools. Formal training will begin in the second half of 1999 when the tools are operational for our pilot sites.

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Meetings and Workshops

(MA = Marta Aguilar, NB = Nathalie Beaulieu, AF = Andrew Farrow, GH = Glenn Hyman, JK = Justine Klass, GL = Grégoire Leclerc, AN = Andy Nelson, JP = Javier Puig, and MW – Manuel Winograd.)

1997:

- Oct 7. (MW) Workshop on Indicators for Natural Resources Management, The World Bank, Washington, USA
- Oct 23-24 (MW) Fourth Expert Meeting on Indicators of Sustainable Development, Department for Policy Coordination and Sustainable Development (DPCSD), United Nations, NY, USA.
- Nov 2-7 (GL, AN, JP, GH) VIII Simposio Latinoamericano de Percepcion Remota, Merida, Venezuela.
- Nov 4-5 (NB) GRFM meeting. Jet Propulsion Laboratory, Palo Alto, CA, USA.
- Nov 23-24 TREES deforestation hot spot expert meeting. Joint Research Center, Ispra, Italy.
- Dec 4 (GL) El fenomeno El Niño en 97/98 y los organismos de cooperación. Bogota, Colombia.

1998:

- Jan 28 (MW) Reunion Nacional de Presentacion del Sistema de Indicadores para la Planificacion y Seguimiento Ambiental de Colombia (SIPSA), Departamento Nacional de Planeacion, Bogotá, Colombia.
- Feb 2-6 (MW) Global Environmental Outlook (GEO-II) coordination meeting, Brasilia, Brazil.
- Mar 25-27 (MW, MA, AF) Launching Workshop CIAT/World Bank/UNEP Project on Rural Sustainability Indicators: An Outlook for Central America, CIAT, Cali, Colombia.
- Mar 25-29 (GH) 94th Annual Meeting of the Association of American Geographers, Boston, MA.
- May 1 (MW) Press Conference Atlas de Indicadores Ambientales y de Sustentabilidad para America Latina y el Caribe: ATLAS CD, CIAT and The World Bank, The World Bank, Washington.

- June 1-3 (JK, GL) First International Conference on Geospatial Information for Agriculture and Forestry: Decision Support, Technology, and Applications. Lake Buena Vista, Florida.
- June 3-4 (MW) Taller Regional Medio Ambiente, Economia e Indicadores Ambientales para Areas Costeras y Marinas, Comision Permanente del Pacifico Sur (CPPS)/ Plan de Accion del Pacifico Sudeste, CIAT, Cali, Colombia.
- June 15-18 (AF) Global Mapping Forum 1998, Sioux Falls, USA.
- June 18 (MW) Demonstration of Atlas CD for CIAT users. CIAT, Cali, Colombia.
- June 24-26 (JK) Inter-American Geospatial Data Network Workshop. Port of Spain, Trinidad.
- Jly 27-31 (GH) 18th Annual User Conference Agenda. San Diego, California.
- Oct 12-12 (GH, GL) Consortium for spatial information launching workshop. Arendal, Norway.
- Oct 14-17 (GH, GL) International poverty mapping workshop. Arendal, Norway.
- Oct 14-18 (JK) 1st International Health Geographics Conference. Baltimore, MA.

Publications

Book and Journal

Boogaard R van den, Alewijnse D, Veneklaas EJ, and Lambers H. 1997. Growth and water-use efficiency of ten *Triticum aestivum* cultivars at different water availability in relation to allocation of biomass. *Plant Cell Environ*, 20:200-210.

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Land Management and Geographic Information Systems Personnel

