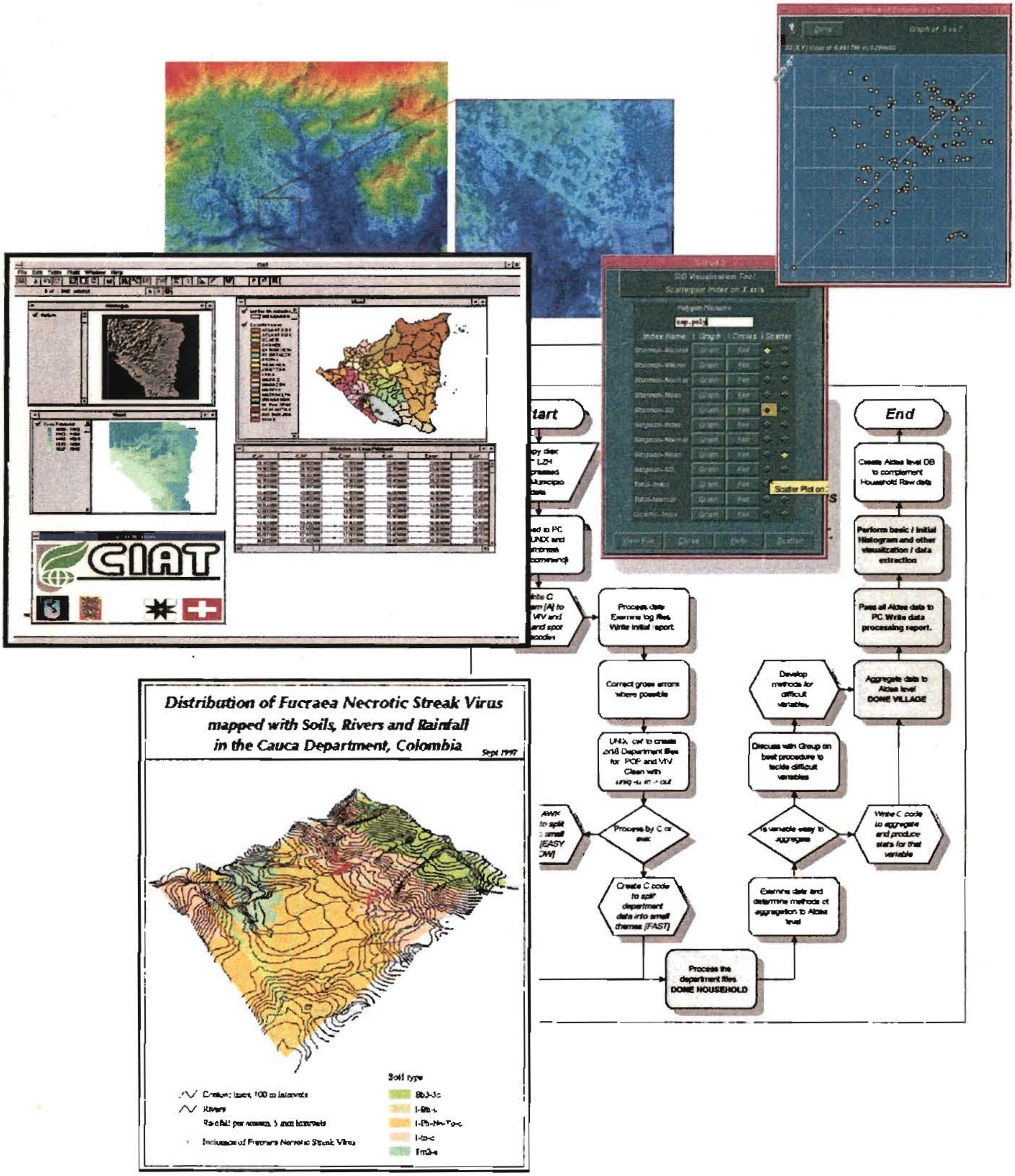
INFORMATION SYSTEMS-GIS



Annual Report 1996-1997

CIAT

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

INFORMATION SYSTEMS UNIT

AND

GEOGRAPHIC INFORMATION SYSTEMS FACILITY

ANNUAL REPORT 1996-97

Centro Internacional de Agricultura Tropical (CIAT)
Cali, Colombia
December, 1997

Contributors:

William Bell, Chief Information Officer, Leader GIS Facility
Marta Aguilar
Nathalie Beaulieu
Justine Klass
Grégoire Leclerc
Andy Nelson
Tonny Oyana
Javier Puig

Edited by:

Annie L. Jones

Information Systems Unit and the Geographic Information Systems Facility Annual Report 1996-97

CONTENTS

EXECUTIVE SUMMARY

This Annual Report incorporates the Information Systems (IS) Unit and the Geographic Information Systems (GIS) facilities, both now under the leadership of Dr William Bell.

The IS Unit

The IS Unit has achieved much this year despite cutbacks in staff and funds. CIAT staff were trained in the use of Windows 95, Microsoft Outlook, and Microsoft Word before the changeover to this system. Some staff were also trained in Excel and Powerpoint.

The three mail systems and Unix mail were integrated into one system under Microsoft Exchange. CIAT's satellite bandwidth, and the Allocate PB software and firmware were upgraded facilitating better communications with the world. CIAT's phone lines from Cali were also upgraded to improve service for on-line access to CIAT's network and the Internet from staff homes.

The network has been improved as far as possible, given lack of funding, to the point where we will have sufficient network backbone bandwidth to the year 2000. The GIS hardware has been upgraded and the new financial system will be ready to start in late January 1998.

A new Oracle database was developed for Dr Pachico's office, and scientific database modernisation has continued. The data backup system has been improved for key users. The Graphic Arts area was also updated during fall 1997.

The GIS Facility

The GIS Facility was included as part of the IS Unit in 1997 to support the general CIAT projects community. The facility is also building its own research component. CIAT's first funded GIS research project began this year. We are developing a stronger operating capacity in radar remote sensing as part of our development strategy. We are participating in Japan's National Space Development Agency's (NASDA's) Global Rain Forest Mapping Program (GRFM), the Canadian funded GLOBESAR II program, and in the Canadian Space Agency's (CSA's) Application Development and Research Opportunity (ADRO) program. We have also contributed to strengthening National Agricultural Research Systems (NARS), and other national institutions, with training and collaboration.

The facility's activities are aligned with strategic directions as expressed in CIAT's mid-term plan, and we are actively working on the spatial characterization of poverty, spatial analysis of biodiversity, integrated pest and disease management, land-use mapping, and analysis in different ecoregional settings, including hillsides. We have collaborated mainly with the following CIAT projects:

- **SB-2** (Enhancing the Understanding and Use of Agrobiodiversity through Biotechnological Methods),
- **PE-1** (Integrated Pest And Disease Management In Major Tropical Agroecosystems),

- **PE-3** (Community Management of Watershed Resources in Hillside Agroecosystems of Latin America),

- **PE-4** (Land-Use Studies: Reconciling the Dynamics of Agriculture with the Environment), and

- **PE-5** (Sustainable Systems for Smallholders: Integrating Improved Germplasm and Resource Management for Enhanced Crop and Livestock Production Systems Projects).

Each project's plans and work breakdown structure are outlined in Annexe 1. The nature of these projects has enabled diverse contributions to be made. Some of these have included: mapping species accessions, calculating diversity indices, mapping crop virus infestations, calculating social indices from census data, mapping population density, forecasting erosion at the watershed level, creating Digital Elevation Models (DEMs), deriving land-use from satellite imagery, and printing materials for presentation of research results in publications and conferences. The GIS Facility has taken some leadership in the subject of poverty mapping, which is a theme included in the PE-3 and PE-4 projects.

Milestones for 1998

The CIAT mid-term plan lays out milestones for all CIAT projects. The GIS Facility contributes to different projects at different times according to perceived needs. This year we have helped make advances on the following project milestones.

SB-2 Molecular linkage maps and DNA-based markers available for assessing diversity of *Phaseolus*.
See page 15 for a first application of mapping of bean genes with CIAT's biotechnology group, using a technique developed for *Pouteria sapota*.

PE-1 Whitefly and geminivirus biodiversity partially characterized.
A GIS database for whitefly in Mexico, Central America, and the Caribbean is nearing completion (see page 18). Databases are also in process for *Fucraea* necrotic streak in Cauca, Colombia and for rice stripe necrosis virus in the main rice-growing areas of Colombia.

PE-3 Instructional materials for community-based resource planning organizations and use of environmental databases.
Most of our work in support of PE-3 has contributed to advances on this milestone (see pages 23 to 34).

PE-4 GIS coverages of administrative regions, climate, population, land use, and watershed data produced, documented, and made available for all continental Latin America.
Our support to the PE-4 project has helped developments on this milestone (see pages 35 to 46).

PE-5 Workshop to analyze the effectiveness of FPR in the development of new technology options for smallholder systems.
The GIS database being built for Pucallpa will be available for use in this workshop.

INFORMATION SYSTEMS UNIT

INTRODUCTION

The Information Systems Unit (ISU) underwent major restructuring in late 1996. The initial appointment of Dr. William C. Bell as acting Chief Information Officer (CIO) in September was confirmed, effective January 1st, 1997. However, the new CIO would spend 50% of his time in GIS management activities, the other 50% of GIS activities being handled by two Research Fellows; Grégoire Leclerc (from Sept 1996) and Nathalie Beaulieu (from Nov 1996).

The uncertain budgetary environment of late 1996/early 1997 and the lack of capital funds for new equipment and software over the last few years has had an effect on our GIS staff. Five left in 1996-97 resulting in a substantial loss of institutional GIS knowledge. Fewer and less experienced staff replaced them so more effort will be spent on training to try to offset the loss of specific expertise and experience.

At the start of 1997 the various information functions were grouped under five major management groups: systems and network administration, user support, applications and database programming, financial systems, and GIS.

All areas had undergone and were actively undergoing major downsizing caused by financial shortfalls in CIAT's 1997 operating budget. However, capital funds were available and major purchases were made both for IS and for all of CIAT's computing infrastructure. This allowed the replacing of much of our 4-year-old hardware and software that could no longer meet CIAT's business and research objectives.

A Strategic Information Management Committee (SIMC) was established, with the CIO as Chair, to determine Information Management priorities for CIAT. During Spring 1997 the following four main priorities were established:

- select and implement a new financial management system over the next 18 months;
- upgrade office systems to Microsoft Office and a unified mail system;
- improve the network failure down-time and response-time; and
- increase the satellite bandwidth of the internet connection to the USA.

The SIMC also established a 3-year life cycle for computer-related equipment and recommended a suitable level of capital funding to be provided to make this possible.

The position of IS at the start of 1997 was critical. No capital funds had been disbursed to IS in over 3 years and all equipment was outdated, being in its fourth year of use. Also, none of the IS staff had attended training courses during that period and their skills had rapidly deteriorated, given that the half life of most IS information is only 18 months. All software was outdated. Added to this, CIAT was experiencing a major downsizing with IS suffering, in real terms, over a 30% cut to its operating budget between Spring 1996 and Spring 1997. This necessitated the lay offs of key, experienced staff, who not only knew CIAT's business well, but also had the database and statistical knowledge to convert data into information—exactly what CIAT needs to remain a strategic research player in the twenty-first century. Further, the major capital funds that were received to update and make the IS system close to current could only be implemented by using the existing curtailed staff complement. It was immediately clear that major operating funds needed to be used immediately for staff development so CIAT staff could cope with the new technologies that they would be required to implement during the year. Essentially, the first 4 months of the year were used to finalize the operating and capital budgets, set priorities with the SIMC, and start investing in our remaining human capital.

ACTIVITIES

To accomplish the SIMC overall priorities the following activities were implemented, starting in April, with the disbursement of capital funds.

Upgrade of Microcomputers

All older computers (e.g., 486-33s or 66s) were upgraded to 486-133s with sufficient memory and disk to run Windows 95, which was considered enough to give them an additional 12 to 18 months of useful life. Some 335 microcomputers were upgraded over a 4-month period. In October, the Miami office and the Carimagua field site were also upgraded. Most of these computers will need replacing in 1998 and the remainder in 1999. It was not an option, nor was it cost effective, to replace all computers in 1997 as most of the available capital funds were needed to update much of the outdated Information Technology (IT) infrastructure.