- * Left CIAT during 1997-98
 ✓ Arrived at CIAT during 1998

Glenn G. Hyman	PhD, Geography	Research Fellow, Acting Project Manager
Nathalie Beaulieu	PhD, Remote Sensing	Research Fellow
Gregoire Leclerc	PhD, Physics	Senior Staff
Manuel Winograd	PhD, Ecology	Senior Staff
Erik J. Veneklaas*	PhD, Tropical Ecology	Postdoctoral Fellow
Peter G. Jones*	PhD, Agricultural Geography	Senior Staff
Samuel Fujisaka	PhD, Rural Anthropology	Senior Staff (80% PE5)
William Bell	PhD, Climatology	Senior Staff (80% IS)
Alexander Gradkov	MSc, Computer Science	Visiting Researcher
Patrick Hill	MSc, Soil Fertility (PhD cddte.)	Visiting Researcher
Ernesto F. Ráez-Luna	MA, Latin American Studies	Research Associate
Marta Aguilar	BSc, Remote Sensing	Junior Research Fellow
Patrice Couillaud*	Ing Electron	Junior Research Fellow
Julie Cox*	MSc RS, MSc GIS	Junior Research Fellow
Andy Farrow	MSc, GIS	Visiting Researcher
Justine Klass	BAH, CGIS	Visiting Researcher
Tamsyn Murray	MSc, Agroecosystem Health	Junior Research Fellow
Andy Nelson	MSc GIS	Junior Research Fellow
Tonny Oyana*	MSc GIS	Junior Research Fellow
Javier Puig	MSc NRM	Junior Research Fellow
José Hernán Trejos	MSc, Systems Engineering	Analyst
Germán Lema	Industrial Engineering	Statistician
Jorge Humberto Becerra	BSc, Economics	Research Assistant
Luz Amira Clavijo	BSc, Geography	Research Assistant
Germán Escobar	BSc, Biology – Entomology	Research Assistant (80% PE5)
Jaime Lozano	BSc, Agronomy	Research Assistant
Otoniel Madrid	BSc, Statistics	Research Assistant
Alix Patricia Ziebell	BSc, Biology – Botany	Research Assistant
Lilian Patricia Torres	BSc, Business Administration	Administrative Assistant
Elizabeth Barona	Systems Technology	Technician
Jorge Antonio Cardona	Systems Technology	Technician
Silvia Elena Castaño	Systems Technology	Technician
Ligia Myriam García	Architectural Drawing	Technician
Herman Usma	Agricultural Technology	Technician (80% PE5)
Yuviza Barona	Bilingual Secretary	Bilingual Secretary
Dionne Martínez P*	Bilingual Secretary	Bilingual Secretary
Trinidad Velasco	Office Systems Support	Bilingual Secretary
Marisol Calderón	Architectural Drawing	Digitizer
Homer Alexander Cuero	Systems Technology	Digitizer
Rafael Dario Hoyos	Civil Eng. Technology	Digitizer
Rosalba López	Statistical Technology	Digitizer
Carlos Nagles	Agricultural Technology	Digitizer
Victor Manuel Soto	Systems Technology	Digitizer

Annex 1: Regional network of institutions participating in the project “Indicators of Rural Sustainability for Central America”

International Institutions

1. The World Bank
2. Programa de Naciones Unidas para el Medio Ambiente (PNUMA)
3. Centro Internacional de Agricultura Tropical (CIAT)
4. World Resources Institute (WRI), Washington
5. Comisión Económica para América Latina y el Caribe (CEPAL), Chile

Regional Institutions

1. Comisión Centroamericana de Ambiente y Desarrollo (CCAD), Guatemala
2. Programa de Desarrollo Sostenible en Zonas de Frontera Agrícola (PFA), Panama
3. Programa Ambiental Regional para Centro América (PROARCA) / Central American Protected Areas Systems (CAPAS)
4. Instituto Interamericano de Cooperación para la Agricultura (IICA), Costa Rica
5. Unión Internacional para la Conservación de la Naturaleza (UICN), Costa Rica
6. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica

National Institutions

COSTA RICA

1. Ministerio de Planificación (MIDEPLAN)
2. Sistema Nacional para el Desarrollo Sostenible (SINADES)
3. Comisión Terra
4. Escuela de Ciencias Biológicas, Universidad Nacional
5. Proyecto Iniciativa Centroamericana en Población y Ambiente
6. Dirección General de Estadísticas y Censos (DGEC)
7. Sistema Nacional de Áreas de Conservación (SINAC)
8. Proyecto Transfronterizo de Centroamérica, Universidad de Costa Rica
9. Observatorio del Desarrollo (OD), Universidad de Costa Rica
10. Centro de Investigaciones en Desarrollo Sostenible (CIEDES)

EL SALVADOR

1. Ministerio de Ambiente y Recursos Naturales (MARN)
2. Dirección General de Estadística y Censos (DIGESTYC)
3. Ministerio de Agricultura y Ganadería (MAG)
4. Proyecto “Agricultura Sostenible en Zonas de Ladera” Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA) – Food and Agriculture Organization (FAO)
5. Dirección General de Economía Agropecuaria (DGEA)
6. Consejo Nacional de Ciencia y Tecnología (CONACYT)
7. Fundación Nacional para el Desarrollo (FUNDE)
8. Programa de Desarrollo Humano Sostenible (PDHS)
9. Fundación Salvadoreña para el Desarrollo Económico y Social (FUSADES)
10. Programa Salvadoreño de Investigación sobre Desarrollo y Medio Ambiente (PRISMA)

GUATEMALA

1. Instituto Nacional de Estadística (INE)
2. Ministerio de Agricultura, Ganadería y Alimentación (MAGA)
3. Sistema de Información Estratégica Agropecuaria (SIEA)
4. Plan de Acción Forestal para Guatemala (PAFG)
5. Comisión Nacional de Ambiente (CONAMA)

HONDURAS

1. Corporación Hondureña de Desarrollo Forestal (COHDEFOR)
2. Ministerio de Agricultura y Ganadería
3. Instituto Nacional Agrario (INA)
4. Secretaría de Recursos Naturales y Ambiente (SERNA)
5. Catastro Nacional
6. Servicio Autónomo Nacional de Acueductos y Alcantarillados (SANAA)
7. Programa de las Naciones Unidas para el Desarrollo (PNUD)
8. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE)
9. Consejo Centroamericano de Bosque y Áreas Protegidas (CCAB-AP)

NICARAGUA

1. Ministerio de Ambiente y Recursos Naturales (MARENA)
2. Facultad de Recursos Naturales Renovables (FARENA), Universidad Nacional Agraria (UNA)
3. Instituto Nacional de Estadísticas y Censos (INEC)
4. Ministerio de Acción Social (MAS)
5. Ministerio de Agricultura y Ganadería (MAG)

PANAMA

1. Contraloría General - Dirección de Estadística y Economía
2. Comisión Nacional de Medio Ambiente (CONAMA)
3. Instituto Nacional de Recursos Naturales Renovables (INRENARE)
4. Ministerio de Desarrollo Agropecuario (MIDA)

Annex 2: Visitors

Short term visiting scientists

Laban MacOpiyo	MSc, Biogeography	Visting Scientist-ILRI
Ahmed Allam	BSc Agronomy	Visiting Scientist-ICARDA
Koulla Pallaris	MSc, Geography	Visiting Scientist-Kings College
Scott Cecchi	BSc, Geography	Visiting Scientist

Name	From
Dr Ernst Schaltegger, Consultant	Swiss Development Cooperation (SDC)
Dr Hans G.P. Jansen	CATIE/Wageningen University
Dr Robert R. Hearne	;Environmental Economics Program; International Institute for Environment and Development (IIED), UK
Dr Maria E. Fernandez	Candidate for the position of Especialista en Género
Dr Javier B. Verástegui	Candidate for the position of BD Officer
Dr James McMillan	Oberlin College, USA
Dr Kristen Probst	Systemwide program on Participatory Research and Gender Analysis
Dr J. Goldstein	Attorney at Law Specialist IPR
Luck Sas	Belgian Development Council
Luis Guillermo Wolf	Empresas Públicas de Medellín
Dr J White	Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico
R. G. Poulter	Department of International Development-London-England
Ian Bevege	Australian Centre for International Agricultural Research (ACIAR), Australia
Josue L. Posner	Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN)
Ing. Jorge Garcia	Universidad del Valle
Group visit	Union Internacional de Conservacion de la Naturaleza (UICN), Switzerland and Canada
Group visit	Comision Permanente del Pacifico, Quito, Ecuador
Group visit	Ministerio de Planificacion, Panama
Group visit	Departamento Nacional de Planeacion,DNP, Colombia
Ing. Manuel L. Cabrera Sandoval	Director of Environmental Evaluation and Order, Instituto Nacional de Recursos Naturales (INRENA), Peru
Group visit	World Bank, Washington
Group visit	Programa de las Naciones Unidas para el Medio Ambiente (PNUMA), Mexico
Fernado Hurtado Pascual	United Nations alternative development project (UNOPS)-Colombia
Jaime A. Escobar	UNOPS- Colombia (Cattle)
Eduardo Marin C., Ing.	Ministry of Agriculture-Nicaragua

Agrónomo	
Jorge Rodríguez Rubí, Ing. Agrónomo	Ministry of Agricultura-Nicaragua
Graciela Pantini	Fundación Polar
Alejandro Imbach	Candidate for the position of Ecoregional Coordinator
Carlos Eduardo Quintero	DANAC
Fernando Ajmad	DANAC
Group visit	IGAC
Dr Maria de J. Aguilera Ospina	Ministry of Agriculture and Rural Development
Ing. Olga Z. Rios del Aguila	Regional Director Ucayali
Javier Soto Calderon	Regional Director Ucayali
Dr Mahendra Shah	Representative of the CGIAR
Dr Josefina Takahashi Sato	Presidente Sec. Técnica de la Coordinación de CGIAR, Perú
Dr Albert Gierend	Candidate to the position of Economist
Dr Dereck Byerlee	World Bank
Dr Todd Niesen	Agronomy/ University of Georgia
Dr Dean Holland	Ag. Extension/ Reading University, UK
Dr Lucio Reco	Visiting Research Fellow - International Food Policy Research Institute (IFPRI)
Joep C. Luijten,	MSc. Graduate Research Assistant University of Florida
Eric Sawyer,	GIS specialist, University of Georgia
Carlos Perea	Manager Cali office of PROSIS S.A.
Mark Mulligan	Kings College, London England