Over 40 new computers were purchased from capital funds, one for each Project and Unit, several for the microcomputer teaching laboratory, and a few for power users. All new computers purchased in the spring were configured as at least Pentium 166s with 32 mb ram and 17" monitors. By August, the minimum configuration had risen to Pentium 200MMXs and by October, the minimum was a Pentium II 233mz MMX machine as prices continued to plummet with new CPU introductions by Intel. These machines have a useful life of about 3 years in today's dynamic IT environment.

Training

Several User Support and System Administration staff were sent for training in Microsoft products and two were sent for SUN Solaris operating system training. They in turn helped train each other and wrote the materials for the courses given to CIAT staff last spring and summer. A networked teaching room, as a temporary addition, was prepared with 15 microcomputers to speed the CIAT staff training process. This benefitted from the new software and allowed its faster implementation.

Over 400 staff were trained in Windows 95, Microsoft Outlook, and Microsoft Word. All staff requiring Excel were also trained in its use and courses were given in PowerPoint. Training was completed before the move from Word Perfect to Microsoft Office software.

Microsoft Windows 95 was adopted as the CIAT standard operating system and was installed in over 450 microcomputers over a 4-month period. Carimagua and Miami were upgraded in

October. Microsoft Office 97 Professional with Outlook was adopted as CIAT's office management system, effective late August 1997.

Unified Mail System

The three mail systems were integrated into a unified one under Microsoft Exchange and all staff were moved from GroupWise to Exchange by September, and from MS Mail to Exchange by the end of October. Unix mail users were also integrated into Exchange by the end of October via Netscape access. All internal and external mail is now fully integrated into a common mailbox. In November all mobile users will be upgraded to use Microsoft Outlook Express/Internet Explorer to access their CIAT Exchange E-mail over the World Wide Web (WWW) wherever access is available. Travelling mailboxes through CGNET will remain available for those who need them, especially for Africa and parts of Asia.

Satellite Link

Over the last 3 years, our use of the CGNET's Integrated Voice and Data Network (IVDN) and of the WWW had increased exponentially, to the point that on-line data access to the rest of the world during the day was becoming practically impossible. To meet this need, the satellite bandwidth was upgraded fourfold in fall 1997 (from 64 kilobytes per second [Kbps] to 256 Kbps) for an additional 40% in cost. Phone use had also increased exponentially and many of our associates reported that they could not easily access CIAT, neither by fax nor by phone, from the USA. In August, IS commissioned ALCATEL, our telephone exchange (PBX) provider, to upgrade the PBX software and firmware to accept E1 digital voice channels. The Allocate PBX upgrade was recently completed. Six additional voice channels to the US, with improved quality due to digital voice compression, should be operational in November. This will also permit additional fax capability, which is much needed.

The demand for on-line access to CIAT's network and the Internet from staff homes to expedite work has steadily expanded over the last year. To meet this growing need, EMCATEL, our telephone provider, responding to an IS request for better service, has upgraded CIAT's phone lines from Cali to two digital E1 circuits, each with 30 digital channels. One E1 channel will be used for IVDN service for digital home computer and telephone access, initially for up to 16 concurrent users by year-end but with future expansion possible for up to 30 IVDN circuits. Additional dial-up lines will also be provided by year-end to meet increased demand for analog access to the network from home.

Improved Network

Network performance continued to deteriorate during 1996 as data volumes continued to rise. Equipment installed in 1992 and 1993 could no longer carry the increased load resulting in frequent catastrophic system crashes, sometimes several times per day. Capital funds were not available in 1996 to remedy the situation. In early 1997 approval was given for some emergency purchases of network equipment, prior to the approval of the capital budget in the spring to help eliminate these catastrophic failures. Essential backbone upgrades of the network were completed in March 1997 to help CIAT through the next few months. Also, to ensure better service during power failures, all wiring closets were upgraded with uninterruptible power supply (UPS) equipment. This carried most of CIAT through the summer and fall with adequate levels of service, except for GIS, which was experiencing a poor level of service. Staff shortages because of other priorities in CIAT meant that nothing could be done for GIS until after completing Microsoft Office and Exchange mail upgrades for all of CIAT.

In November, after major third quarter falls in 10/100 megabytes/second (Mbps) switch prices, further improvements to the network were purchased and will be implemented in late November to provide sufficient network backbone bandwidth to the year 2000 except for minor additional purchases at board level. However, insufficient funds are available to increase bandwidth to the desktop for all users at this time, nor is this needed. Each year, some of our 26 buildings will be updated from those with the highest additional network traffic as intranet applications, video, document imaging, and voice continue to play an ever important role on the desktop. By the end of 1997 we will have upgraded service to five buildings from 10 Mbps shared hubs with 10 Mbps trunks to a mixture of hubs and 100 Mbps switches with 100 Mbps trunks. This will substantially improve system response in those buildings.

GIS Hardware Upgrade

A start was made on upgrading the GIS facilities in September/October and this work will continue throughout November. New SUN servers are being implemented to meet the needs of higher resolution GIS and remotely sensed image data. Several new workstations were purchased and eight 1993 Sparc 5s were given minor memory and CPU upgrades to get them through another year, after which they will need replacing. Major software upgrades were made in the field of radar imagery analysis software (Atlantis APP processor) and the number of licenses for ESRI's GIS software and PCI software were greatly increased from their 1995 levels. In all cases substantial discounts were secured from both the hardware and software vendors. Some of our older plotters were also replaced and some new global positioning system (GPS) equipment with lower resolution (1 m) differential was purchased to complement our existing higher resolution equipment. In November/December major upgrades will be performed to the GIS network backbone where a one gigabyte/ second backbone will be installed connecting the two new high-speed servers. Several 100 Mbps switched ports will be installed to connect SUN workstations to efficiently handle the high volumes of radar, ortho-image, and optical remote-sensing data now being processed.

Financial System

During the year, numerous minor upgrades were made to the financial reporting system to meet new legal requirements for reporting and analysis that are more complex. However, the nature of the existing financial system is such that any changes made are extremely time intensive and usually result in slower access to other data, given that the AS400 computers are both at 100% capacity despite the purchase of increased memory and disk upgrades for both main systems this year. With the implementation of a new financial system in 1997 it was not felt economical to purchase newer, larger capacity AS400s at this time. To permit some upgrades we decided to move some of the less sensitive financial data from the AS400s to the SUN 2000 main CIAT server on a daily basis. A program to convert the data from the DB2 database to the Oracle database was written and we were then able to develop an on-line financial reporting system for project managers and their staff using modern PowerBuilder software.

During June and July a user-needs analysis was completed for CIAT's proposed new financial system with inputs from both administrators and scientists. A *Request For Information* was subsequently drawn up and sent to five selected vendors based upon the experience of the Financial System Evaluation Committee (William Bell, Juan Garafulic, and Barry Keenan). Initial vendor responses were reviewed in early August and, in consultation with a group of users, the committee drew up a short list of two. Further discussions with the two short-listed vendors were undertaken in August, September, and October. Several client site visits were organized and conducted in late September and October. The CIO is now seeking additional details from both vendors and has asked for updated cost estimates for both the software and its implementation. Negotiations will continue in November. We anticipate that initial implementation of the new financial system will start in late January or early February 1998 with about a 9-month implementation for the core financial systems.

In the fall, a major effort was undertaken to map all of CIAT's business processes and the information flows and decision points among them. This work was completed in early November and has already been distributed to the two vendors to help them better understand CIAT's existing business model. From this, they are better able to evaluate the cost and impact of implementing one of their many business models as we implement our new financial system in 1998.

Much has been accomplished over the last year. The ISU is leaner, but much more up-to-date, and morale is higher than ever. Objectives have been met and exceeded. Clearly we are far from finishing the first complete overhaul of IS since 1992/93. To do so will take more time and resources. All scientific systems are functioning reasonably well, as are the office automation-type functions.

Projects Database

A major unplanned project was undertaken for Dr. Pachico's Office in mid and late 1997. Large quantities of project-related data were entered into a unified database from a wide variety of computers, programs, and paper sources. The new Oracle database permits queries on personnel, projects in progress, donors and donor priorities, and project reports due et cetera. This project should be completed in December.

Scientific Databases

The modernizing of scientific databases continued throughout 1997 as more of CIAT's databases were converted from character line-interfaces to more friendly graphics user interfaces using fourth generation language tools for better data queries. This work will continue in 1998. The International Crop Information System (ICIS), based at the Centro

Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), was adopted by CIAT this year as a possible system for better managing our germplasm database data. A pilot project, funded by CIMMYT, is now operational and the first populated database should be available for use in March, prior to the International ICIS Users Group Meeting to be held at CIAT. Despite the progress in this area, much additional work needs to be done if CIAT is to remain competitive in the new information age. This simply cannot be done with the present IS staff complement.

Data Backup System

In the past, CIAT had no satisfactory data backup policy and data archiving system. Indeed, it remains unclear as to who actually owns the data in many cases, but a new CIAT policy in this area is being considered by the management team and should be implemented in 1998. Meanwhile, IS will implement an improved backup system in late November for scientific data on CIAT servers. In January, key users such as Directors and some Project Managers will be able to backup their PC data centrally on a daily basis to high-quality, high-capacity, magnetic tape. Backup procedures will be further refined in 1998 after the data ownership policies are implemented, but remote backups are interdependent upon improving the networking infrastructure to the desktop.

Graphic Arts Upgrade

The Graphic Arts area was updated during the fall of 1997. These upgrades to Computers, Color Laser Printers, scanners, and slide makers greatly improved efficiency in the unit. Video compression equipment was tested and implemented by IS, enabling Graphics Arts to prepare PowerPoint presentations with embedded video. Dr Scobie gave such a presentation at Centers' Week.

THE GIS FACILITY

INTRODUCTION

CIAT's capacity and experience in the field of computer mapping and GIS was developed in the Land Management Program for over 10 years. At the beginning of 1997, using this capacity and experience, CIAT included the GIS Facility as part of the ISU, to support CIAT's projects.

The GIS Facility's Role

Its role is to meet CIAT's needs in terms of spatial data management, analysis, modeling, data acquisition planning, decision support, and communication of scientific results. Its purpose is both to produce maps and to provide projects with tools to improve their understanding of problems and their vision of solutions, towards the ultimate goal of decision-making. Its activities are aligned with the strategic directions as expressed in CIAT's mid-term plan, actively working in the spatial characterization of poverty, spatial analysis of biodiversity, land-use mapping, and analysis in different ecoregional settings, including hillsides. Through training and collaboration it is also contributing to strengthening NARS.

Challenges

The GIS Facility faces many challenges that are helping it evolve into a solid, open-minded, visionary, and efficient unit helping CIAT fulfil its mission. These challenges are to:

- follow decision-making goals rather than blindly collect, map, and analyze data,
- collaborate and become involved in CIAT's projects rather than provide products,
- maintain a working environment that attracts and maintains talented scientists and technical staff,
- produce cutting-edge research in the technologies of GIS and Remote Sensing while not losing sight of the applications of these technologies towards CIAT's mission, and
- produce tools that have impact at the level of communities and decision makers through the distribution of accessible, user-friendly, data interfaces.

To be able to face these challenges, the GIS Facility has been developing a team of interdisciplinary staff, who collaborate with the different projects and strengthen capacities through this involvement. Acquiring and updating new hardware and software has enhanced work efficiency, developed new applications, and improved techniques used.

Team-building objectives are achieved through regular staff meetings, reporting, and evaluation. Various sub-teams have been formed, composed of two or three people working on the same subject. The working environment encourages open discussions between groups, which creates an excellent "team-feeling" and makes troubleshooting less painful.

Hardware and Software

Rapid advances in computer technology, scientific methodology (demand), and access to larger and larger GIS and remote sensing datasets continue to drive GIS and remote sensing technology forward at an increasing pace. CIAT's GIS operation is fortunate in having excellent physical and computational facilities. During 1997, the GIS section received a major CIAT capital equipment grant to update most of the 4-year-old facilities and their associated networking infrastructure. Recently, incorporated in CIAT's overall networking facilities, a GIS subnet was installed to limit within the GIS group the large data volumes associated with the group's remote sensing analysis and continental GIS database operations. This data segregation has maximized the network's efficiency for both GIS users and the rest of the CIAT.

During November, a new gigabyte backbone will be implemented within the GIS network to handle the huge data volumes associated with today's radar analyses. This is important for the 40- to 100-fold increases in visible satellite, remote sensing data volumes expected in 1998, when new, high-resolution satellites are expected to be fully operational. The 4-year-old GIS server has also been upgraded and two new SUN Ultrasparc 2-300 servers have been added with six new workstations and several high-speed raid arrays. These permit a 10-fold increase in access speed between the data on the disk and the computer CPU. Several older, Sparc 5, computers were also given limited upgrades to increase their useful life for a further year. They can then be upgraded to faster workstations that are required to handle the increased volumes of data necessary for CIAT to remain competitive in this discipline.

DIFFUSION OF DATA AND INFORMATION

Creating a Web Site for the GIS Facility

In July 1997, an entirely new version of CIAT's WWW site was made available at http://www.ciat.cgiar.org. The new site was organized largely on the basis of projects and research themes. Most of the initial content comes from a new brochure entitled "This is CIAT", and from brief profiles prepared for the center's 16 projects. Directors and Project Managers have reviewed the contents of both the brochure and profiles.

The GIS Facility decided to contribute to this web site with a subsite of its own. Figure 1 illustrates the structure and content of the subsite. The aims are to:

- raise public awareness of GIS at CIAT and the potential applications and use of GIS within the Consultive Group on International Agricultural Research (CGIAR) system,
- use cutting-edge technology to reproduce our work on the net in an interactive and accessible format,
- increase the number of publications within the GIS unit,
- keep donors up-to-date with our progress and allow them otherwise impossible access to data, imagery, and current methodology,
- ease contact with CIAT staff and facilitate access to information, and
- link our activities to related activities inside and outside CIAT.

The site is now operational (http://gis.ciat.cgiar.org.) The next version will include interactive maps allowing browsers to investigate our results, and an interactive map library, documenting location, type, and availability of all hard-copy maps in CIAT. In particular, we wish to:

- maintain a record of visitors accessing our datasets (i.e., E-mail address, company name, and use of data),
- create an on-line, hard-copy, map database,
- incorporate on-line, house-written, software allowing visitors to run programs on the web site using their data, download full software versions, and increase publication of papers and completed project work on the site.

Maintenance of the website is expected to occur on a weekly basis and will include: updating website management software, adding the planned interactive facilities, improving multi-browser/cross-platform performance, and reacting to visitors' advice, requests, and criticism.

ArcStorm Database

At present, CIAT has an enormous amount of data scattered on numerous disks and tapes, and little or no inventory on what exists. This makes it difficult to locate required data. With the recent purchases of additional disk capacity and a donation of ArcStorm indexing software, we will be able to make great improvements in this area. In the next few months, an inventory of our data will be compiled and gradually integrated into an ArcStorm database. The purpose is to organize, inventory, and manage the data, enabling users across a network to access the data easily and efficiently.

ArcStorm is the data manager for Arc/Info. It provides a storage facility and a transaction manager for spatial information, which allows various users to access a given spatial database at the same time. ArcStorm is a feature-oriented, continuous, geographic database that can be integrated with relational database management systems such as Oracle. Once the database is established, data integrity is maintained and only the ArcStorm database administrator can modify its schema. Thus, ArcStorm is useful for managing large datasets and preventing data corruption caused by user-access problems. Also, users can easily access the data through a graphical user interface.

All CIAT's Arc/Info coverages will be managed using ArcStorm. Before we can create the database we must assess the users' needs and study the existing and anticipated data to be stored.

We have initiated the inventory for all the data at CIAT that currently exists. Once completed, the data resolution, data content (i.e., climate, soils, crops etc.) and maintenance procedures required can be assessed. A trial run will be conducted when the main layers of the ArcStorm are created. With feedback from users, amendments will be made to ensure the final database runs efficiently. The ArcStorm database is in construction and should be operational by Jan/Feb 1998. The GIS Facility will train users.

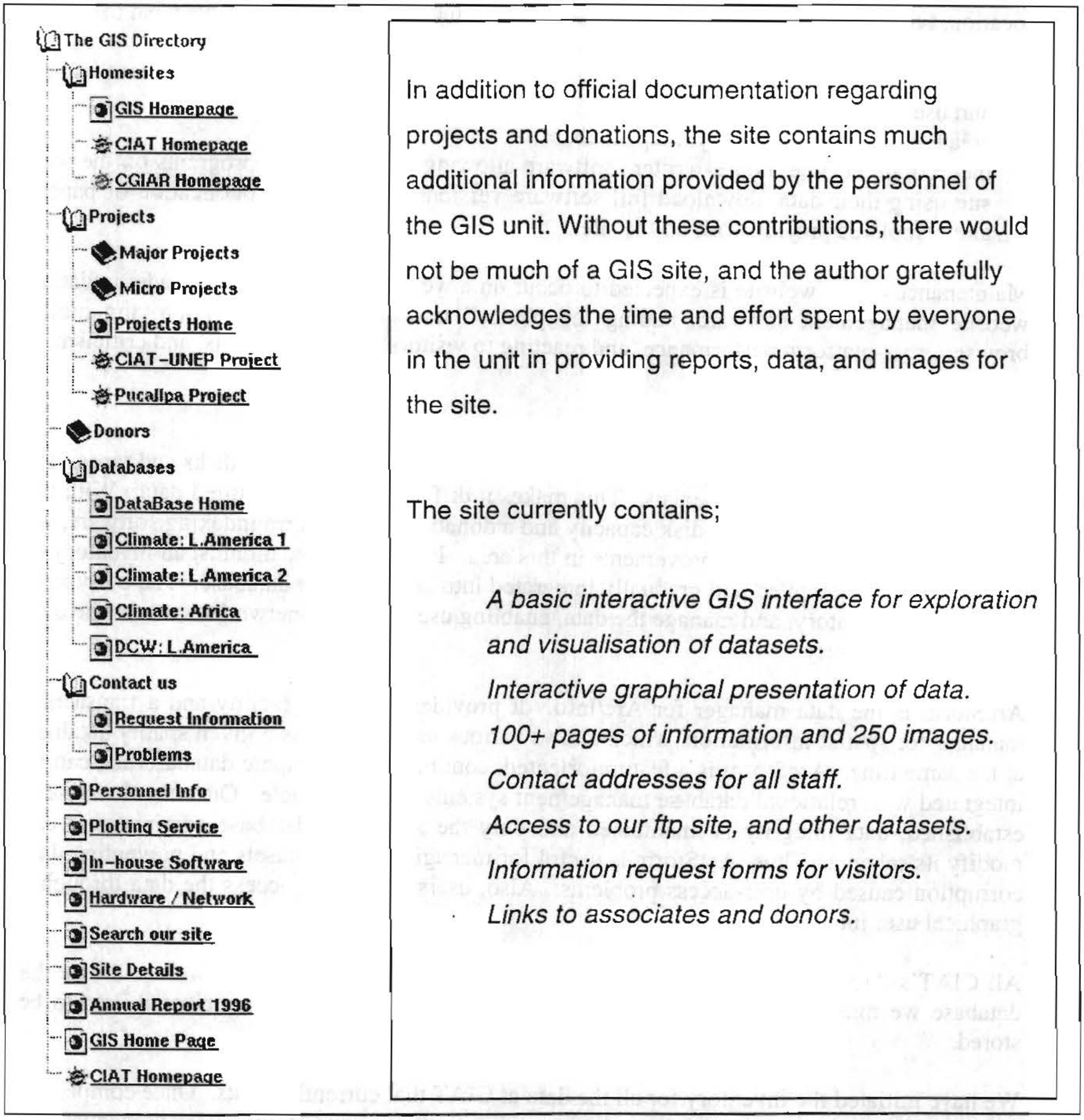


Figure 1. The first "Directory" level of the GIS web site.

Strategic Databases

Users' data requirements have risen exponentially in the last few years. Only 3 years ago we were working at regional level in Latin America and at the municipality level for parts of a few countries. Today we have the entire continental administrative boundaries for Latin America at the municipality level of detail, several countries' population and agricultural data down to the village level, and a few to the individual level. To use Honduras as an example, just over 2 years ago we mapped it at regional level with 18 divisions, then we moved to municipality level with under 300 divisions. Then 1 year ago we moved to village level with about 3700 village divisions. By 1997 we had all 3 800 000 individual population census forms for the 1974 and 1988 population census and over 500 000 individual farmer response forms for the 1974 and 1993 agricultural censuses. Honduras is not unique in this respect and we have access to similar data for Peru, Ecuador, and parts of Brazil. Not all these data are loaded in the database, nor will they be soon. The reason is the lack of a direct, immediate, clear need for some of the data coupled with current personnel and budgetary constraints, which allow the analysis of only small, clearly targeted parts of these data.

Most of these data acquired for specific projects are now of strategic use at CIAT and worldwide. Little such data existed 2 years ago. We have insufficient staff to fully manage these data as GIS core (non-project) operations have been cut back by almost one third. These datasets are on the increase and are opening up new areas for potential research and National Research Center cooperation, both in agriculture and with Census, National Planning, and Social Service Agencies.

A STRONGER RESEARCH COMPONENT

Methodologies for Integrating Data - Honduras

The project "Methodologies for Integrating Data Across Geographic Scales in a Data Rich Environment - Examples from Honduras" is CIAT's first funded GIS research project. It mainly focuses on GIS as a tool for integrating data acquired and represented at different scales and levels of accretion. A major output will be to generate new methodologies to fill gaps in the data represented at a certain scale, using data acquired and represented at another scale. The Dutch government provides funding of US$500 000 over 3 years to CIAT's PE-3 project and its collaborators. Collaborating institutions include the Wagenigen Agricultural University in the Netherlands, and the Royal Agricultural College and Leicester University in the UK.

Radar Remote Sensing

As part of its development strategy, the GIS Facility has decided to develop a strong operating capacity in radar remote sensing. Acquisition of remote sensing data over many of the research sites studied at CIAT has been delayed or made impossible because of cloud cover. Radar sensors can acquire imagery even through cloud cover, and therefore allow multiseasonal observations. However, our operational experience with radar remote sensing is less strong than with images from the optical domain. Radar images exhibit relief-induced geometric and radiometric distortions and are sensitive to many factors such as soil roughness and water content, which can complicate the monitoring of the vegetative cover. Although radar images have an indisputable utility for many applications, we must explore their potential for the applications sought at CIAT to protect ourselves from false expectations. The applications of interest are related to land-use mapping and monitoring of deforestation. We will also be actively exploring the use of radar imagery for the derivation of DEMs using stereo imagery or interferometry, because DEMs are a most important source of data needed for watershed studies.

Recently the Canadian Space Agency (CSA), the Canada Center for Remote Sensing (CCRS), and NASDA of Japan created research opportunities allowing investigators of approved proposals to receive free imagery and to take part in stimulating multi-institutional exchanges between investigators. CIAT is taking part in the programs managed by these three institutions, which allows us to inexpensively test and apply images from the Canadian RADARSAT and the Japanese Synthetic Aperture Radar Satellite (SAR), JERS-1, and to establish linkages with other institutions through collaborative research and meetings.

Participating in NASDA's Global Rain Forest Mapping Program

NASDA has created the GRFM program, where a great many radar images from the JERS-1 have been acquired since 1995 to cover the world's tropical areas. Efforts have been deployed among different institutions to form mosaics with these images to allow the mapping of the tropical forest. The JERS-1 SAR works with the L band, with a wavelength of about 23 cm, which produces good contrasts between forest and agricultural areas. Early in 1997, NASDA opened the program to additional institutions. We submitted a proposal, which was accepted, entitled "Evaluating JERS-1 SAR images for mapping Forest Extent and Interventions at Agricultural Frontier Sites in Latin America". Participating in the GRFM program entitles us to request up to 40 full-resolution scenes and to have access to mosaics produced by other institutions in exchange for our research contribution. Our contribution includes the demonstration of applying the imagery to problems at the sites studied by the Land Management and Hillsides Projects, corroborating between field measurement results and image parameters, and adapting a method to correct relief-induced, radiometric distortions in SAR imagery (Leclerc and Beaulieu, 1996). It will also probably include a collaboration with the Jet Propulsion Laboratory in Pasadena, California, to mosaic the images of Central America.