Abbreviations and Acronyms

ACIAR	Australian Centre for International Agricultural Research, Australia
ACIN	Asociación de Cabildos del Norte del Cauca, Colombia
AEZ	agroecological zones
ANU	Australia National University
ATM	aboveground tree mass
BA	basal area
BGMV	bean golden mosaic virus
CAPAS	Central American Protected Areas Systems
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CCAB-AP	Consejo Centroamericano de Bosque y Areas Protegidas, Honduras
CCAD	Comisión Centroamericana de Ambiente y Desarrollo, Guatemala
CCRS	Canadian Centre for Remote Sensing
CDM	Concurrent Decision-making Methodology
CENTA	Centro Nacional de Tecnología Agropecuaria y Forestal, El Salvador
CEPAL	Comision Economica para America Latina y el Caribe, Chile
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International Development Agency
CIEDES	Centro de Investigaciones en Desarrollo Sostenible, Costa Rica
CIESIN	Consortium for International Earth Science Information Network, Michigan, USA
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CLUE	Conversion of Land Use and its Effects model
CODESU	Consorcio para el Desarrollo Sostenible de la Región Ucayali, Peru
COHDEFOR	Corporación Hondureña de Desarrollo Forestal, Honduras
CONACYT	Consejo Nacional de Ciencia y Tecnología, El Salvador
CONAMA	Comisión Nacional de Ambiente, Guatemala
CONAMA	Comisión Nacional de Medio Ambiente, Panama
CONDESAN	Consorcio para el Desarrollo Sostenible de la Ecorregión Andina
CORPES	Consejo Regional de Planificación Económica y Social, Orinoquia, Colombia
CORPOICA	Corporación Colombiano de Investigación Agropecuaria
CPPS	Comision Permanente del Pacifico Sur
CRES	Centre for Research and Environmental Studies, Australia
CRISEC	Centro de Investigación y Servicios Comunitarias de Santander de Quilichao, Colombia
CSERGE	Centre for Social and Economic Research on the Global Environment, UK
CSI	Consortium for Spatial Information
DANIDA	Danish International Development Agency
DBH	diameter at breast height
DDGs	Deputy Director Generals
DEM	digital elevation model
DGEA	Dirección General de Economía Agropecuaria, El Salvador

DGEC	Dirección General de Estadísticas y Censos, Costa Rica
DGGE	denaturing gel electrophoresis
DGs	Director Generals
DIGESTYC	Dirección General de Estadística y Censos, El Salvador
DN	digital number
DNP	Departamento Nacional de Planeación, Colombia
DPCSD	Department for Policy Coordination and Sustainable Development, United Nations
DSS	Decision Support System
DSSAT	Decision Support System for Agrotechnology Transfer
ECOHEALTH	Ecosystem Approaches to Human Health of the International Development Research Centre, Canada
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria
ESA	European Space Agency
ESNACIFOR	Escuela Nacional de Estudios Forestales, Honduras
ESRI	Environmental Systems Research Institute, Redlands, California
FAO	Food and Agriculture Organization, Rome
FARENA	Facultad de Recursos Naturales Renovables, Nicaragua
FEDEARROZ	Federación Nacional de Arroceros de Colombia
FHIS	Fondo Hondureño de Inversión Social
FR	farmers reporting
FUNDE	Fundación Nacional para el Desarrollo, El Salvador
FUSADES	Fundación Salvadoreña para el Desarrollo Económico y Social, El Salvador
G/DSS	Group Decision Support System
GCP	ground control point
GEO	Global Environmental Outlook meeting
GIS	geographical information systems
GLASOD	Global Assessment of Soil Degradation
GO	government organization
GPS	global positioning system
GRID	Global Resource Inventory Database, Arendal, Norway
IARC	International Agricultural Research Center
IBSRAM	International Board of Soil Resources and Management, Thailand
ICARDA	International Center for Agricultural Research in the Dry Areas, Syria
ICRAF	International Centre for Research in Agroforestry, Kenya
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IDRC	International Development Research Centre, Canada
IFPRI	International Food Policy Research Institute, USA
IGAC	Instituto Geografico Agustin Codazzi, Colombia
IGDN	Interamerican Geospatial Data Network
IGN	Instituto Geográfico Nacional, Costa Rica
IICA	Instituto Interamericano de Cooperación para la Agricultura, Chile
IIED	International Institute for Environment and Development, UK
ILRI	International Livestock Research Institute, Nairobi, Kenya
INA	Instituto Nacional Agrario, Honduras
INDERENA	Instituto Nacional de los Recursos Naturales y Renovables del Ambiente, Colombia