Images have been requested and received over the Colombian *Llanós*, in an area spanning Puerto Lopez to Carimagua, over the Pucallpa study site in Peru, over the Pedro Peixoto site in Acre, Brazil, and over the watershed of the El Angel river in Ecuador. Results obtained in the Colombian *Llanos* on the determination of weaknesses in the riparian forest and preliminary results obtained for Pucallpa on the mapping of agricultural settlements are presented here under the PE-4 Project. Results obtained with lower resolution (averaged) JERS-1 images between the colonies of Pedro Peixoto and Theobroma in Brazil are also presented. These results show that the monitoring of the riparian forest is an operational application of the JERS-1 images, needing no further investigation to prove their potential. They can also allow the mapping of agricultural settlements in the Amazon forest but we have identified some cases in which agricultural land can be confused with forest. Preliminary observations for Ecuador suggest that the JERS-1 images could allow us to discriminate between agricultural areas, *paramo,* and forest, but we will need to correct the relief-induced radiometric distortions to verify this hypothesis.

Since December 1996, we have also been granted a research status to be eligible for the purchase of optical-domain imagery at marginal prices from the Remote Sensing Technology Center of Japan (RESTEC), the commercial office at NASDA.

Nathalie Beaulieu attended the GRFM Principal Investigators meeting (Nov 4-7) at the Jet Propulsion Laboratory (JPL). This allowed us to consolidate contacts with investigators from Japan, the United States of America, Europe, and Brazil. With investigators from JPL, we discussed a possible project on the use of JERS-1 interferometric image pairs to derive DEMs for the sites studied by the Consorcio para el Desarrollo Sostenible de la Ecoregión Andina (CONDESAN).

Participating in the GLOBESAR II Program

The Canadian International Development Agency (CIDA) funds the GLOBESAR II program, which the CCRS coordinates. The program aims at diffusing the use of RADARSAT images in Latin America, and has subprojects in Central America, Colombia, Peru, Uruguay, Argentina, Brazil, and Bolivia. CIAT presented a project underway in the Puerto Lopez area (Colombian lowlands) focused on discriminating native and improved pastures, identifying degraded pastures, and characterizing the riparian forest through multiseasonal image acquisitions. This project is a collaboration between the Land Management (PE-4) project and the GIS Facility. Participating in the GLOBESAR II program grants us four images from the RADARSAT satellite (with a value of US$3500), of which two have already been acquired. The project also grants funding to cover some of the fieldwork costs and funded CIAT's participation at the Geomatics at the Era of Radarsat (GER)-97 conference in Ottawa (May 24-30). Preliminary results of our work in the area of Puerto Lopez are presented in the PE-4 project results. They suggest that unless the area has been affected by rainfall, improved pasture fields can be distinguished from native pastures in the moderate relief of the *altillanura* landscape because they appear brighter, even when overgrazed.

Participating in CSA's ADRO Program

CIAT is collaborating with the Instituto Geografico Nacional (IGN) and the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Costa Rica, and with AERDE Inc. Environmental Research, Canada, on a project entitled "Comparison of Radarsat Imaging Modes to Monitor Land Use in Coastal Areas". This project allows us to collaborate with these institutions and to explore the application of radar imagery to agricultural problems in coastal areas. Although such areas are not part of CIAT's mandate, they foster many agricultural issues that could demand our institution's attention in the future. Developing our experience in these areas enhances our chances of leading or taking part in funded projects with a coastal component. Preliminary results of the project have been presented at GER-97 in Ottawa. They included that RADARSAT images of all modes are suitable for monitoring the expansion of aquaculture ponds in mangrove and mudflat areas, and for mapping the presence of banana and rice, which are crops that can affect the coastal ecosystems by the intensive use of agrochemicals. RADARSAT images acquired in the large incident, angle modes are suitable for mapping agricultural extensions that remain bare before the start of the rainy season. Eight images have been granted for this research over two sites in Central America, both on the Pacific coast. One of these sites is the Estero Real in northern Nicaragua, the other is the area surrounding the Térraba and Sierpe estuaries in southern Costa Rica. Two images remain to be acquired to complete the study. The outputs will include a map of the extension of shrimp ponds and banana plantations at both sites, between May 1996 and November 1997.

Deriving DEMs from SAR Imagery

We have been acquiring the capacity to derive DEMs using SAR imagery. We have acquired three RADARSAT fine-mode images allowing two different stereo configurations over the watershed of the Río El Angel in Carchi, Ecuador, through the ecoregional project (component coordinated by Ruben Darío Estrada). PCI Inc. has developed the only commercial software that allows the derivation of DEMs with stereo RADARSAT imagery. The software has not yet been distributed commercially, but we will be able to use it in November 1997 because we have recently been approved as a "beta" testing site.

We have also acquired the software developed by Atlantis Scientific Systems Inc. to process raw SAR images and to derive slope and elevation from SAR interferometric pairs (In-SAR).

Accepted Projects and Contracts

"Methodologies for Integrating Data Across Geographic Scales in a Data Rich Environment - Examples from Honduras" and "Training for the Canada Center for Remote Sensing's GLOBESAR-II project" have already been reported under A Stronger Research Component.

Dynamics and sustainability of farming and regional systems in the South American savannas

We defined the work plan for IS-GIS support to this project. It will cost US$42 000 over 3 years.

Modification of the course of the Amaime river, Valle, Colombia

This was a short consulting contract with Ingenio Providencia that provided US$ 1300 for 5 days of work. The aim was to determine the variations in the course of the Amaime river in the area surrounding its confluence with the Nima river using scanned aerial photographs. Ingenio Providencia requested this analysis for legal purposes. Aerial photos of six dates over a time span of 52 years were georeferenced to a map of roads created in 1995. The Amaime River was digitized on the computer screen over the display of the photographs of the six dates. We generated 1:50 000 scale maps showing the course of the river at the different dates, which Ingenio Providencia used to resolve a land ownership problem. A neighboring farm claimed that, because of changes in the river's course, the Ingenio was cultivating land that belonged to the farm. The analysis of the aerial photos showed that the river course has moved as a result of erosion and sedimentation, but has always remained within the narrow limits of a well-defined floodplain, and had therefore not affected the cultivation area. The river's influence area is colonized by secondary vegetation that constitutes a protective fringe. A report was written, entitled "Modificaciones del recorrido del río Amaime" (Puig, 1997).

CONTRIBUTIONS TO CIAT PROJECTS

GIS SUPPORT TO SB-2

SB-2 Output 1: Understanding of the genetic diversity of wild and cultivated species for the use and conservation of improved genetic resources.

SB-2 Activity 1.1: Enhancement of knowledge of gene pool structure at intra- and interspecific level.

Activity: Spatial Analysis of Intraspecific Diversity: A Point-Centered Approach

- ✓ *First application with mapping of bean genes with CIAT's biotechnology group*
- ✓ *A computer program to compute 14 diversity indices, including unpublished ones*
- ✓ *A prototype interface for increased accessibility to the program by the scientific community*

Diversity is a dual concept, with variety and variability as components. However, diversity indices are single mathematical numbers. An assessment of indices of diversity must concern the way variety and variability are incorporated into the numbers. Indices incorporating the relative abundance of species also address the variability component of biodiversity. When the proportions of a species in a community are more similar, then species selected at random from the population will be more variable. Diversity indices can be useful in identifying in situ conservation areas or the location of areas most worthy of collecting trips and, together with additional GIS analyses, may show potential in predicting new areas of high diversity. Conversely, areas of low diversity might help us to better define environmental factors relating to endemic species.

Most diversity measures are usually aimed at species diversity and based on the principal of discrete countable units, the most famous ones being the Shannon-Weaver index (Shannon and Weaver, 1949) and the Simpson index (Simpson, 1949). Peet (1974) provides a thorough discussion of many of these indices and their theoretical strengths and weaknesses. The Shannon-Weaver index is defined as follows:

$$SW = \sum_i P_i \ln(P_i)$$

where P_i is the value characterizing the accession (e. g., cluster number).

When used for spatial analysis, these indices are generally calculated on the basis of a grid giving a value for each grid square analyzed. Instead of a grid, we prefer to use a circle centered on each accession point and compute the diversity index based on all the points falling within the circle and assign the result index to the center point. We refined the approach by giving more weight to a point closer to the center point according to a distance-weighted function. An external surface (e. g., a DEM) can also be used to modulate the weighting function. For example, we would not like to consider together accessions from two valleys separated by a high cordillera.

A computer program in C language has been written to implement this method under a UNIX environment (see GIS section of CIAT homepage). Thirteen different indices (including new normalized ones) are currently computed within an interactive interface allowing data entry, computing of indices, visualization of spatial distribution, scatter plots of different indices, and graphing. We are currently implementing the interface on the WWW. We have also implemented a new method for measuring diversity, where genetic distances are interpreted into diversity indices. We worked closely with the International Plant Genetic Resources Institute (IPGRI) to develop the model. We used data from field studies of *Poutería sapota* in Central America for testing the model. Six quantitative descriptors from 227 individuals were used as trial data and clustered into 22 groups. The program has also been applied to peanut accessions in Ecuador, and to bean genetic information.

Figure 2 shows the results obtained for *Poutería sapota*, with a search radius of 0.25 degrees inverse-distance and DEM weighting. The radius of the circles is proportional to the Shannon-Weaver index. We find areas of high diversity in Nicaragua and along the Pacific coast of Central America, and low diversity areas along the Atlantic coast in Costa Rica. *Poutería sapota* does not naturally spread easily so its diversity is probably more linked to human factors such as emigration and access. In effect, the Pacific coast of Central America was the first colonized, while the Atlantic coast lacked transportation infrastructure until the 1940s. A larger radius allows more data to be included in the calculations for a given point (and improved statistics), but then spatial specificity is lost. The way diversity indices vary with the influence radius gives insights on the nature and origin of diversity. Current research is ongoing to truly exploit this new spatial analysis tool.

<u>Contributors:</u>
Andy Nelson
Grégoire Leclerc
Mikkel Grumm, IPGRI
David Williams, IPGRI
Joseph Tohme, CIAT biotechnology group

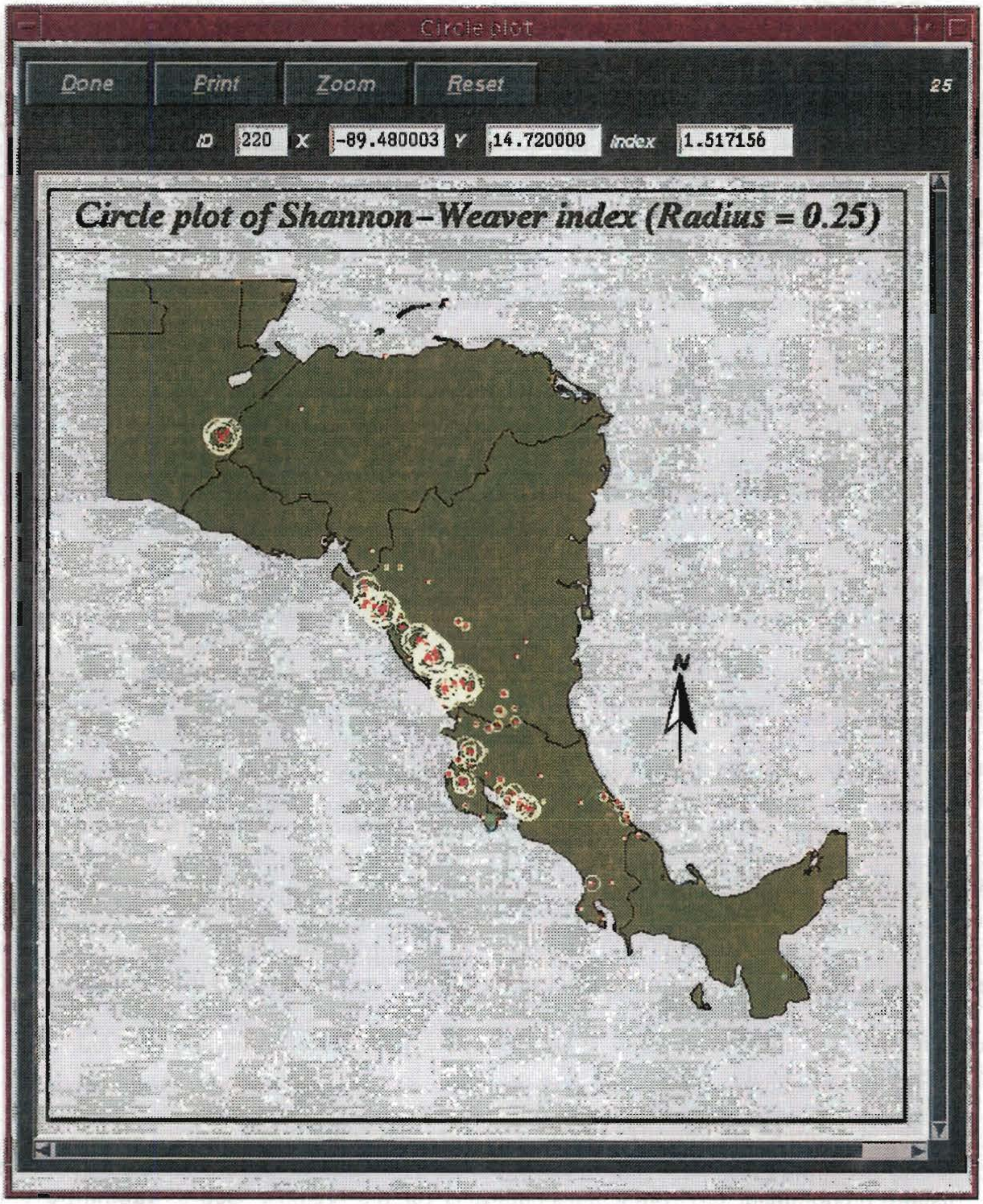


Figure 2: Results of the calculation of the Shannon-Weaver index *for Pouteria sapota*, with a search radius of 0.25 degrees inverse-distance and Digital Elevation Model weighting. The radius of the circles is proportional to the value of the index.

GIS SUPPORT TO PE-1

PE-1 Output 1: Improved understanding of pest and disease management components and implementation strategy developed for CGIAR commodity crops.

PE-1 Activity1.1: Identification and quantification of major arthropod complexes in selected agroecosystems.

Activity: GIS Database for Whitefly

✓ *GIS database in process for whitefly in Mexico, Central America, and the Caribbean*

The problems caused by whiteflies as pests and vectors of plant viruses have been recognized for over 100 years. Until recently, serious whitefly damage has been limited to a few crops in particular geographic regions, such as the bean golden mosaic virus (BGMV) in Brazil. In the past decade, this has changed dramatically and historically; damaging whitefly-transmitted viruses have extended their range to include new crops, such as tomato and cabbage.

Whiteflies have become a serious crop protection problem in the tropics, both as pests and vectors of plant viruses. Although Mound and Halsey (1978) catalogued 1156 species of described whiteflies (Homoptera: Aleyrodidae), only a limited number of whitefly species are commonly found infesting plants of economic importance (Martin, 1987; Caballero, 1992). Based on geographic distribution, host plant range, density on host plants, and difficulty of control in Central America and Colombia, Caballero classified two whitefly species as key pests; *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood). Undoubtedly, the most important whitefly is *B. tabaci* as a vector of geminiviruses.

With the aid of a GIS, we can locate areas with similar environmental conditions at a microscale and a macroscale. This can improve the efficiency of locating potential "hot spots" based on the critical factors that need to be present for the virus to occur. Once critical areas have been identified, more intensive site characterization and diagnosis can be carried out together with epidemiological field studies. Also, further analysis can be conducted to determine the social and economic impact of the affected areas, and used for risk assessment.

This contribution aims to develop a GIS database for Central America, Mexico, and the Caribbean that will enable users to:

- display agricultural regions affected by whiteflies and whitefly-transmitted viruses,
- display cropping systems, enabling users to identify crops and seasonal cropping patterns,
- display predominant environmental conditions for the regions, such as rainfall, average temperatures, elevation, and altitude,
- analyze the data and determine the predominant environmental conditions associated with the cropping systems affected by whiteflies and geminiviruses,
- identify sites containing the same or similar characteristics required for whitefly infestations, based on factors such as crop type, climate, and elevation,
- perform a critical area analysis, based on site characterization, that will enable "hot spots"

to be identified,

- develop an interface that will help users query the data and develop modeling tools to be used together with the GIS,
- display dynamic virus patterns, enabling the dispersion pattern of the virus to be viewed spatially over time, and
- access historical and present records of whitefly sightings together with environmental conditions existing at those sites, i.e., climate, soil, altitude, date, season, species of whitefly, disease incidence, pesticide use, crop type, virus, and yield loss.

We have assembled a GIS database. It currently contains roads, the hydrologic network, country and municipal boundaries, towns, soil type (by the Food and Agriculture Organisation [FAO] classification), United States Geological Survey (USGS) DEM with a grid size of 900 m, tomato geminiviruses by municipality and by country, rainfall stations from the CIAT database linked to maximum and minimum temperature data, rainfall stations, and corresponding data. The PE-4 project is creating interpolated surfaces of the climate data. Crop data are currently being collected and should be available by the end of Nov/Dec. Whitefly accession points are currently being verified and input into a database.

Planned analysis includes:

- assessing the presence and absence of whiteflies and/or viruses: using logistical regression analysis,
- identifying areas of potential infestations using linear regression analysis, and
- site characterization.

For sites with the presence of whiteflies, a report of the characteristics of the site can be created. This will include climate profiles, crop type, presence of viruses, and elevation.

Outputs currently include the GIS database and maps illustrating the location of various viruses transmitted by whiteflies in the Americas. Figure 3 illustrates the occurrence of BGMV in the 1990s. This virus was first found to occur in São Paulo, Brazil in the 1960s. Today, the virus exists throughout the Caribbean, Central America, Mexico, and Argentina. Once the database is complete, further analysis will be conducted on the occurrence of whiteflies in critical areas. Additional outputs will include frequency maps, site characterization reports, and virus diffusion maps. The goal is to have the database completed by Dec 1997 / Jan 1998 and conduct field investigations at two study sites.

Contributors
Justine Klass
Grégoire Leclerc
Francisco Morales, PE-1 project
Pamela Anderson, PE-1 project

Figure 3. **Known distribution of bean golden mosaic virus in Latin America in the 1990s.**

PE-1 Activity 1.3: Identification and characterization of major viruses; development of rapid detection methods.

Activity: Mapping the Distribution of *Fucraea* Necrotic Streak Virus

✓ *GIS database in process for fique virus in Colombia*

Fucraea is harvested for its fibers and is susceptible to the *fucraea* necrotic streak virus. The virus may have a soil-inhabiting vector and is transmitted by mechanical inoculation and grafting (Brunt et al, 1996). With the aid of a GIS, it may be possible to identify if a correlation exists with disease incidence and location-specific factors, such as climate, soil type, and altitude.

This study aims to investigate the distribution of the virus in two municipalities, Popayán and Silvia, Cauca Department, Colombia and to determine if the disease follows a random or particular pattern.

We have assembled a GIS database that currently contains a DEM, soil types, disease incidence (collected using a GPS for 106 farms), climate station points, hydrological network, terrain slope, and terrain aspect.

Several sets of maps of virus occurrence have been produced by combining different parameters. The virus was found to occur in a specific soil type, I-to-c, at an altitude of 1800 m to 2800 m, and with an annual precipitation of 160 mm to 180 mm. Also, viruses seem to prefer southeast-facing slopes. Further investigations are being conducted on the farms with a high incidence of the virus.

Contributors:
Justine Klass
Francisco Morales, PE-1 project

Activity: Mapping the Distribution of Rice Stripe Necrosis Virus

✓ *GIS database in process for rice virus in Colombia*

Rice is a staple crop in Colombia, with a per capita consumption of 20-30 kg yr^{-1}. Colombia has three main rice growing areas, the Central Magdalena River Valley, the Northern Departments (Cesar, Bolivar, and Sucre), and the Eastern Plains (Meta and Casanare), in which about 300 000 ha of rice are cultivated. The Eastern Plains are one of the most important of these regions in Colombia in terms of agricultural production and natural resources, cultivating about 80 000 ha of rice (Morales, 1996).

In 1991, the threat of a new disease, "*entorchamiento*" (or crinkling), emerged (Morales, 1996). This is a virus that is transmitted underground by an exotic fungal vector and is present in all the rice-growing regions of Colombia. Once the virus was identified, crop protection practices were implemented to help relieve the problem. With increased use of pesticides and a doubling of the amount of seeds used, production costs increased by about 10%. The effects of crop viruses in terms of economic and social costs are quite strong. If potential areas can be identified and critical factors associated with the virus diagnosed, then the overall effects of the virus can be minimized. A GIS, once established, can be used as a tool to identify critical areas. Within the "hot spots" further analysis can be performed to try to identify the main factors required for the virus to exist. This study aims to investigate the distribution of rice stripe necrosis virus and determine if the disease follows a random or particular pattern.

We have assembled a database that includes disease incidence, soil types, hydrologic network, DEM, terrain slope, terrain aspect, temperature, and rainfall.

For the present, general maps have been produced to illustrate the location of the virus in Casanare and Meta, Colombia. For Meta, the occurrence of the disease has been observed and classed as low, medium, or high incidence. For Casanare, the main virus-occurring areas have been distinguished with the surveyed areas illustrating the areas of greatest concern. The information used is compiled from general observations.

<u>Contributors:</u>
Justine Klass
Francisco Morales, PE-1 project

GIS SUPPORT TO PE-3

PE-3 Output 1: Procedures established for use of databases to target problems, priority areas, and beneficiary groups for intervention in watershed management.

PE-3 Activity 1.1: Revision, edition, consolidation, and georeferencing of data into user-friendly biophysical and socioeconomic databases, including for gender.

Activity: Population Census 1988

✓ *Census verified, aggregated to villages, and loaded into Oracle*

A set of documented routines have been developed to error-check raw census data and produce files more readily handled by Oracle. The error-check step allowed a characterization of the reliability of the data to be analyzed.

For all of the numeric database fields, we computed the following statistics for each village to characterize the distribution of data: total or sum, minimum value, maximum value, mean value, standard deviation, skewness, and kurtosis.

The household **and** village level data are now being loaded into an Oracle database.

Contributors:
Andy Nelson
Patrice Couillaud

Activity: Classifying Remote Sensing Images of Northern Nicaragua

✓ *Landsat TM images, 1985 and 1993, classified for part of northern Nicaragua*

Four Landsat TM quadrants of February 1985, Nicaragua, were georeferenced and classified to be used in a multi-temporal study of land-use changes in the northern part of Nicaragua. A Landsat TM image of February 1993 was also classified. Figure 4 shows results of the 1993 classification.