INE	Instituto Nacional de Estadística, Guatemala
INEC	Instituto Nacional de Estadísticas y Censos, Nicaragua
INEI	Instituto Nacional de Estadística e Informática, Peru
INETER	Instituto Nicaraguense de Estudios Territoriales
infoDev	Information for Development project of the World Bank
INPE	Instituto Nacional de Pesquisas Espaciais, Brazil
INRENA	Instituto Nacional de Recursos Naturales, Peru
INRENARE	Instituto Nacional de Recursos Renovables, Panama
IPGRI	International Plant Genetic Resources Institute, Italy
IPM	Integrated Pest Management
LAC	Latin America and the Caribbean
MAG	Ministerio de Agricultura y Ganadería, El Salvador
MAG	Ministerio de Agricultura y Ganadería, Nicaragua
MAGA	Ministerio de Agricultura, Ganadería y Alimentación, Guatemala
MARENA	Ministerio de Ambiente y Recursos Naturales, Nicaragua
MARN	Ministerio de Ambiente y Recursos Naturales, El Salvador
MAS	Ministerio de Acción Social, Nicaragua
MIDA	Ministerio de Desarrollo Agropecuario, Panama
MIDEPLAN	Ministerio de Planificación, Costa Rica
MLC	Maximum Likelihood Classifier technique
NASA	National Aeronautics and Space Administration, USA
NASDA	National Space Development Agency, Japan
NDVI	normalized vegetation index
NGO	nongovernment organization
NRM	Natural Research Management
OD	Observatorio del Desarrollo, Universidad de Costa Rica
ODI	Overseas Development Institute, UK
OS	operating system
ox C	oxidizable carbon
P.O.M.	particulate organic matter
PAFG	Plan de Acción Forestal para Guatemala
PAIGH	Pan American Institute of Geography and History
PAT	Polygon Attribute Table
PC	principal component
PDHS	Programa de Desarrollo Humano Sostenible, El Salvador
PFA	Programa de Desarrollo Sostenible en Zonas de Frontera Agrícola
PNUD	Programa de las Naciones Unidas para el Desarrollo
PNUMA	Programa de las Naciones Unidas para el Medio Ambiente
PRISMA	Programa Salvadoreño de Investigación sobre Desarrollo y Medio Ambiente, El Salvador
PROARCA	Programa Ambiental Regional para Centro América
P-S-I-R	Pressure-State-Impact-Response framework for indicators
ROLAC	Regional Office for Latin America and the Caribbean, of the United Nations Environment Program
S&B	slash and burn
SANAA	Servicio Autónomo Nacional de Acueductos y Alcantarillados, Honduras
SAR	synthetic aperture radar

SDC	Swiss Development Cooperation
SECPLAN	Secretaria de Planificación Coordinación y Presupuesto, Honduras
SERNA	Secretaria de Recursos Naturales y Ambiente, Honduras
SID	spatial intraspecific diversity
SIEA	Sistema de Información Estratégica Agropecuaria, Guatemala
SINAC	Sistema Nacional de Areas de Conservación, Costa Rica
SINADES	Sistema Nacional para el Desarrollo Sostenible, Costa Rica
SIPSA	Sistema de Indicadores para la Planificación y Seguimiento Ambiental de Colombia
SOTER	Global and national Soils and Terrain digital databases
T.O.C.	total organic carbon
TGGE	temperature gradient gel electrophoresis
UBN	unsatisfied basic needs
UGA	University of Georgia, Atlanta
UICN	Union Internacional para la Conservación de la Naturaleza, Switzerland and Canada
UMATA	Unidad Municipal de Asistencia Técnica Agropecuaria, Colombia
UNA	Universidad Nacional Agraria, Costa Rica
UNA	Universidad Nacional Autónoma, Nicaragua
UNDP	United Nations Development Program
UNEP	United Nations Environment Program, Geneva
UNESCO	United Nations Educational, Scientific, and Cultural Organization, France
UNOPS	United Nations alternative development project
UPA	Unidad de Planeación Ambiental del Departamento Nacional de Planeación, Colombia
USGS	United States Geological Survey
USLE	universal soil loss equation
vid	visualizing diversity
WAU	Wageningen Agricultural University, the Netherlands
WRI	World Resources Institute, Washington
WSM	wood specific mass