Contributors:
Marta Aguilar
Javier Puig

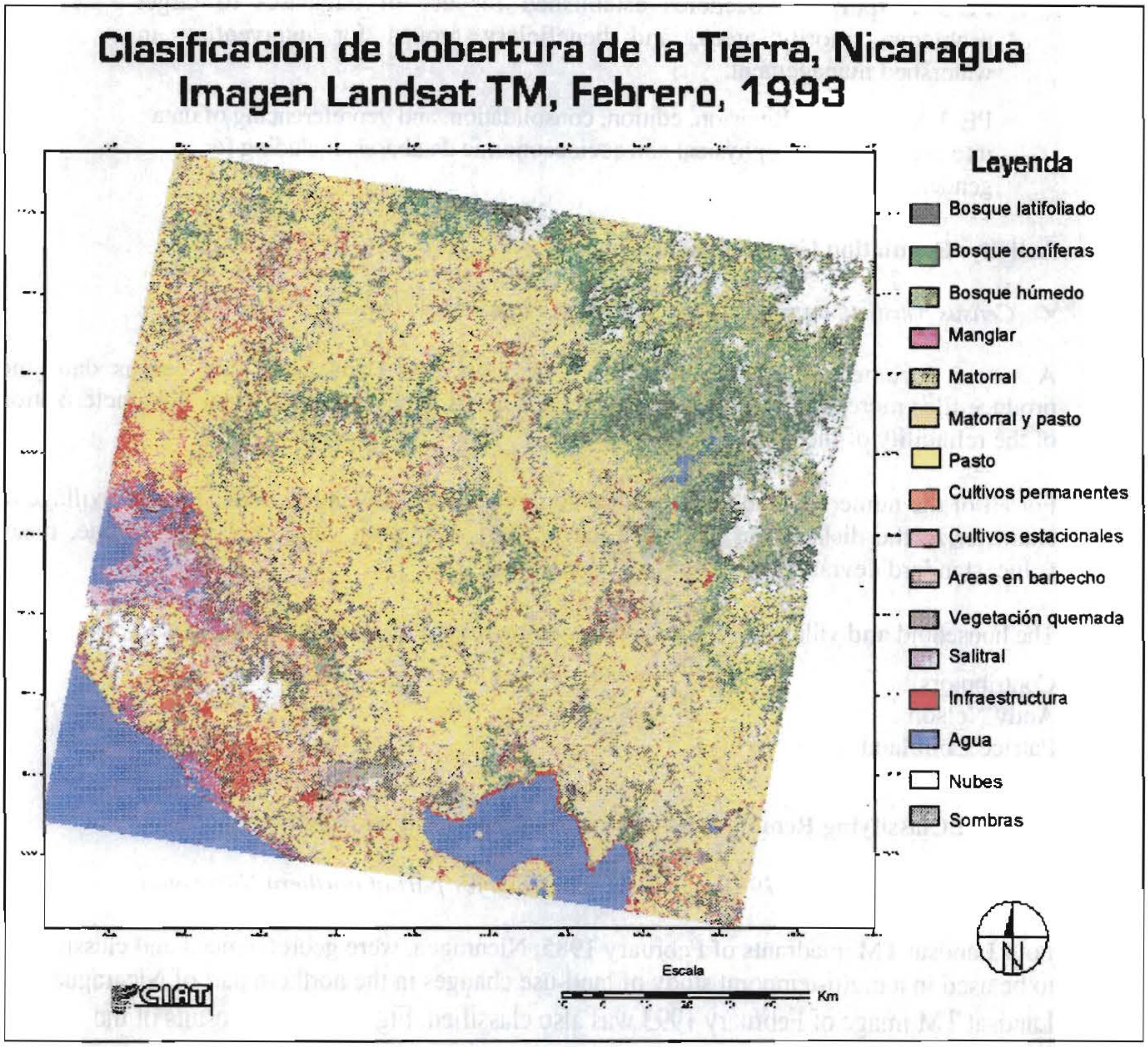


Figure 4. Classification of Remote Sensing images of the northern portion of Nicaragua with Landsat image, 1993.

PE-3 Activity 1.2: Development of a step-wise framework for increasing the precision and resolution of spatial data ("successive refinement")

Activity: Methodologies for Integrating Data across Geographic Scales, Honduras

✓ *Applications developed to help analyze multiscale data, Honduras*

The project "Methodologies for integrating data across geographic scales in a data rich environment – examples from Honduras" was initiated this year. Natural resource management (NRM) problems and economic problems related to agriculture often transcend field or farm boundaries, and can only be understood and corrected through adopting broader perspectives. The temporal and spatial perspectives and interdependence that so characterizes many NRM problems therefore necessitates some form of collective action among landscape users. The project aims to develop and document principles and procedures for building a scale-consistent database and for performing multiscale characterization of agroecosystems using the Honduran hillsides as an example.

We have loaded, error-checked, corrected, and documented the 1988 Honduran Population Census, with a set of self-developed, holistic programming tools, which are reusable. The Census is at the interview level, which represents 4 000 000 people with 5 000 000 records. This data was then aggregated to the village level to create a general purpose, portable set of data that is comprehensive yet 50 times smaller than the original—4 000 000 people are now represented with only 8000 records. The aggregation was performed with a set of documented, in-house computer programs.

We have undertaken a preliminary analysis on Honduran population mapping methods, creating new visualizations of population at the town and district levels. We also researched into cross-scale modeling, state-of-the-art issues in data generalization, and analysis of socioeconomic census data. From this literature review, Leeds University in the UK was highlighted as the premier research center for this area and has been approached as a potential collaborative research partner.

This study deals with a data-rich environment. Such environments can be described as locations where there exist:

- socioeconomic data at the fourth level (village) administrative boundaries or better,
- satellite imagery and air photography for several dates and seasons,
- biophysical data such as soil type altitude, slope, and climate, and
- a number of sources of well-sampled household and farm data.

To characterize the Honduran hillsides, a methodology of cross-scale modeling has been adapted. This aims to link together different representations of the same data so that data integration can be a controlled and 'intelligent' process and the interaction of variables across scales can be modeled within an information system. Essentially, cross-scale modeling enables an understanding of which spatial processes are taking place and at which scale they occur.

The first phase of the project has prepared a quality-controlled, multiscale database for biophysical and socioeconomic data. The second stage addresses the concepts of implementing a study of cross-scale GIS, and includes the issues of data structure and data generalisation.

Data structure has been addressed to accommodate multiple representations of the data, and to organize multiple topological and metrical versions for efficient access. With this we can logically and explicitly connect various models but continue to maintain consistency. It also provides measures of the variation in response to a database query made at different scales of resolution and hence we can determine if this variation is more readily predictable for particular variables or particular levels of resolution.

Generalization can be viewed as deliberately induced error and is arguably one of the most fundamental of GIS research problems. It is a process that creates a derived dataset with more desirable and usually less complex properties than that of the original. Questions such as scale selection (i.e., at which scale to query or view the data) are closely related to the specific task for which the data is to be used and the characteristics of the geographical data.

When any change of scale takes place we are working on how to define the data characteristics required to ensure that certain types, sizes, and patterns of geographical structures may be detected and then selected or rejected from the data, using defined algorithms. An important part of any generalization algorithm is qualitative and quantitative measurement of accuracy, reliability, and data loss through generalisation. Accompanied with a knowledge base within the cross-scale model, this allows us to assess and adapt the model as it used.

Finally, to be able to assess the output from the cross-scale model, we have identified the following critical factors that must be satisfied.

Graphical	The display configurations and visual acuity of the digital feature.
Structural	Capturing the essential character of some phenomena and removing unnecessary spatial and attribute detail.
Applicational	The conditions that are specific to map purpose.

Contributor:
Andy Nelson

Activity: Mosaic of Aerial Ortophotographs of the Tascalapa River Watershed, for Participatory Research

✓ *GPS surveys of control points for the generation of high resolution orthophoto mosaics*

A mosaic of aerial orthophotographs was produced for the area of the Tascalpa river watershed in the department of Yoro, Honduras as a first step towards the characterization of land use and land cover. The orthophotos were generated in 1996 from digital stereo pairs of 1:40 000 scale aerial photographs. We used 33 photographs to form the mosaic and cover the 11 200 ha watershed. We investigated a low-cost alternative to the reduced styrofoam models that have been used with success in the Cabuyal river watershed, in Colombia. The alternative consists of a printout of an orthophotomosaic that can be viewed with a three-dimensional perception through color encoding of the elevation based on a chromostereoscopic technique, as shown in Figure 5.

The three-dimensional viewing is meant to provide a tool allowing farmers, extentionists, and members of institutions working in the area to appreciate the relief of the watershed and its land use. This technique can be used to generate alternative products for the visual and digital analysis of remote sensing images. We experimented with different scales (1:3000, 1:6000, 1:12 000, and 1:24 000) and color coding algorithms to determine which produced the best results for visualizing different types of land use and land cover. The 1:6000 and 1:12 000 scales produced the best results for interpreting land use. The overlay of elevation contour lines improved the appreciation of relief.

Contributors:
Javier Puig
Grégoire Leclerc

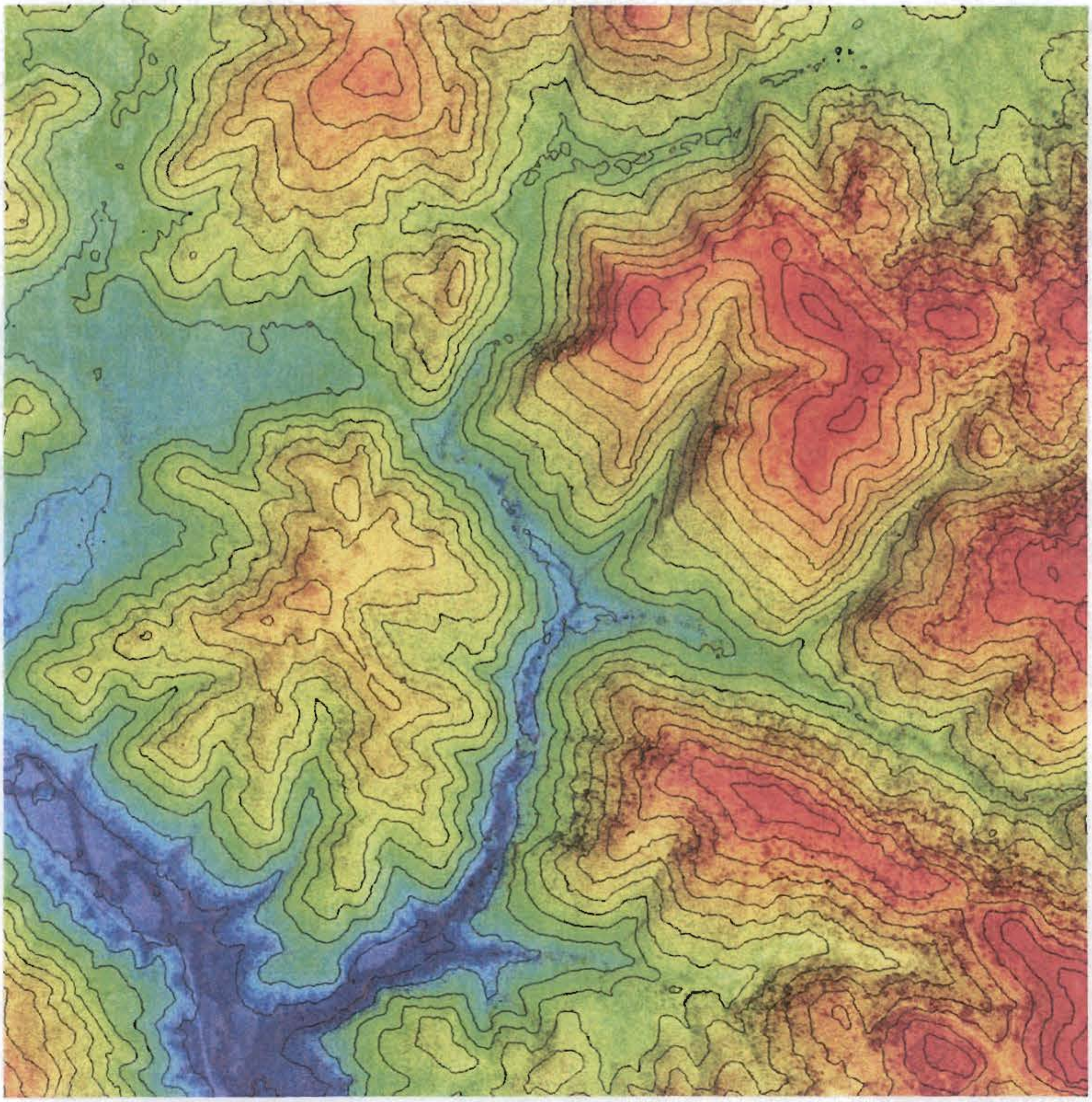


Figure 5. Portion of the color-encoded orthophoto mosaic of the Tascala river watershed, Yoro, Honduras.

Activity: GPS Survey of Watersheds of Cuscateca and Calico Rivers

✓ *High-precision GIS layers for Cuscateca and Calico river watersheds generated*

As a first step towards the derivation of a DEM with aerial photograph stereopairs, the precise location of control points were measured with a differential GPS in the watersheds of the Cuscateca river (Danli, Honduras) and the Calico river (San Dionisio, Nicaragua). The control points were first identified on the aerial photographs on the base of aerotriangulation principles. To ensure optimum precision in determining elevation values, the location of at least one ground control point (GCP) for every three photographs was measured in the field. The location of points falling outside the watersheds was also measured because they will be used for triangulation. For each GCP, we made a detailed description of land use and land cover, and took photographs and videos to help the photointerpretation. To assess the accuracy of the slope maps produced from the high-precision DEM, we also compiled several measurements of terrain slopes using a bubble clinometer. For the Cuscateca river watershed, we produced an orthophoto mosaic, a high-resolution DEM, and a set of maps of, for example, land cover, drainage, and transportation network.

<u>Contributors:</u>
Javier Puig
Grégoire Leclerc
Nick Thomas

PE-3 Output 2: Strategic techniques developed to strengthen capacity for location-specific diagnosis, monitoring, and impact assessment of environmental problems and interventions

PE-3 Activity 2.2 Development of natural resource evaluation techniques, both financial and non financial

Activity: Soil Erosion Modelling for the Cabuyal Watershed

✓ *GIS databases for evaluating mechanisms to redirect part of revenues from the use of watershed resources towards alleviating poverty*
✓ *Plot erosion data extrapolated to watershed level in the Cabuyal watershed*

Existing erosion data from Universal Soil Loss Equation (USLE) field-plot experiments in the Cauca valley can potentially be used for modelling exercises, validating models, and monitoring long-term trends. This project aims to produce user-friendly software to help investigate the influence of different management strategies.

The USLE is an empirical model that uses physical factors (amount and severity of rainfall, soil erodibility, slope length and steepness, and vegetation cover) to quantify the amount of soil lost per hectare per year. Originally developed to analyse soil losses from agricultural lands in the USA, it has since been updated and applied to many other land types.

Incorporating the USLE into a GIS model makes it possible to calculate soil losses for particular areas (e.g., watersheds) or to analyze potential management strategies. By adjusting factors in the equation (e.g., vegetation cover) and rerunning the model, the output of alternative scenarios and changes over time can be compared. The use of digital information in a computer system enables much faster processing and analysis and offers the opportunity for new approaches.

In this study, plot-level data was scaled up to the watershed. A SUN Sparc5 network computer (UNIX operating system) was used with Arc/Info. Erosion risk maps were produced for different scenarios for comparison. Data from various sources were incorporated into a GIS database for the watershed.

Contributors
Mandy Kingstom
Grégoire Leclerc

PE-3 Activity 2.4: Incorporation of indigenous indicators into knowledge-based decision support tools, and their consolidation with spatial (GIS) analysis.

Activity: River Cabuyal Survey

✓ *Integration of GPS measurements related to socioeconomic surveys*
✓ *GIS analysis to plan socioeconomic survey*
✓ *GIS analysis of the results of the survey*

GPS measurements that were related to socioeconomic surveys were integrated and an analysis made to plan such survyes.

A survey was taken of 198 households in the Cabuyal river area. GIS was used to stratify the households according to household well-being. This helps compare land-use strategies of the poorest, less poor, and least poor households. Results of the survey were analyzed using GIS. Lacking economic resources and with immediate needs to satisfy for survival, poor farmers are assumed to offset concerns with long-term sustainability. Thus already degraded, natural resources are further degraded in turn aggravating farmers' poverty in a continuing "vicious cycle". Contrary to the "vicious-cycle hypothesis", the results showed that poor farmers were **not** less likely to have land in fallow than richer farmers. About 60% of all households in Río Cabuyal have land in fallow. All categories allocate about 20% of their land to fallow.

An implication of this analysis is that research aimed to impove fallow may not be successful among the poorest farmers for whom fallow is a response to unpredictable lack of resources. In general terms, the analysis shows the need to question and validate the existence of a "vicious-cycle relationship" between poverty and NRM.

Contributors:
Jorge Rubiano, PE-3 project
Helle Ravnborg, PE-3 project
Grégoire Leclerc

PE-3 Output 4: Institutional capacity to use decision-support tools established for community-managed development for watershed resources.

PE-3 Activity 4.6: Management of project reporting, documentation, and information exchange.

Activity: An Inventory of Existing Poverty Assessment Methods

This work has been initiated by IS-GIS, as an input to PE-3 and PE-4 poverty assessment activities. It contributes to a better identification of the poor and to CIAT's ultimate goal, which is poverty alleviation.

We need to inventory existing poverty assessment methods to be able to identify the appropriate ones to apply and develop poverty indicators for policy design. However, the methods used depend upon the conceptual understanding of poverty and the context in which the method is applied. Poverty assessment and measurement methods can be broadly grouped into two. First, the top-down methods are based on the absolute or relative understanding of poverty. Second, the bottom-up methods are based on people's perception of poverty, well-being, and livelihood systems. Through a participatory research approach, the people and the community are able to identify key indicators describing their socioeconomic, physical, political, and environmental conditions.

Top-down poverty assessment methods

The most commonly used of these are drawn from the domain of economics. Economists have developed a range of options to measure poverty mainly in monetary terms.

Determining the household income/consumption of individuals provides necessary indicators that help monitor and target the problem of poverty. Some studies adjust anomalies of income and expenditure to minimize over- or under-estimations of poverty using household expenditure to determine expenses. Other studies have used the consumption approach. This determines market- and home-purchased goods, considering education and health separately, or collapsing them together within the market-purchased goods. Using the above techniques, we can derive the income threshold of households in an area. We can also locate which households and socioeconomic groups are poverty prone.

Examples of applications

- The Head Count Index (HCI) is based on how much of the population has a lower income or consumption than the accepted and defined level required to meet minimum nutrition requirements per capita.
- The International Fund for Agriculture Development (IFAD) approaches measuring poverty at the national level, based on the indices of food security, relative welfare, integrated poverty, and basic needs. The last two are derived from income and consumption data.
- The Social Dimensions of Adjustment (SDA), as used by the World Bank, are based on measurements of household expenditure that are aggregated from the consumer's

expenditure on food, consumption of home production of non-food items, non -food expenditures, remittances paid out, and imputed value of wage income in kind.

- The Living Standard Measurement Survey (LSMS), developed by theWorld Bank, is based on total monthly expenditures per capita derived from food/ non food expenses.

Other methods have been developed to complement those of economics. These multidimensional composite measures include the following three.

First, the Human Development Index (HDI), developed by the United Nations Development Program (UNDP), is designed to determine a composite measure of human progress. It calculates the average level of human capabilities from the national income using two social indicators—adult literacy and life expectancy. The index is calculated as the sum of the elements in Table 1. The method is currently being used to map poverty in West Africa (Heberlein and Desforges, 1997). Using GIS, the HDI is linked to biophysical data (agroclimatic zones and land degradation) and socioeconomic data (population density and accessibility) to produce a series of maps for each indicator and an aggregated poverty map of the region.

Table 1. Elements used to construct the Human Development Index.

Values	Set Range	
	Minimum	Maximum
Life expectation (yrs)	25	85
Adult literacy (%)[a]	0	100
School combined enrolment ratio (%)[a]	0	100
GDP per capita (PPP)[b]	100	40 000

a. The Educational Index is calculated on the basis of combined adult literacy and three levels of school education; primary, secondary, and tertiary.

b. Gross domestic product (GDP) with threshold level for average world income set at purchasing power parity (PPP) expressed in US$.

The Capability Poverty Measure (CPM), also developed by UNDP, is based on the material standard of living, which is assumed to determine an individual's well-being. The HDI measures human capabilities. Conversely, the CPM measures lack of capabilities, nor does it include income in its calculations. The CPM considers three variables by taking the following percentages: underweight children less than 5 yrs old, births unattended by trained health professionals, and illiterate women aged 15 years and above. The three variables are given the same weighting and averaged to obtain the value of CPM.

The third example is the E delbecq-delphi method, which relies on experts reporting on the study area. For example, for the vulnerability mapping in Bangladesh, four panels were drawn from technical experts, aid distributors, senior retired government officials, and village elders to rank and provide weight for defined indicators.

Bottom-up poverty assessment methods

These methods follow a possible model of sustainable development that is people centered. The people themselves must be the main stakeholders, able to identify, communicate to others, and solve their development problems. In other words, no-one moves people out of their helpless situation, they themselves know the situation and therefore must solve their own problem. This approach can provide microlevel information about poverty to ensure correct program implementation. The main methods are:

Participation in poverty assessment (PPA)
Participatory rural appraisal (PRA)
Beneficiary assessment (BA)

The last two methods share many core techniques described below. The PRA and BA use conversational and semi-structured interviews, and focus on group interviews and participation observation. The PRA also focuses at community level, rather than household level, using other techniques like thematic mapping, wealth and preference ranking, and a range of other options depending on the participators' objectives. The main difference between the two is that PPA selects participators, so suffering the danger of being exclusive, whereas PRA ideally includes all members of the community under study.

PPA is based on a broad input from stakeholders to assess poverty, aiming at building a strong in-country capacity response to the problems of the poor. With the participation of government and other institutional stakeholders in all aspects of work, sensitivity will be enhanced when dealing with poverty issues, improving the level of analytical thinking among the key actors, and forging a willingness to fight poverty. The PPA approach involves identifying key actors such as senior government official, nongovernment organizations (NGOs), local researchers selected from academic institutions, opinion leaders, and civic leaders.

This method has been applied in several countries. In Cameroon, it involved the National Statistical Office in preparing poverty profiles, and the Center for Nutrition Research in addressing food insecurity issues. A number of other donor agencies, local NGOs, advocacy groups, and research institutes also participated.

PRA has a range of techniques that are used in assessing poverty and community resources, developing community action plans, and research. PRA methods have been successful in improving community fellowship and working towards sustainable development. PRA also helps explore how people perceive poverty. This method has been applied in many countries. For example, in Zambia, villagers were asked to sort a stack of cards (each labelled with the name of a head of household) into piles according to relative wealth of households using any criteria they wished. This method is currently being implemented in 90 households selected from rural Honduras. This is being done within PE-3 for the CIAT poverty project, "Desarrollo de un sistema de información y tecnología para mejorar el manejo de los recursos naturales y para el alivio de la pobreza en america latina". The GIS database has been used to help design the sampling frame for selecting representative villages and households.

The BA method provides qualitative input. It focuses on human conditions that have a bearing on poverty—motivation factors, delivery systems, and institutional factors—and their significance in relation to limiting available options and opportunities. Also, the importance of informal and formal safety nets are examined while considering these factors. BA is a vehicle for reaching the 'hard-to-reach' beneficiaries and provides a voice for the poor to be heard. We describe this method as a process-oriented approach, because the first stage results are an input into the second stage and so on.

The method was used in Mali in an education project aimed at understanding why parents in rural areas did not send their children to school, and why the attendance of girls was extremely low. The study showed that transport and food costs plus the costs of losing a child's labor at home outweighed the small benefits of a poor-quality education and few prospects of finding a job. The results led to policy reformulation.

Contributors
Tonny Oyana
Grégoire Leclerc
Patrice Couillaud
Helle Ravnborg, PE-3 project.

GIS SUPPORT TO PE-4

PE-4 Output 1: Environmental opportunities and constraints identified and assessed.

PE-4 Activity 1.2: Perform field characterization of study sites.

Activity: Forests in a Savanna Landscape - the Yucao Watershed

✓ *Digital elevation model created*

In the second half of 1996, PE-4 started a project on the distribution, composition, structure, and functions of the riparian forests. The watershed of the Yucao river (about 2500 km^2) was chosen, a typical *Altillanura* watershed where land use is being intensified and accessibility improved. Physiographically, the watershed represents the flat and undulated subtype of the well-drained savanna. CIAT has been working on socioeconomic characterization and on-farm research in improved pastures. The focus on forests in this project is important because of the goods and services it provides, some of which are undocumented and underinvestigated. Also, the threat to this ecosystem is likely to become severe when agricultural intensification proceeds as expected.

A DEM was created by interpolation from contour lines and altitudinal points that were digitized from 1:25 000 scale maps. The digitized rivers were used to force flow in the appropriate direction to eliminate spurious sink holes. From this DEM of 25-m grid size, we calculated the flow direction and accumulation for each cell. We calculated the drainage area contributing to river flow for each of the 29 transects used to sample the riparian forest, for the location of the flow measuring station (225 900 km^2), and for the entire watershed (227 000 km^2).

Because of the network of streams, the average distance from any point in the savanna to a stream is short. The last 20-200 m of that drainage pathway runs through forest, which therefore has a potentially important buffering function for surface fluxes of water, sediments, and nutrients. The flatness of the terrain, the dense vegetation, and the high infiltration capacity of the soil contribute to that function. On the other hand, widths of streams increase considerably because of flooding in the rainy season, thus reducing the effective pathway through the forest. Maintaining the present forest cover is therefore crucial. An increased load of sediments and nutrients would severely alter the ecology of the streams and negatively affect their species richness.

Contributors:
Nathalie Beaulieu
Erik Veneklaas, PE-4 project

PE-4 Output 2: Land use patterns and their spatial distribution classified, and correlated with environmental and socioeconomic data.

PE-4 Activity 2.1: Characterization and mapping of land use patterns in hillsides, forest margins, and savannas.

Activity: Deforestation along Highway BR364, Brazil

✓ *Deforestation along highway/colony swath in Brazilian Amazon analyzed*

A mosaic of 31 JERS-1 radar images from October 1995 was constructed to examine deforestation in the swath along the highway, BR364, and from the city of Río Branco and the colony of Pedro Peixoto in Acre, through the city of Porto Velho in Rondonia, and to the colony of Theobroma and the town of Jaru in Rondonia (Figure 6). The radar images have been averaged and resampled to result in a pixel spacing of 100 m. They are in L-band and HH polarization. The L-band, with a wavelength of 23 cm, makes JERS-1 imagery suitable for mapping deforestation. Deforested areas corresponding to government-sponsored colonies, cattle ranches, and spontaneous settlements were distinguished and classified by pattern and shape.

The most deforestation was encountered in the Theobroma area, followed by Pedro Peixoto, and the cities of Río Branco and Porto Velho. The mosaic shows that much of the area between the two colonies remains forested.

The mosaic covered 117 222 km^2, of which 7885 km^2 (6.7% of the total) were classified as non-forest. Large cattle ranches accounted for 1923 km^2 (1.6% of the total and 24% of the non-forest area).

Buffers were established around the highway from Río Branco/Pedro Peixoto to Jaru/Theobroma at 0-5 km (BFR1) and 5-20 km (BFR2). The buffers covered 7168 km^2 (BFR1) and 21 824 km^2 (BFR2), of which 21.7% (BFR1) and 12.4% (BFR2) was deforested, and 5.0% (BFR1) and 2.4% (BFR2) represented clearing by large holdings (Figures 7 and 8).

Clearly, deforestation was heaviest closer to the highway, in and around the colonies, and in the cattle-ranching area northeast of Theobroma. Away from the city of Porto Velho and the colonies, deforestation along the highway was substantially less. Prior to highway construction, settlement in the region was largely along the rivers. Our analysis shows that clearing along the area's rivers was relatively minimal.

Deforestation was heaviest where highway and colony combined. Where there was highway but no colony, clearing was much less—although deforestation did take place along the highway. Of the deforestation in the mosaic, 54% took place within the two buffers (i.e., within 20 km of the highway).

Contributors
Nathalie Beaulieu
Sam Fujisaka, PE-4 project

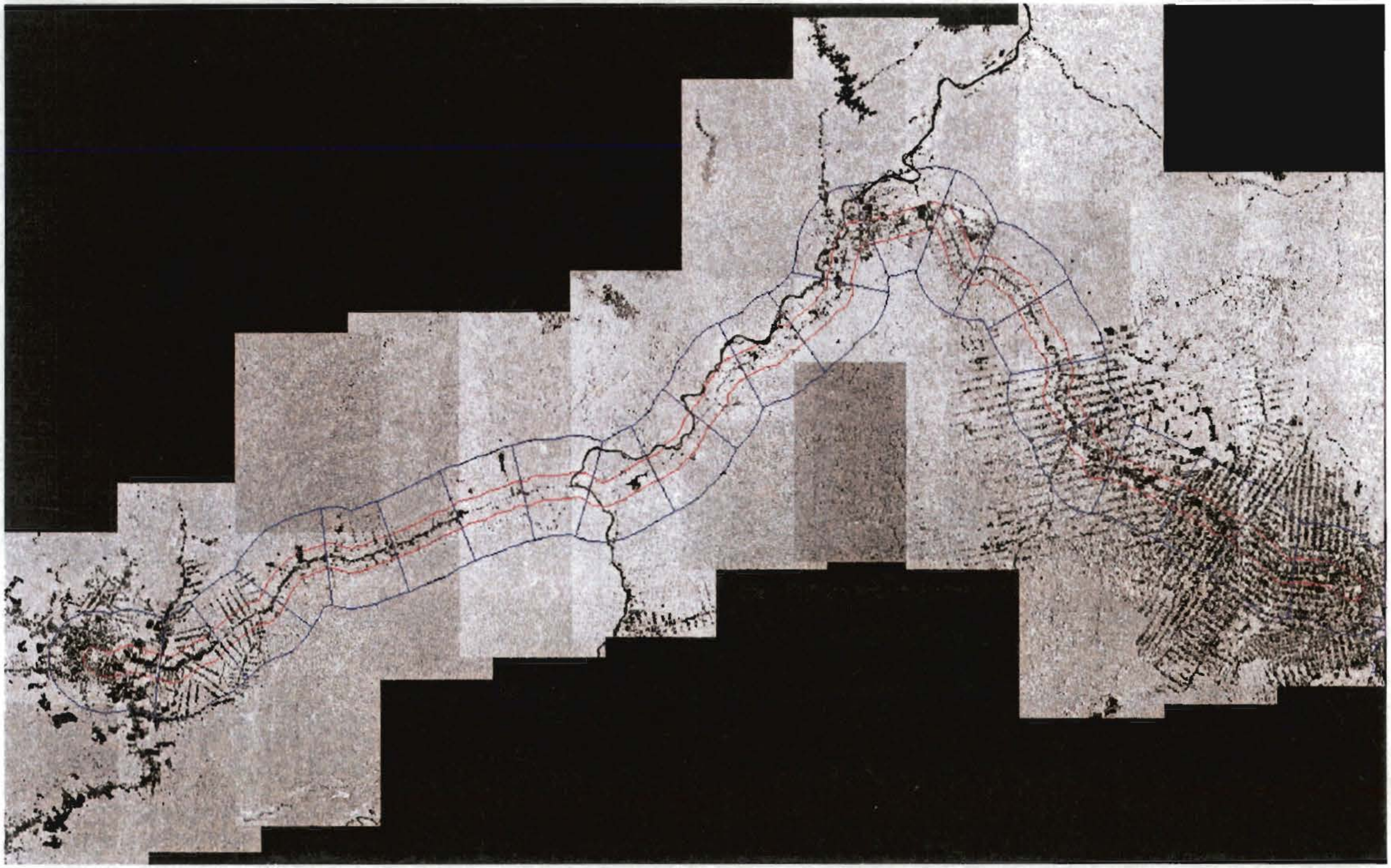


Figure 6. Mosaic of 31 JERS-1 SAR images, 5 km buffer shown in red, 5-20 km buffer in blue

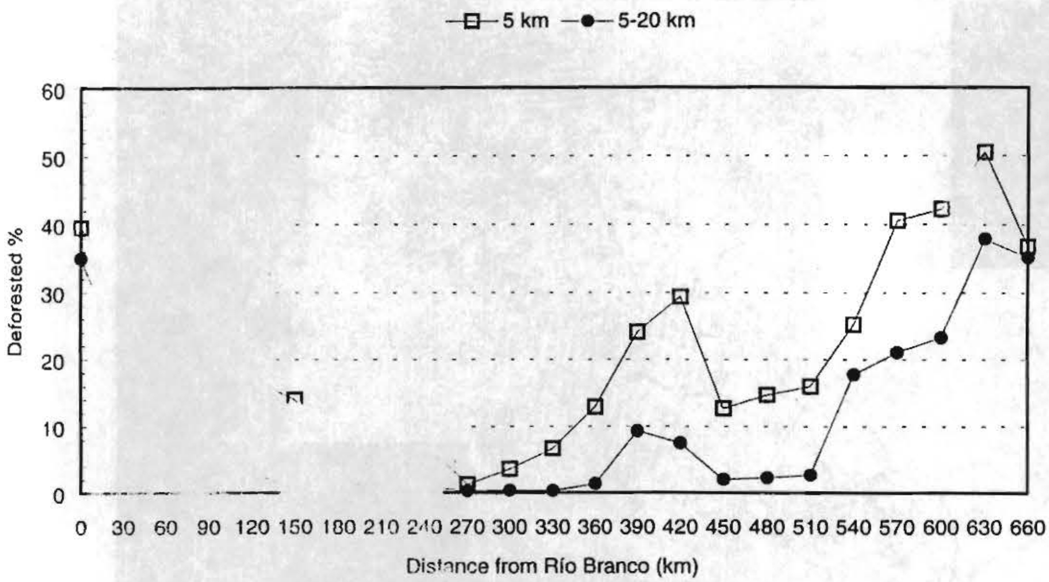


Figure 7. Percentage of deforestation along BR364 from Rio Branco/Pedro Peixoto to Jaru/Theobroma, Brazil, along 0-5 km and 5-20 km buffers.

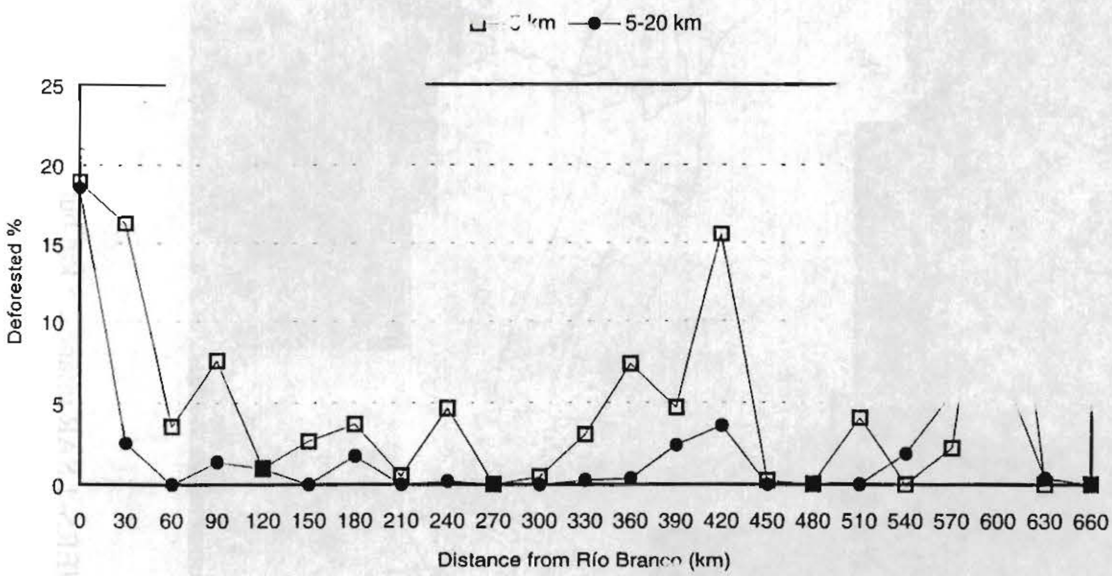


Figure 8. Percentage deforestation by large-scale cattle ranches along BR 364 from Rio Branco/Pedro Peixoto to Jaru/Theobroma, Brazil, along 0-5 km and 5-20 km buffers.

PE-4 Activity 2.2: Implementation of digital maps of land use, environmental degradation, and poverty for Latin America.

Activity: Improving Population Data

✓ *Vector to raster conversion applied to population data of Latin America*

Interest in the social and demographic aspects of environmental change and agricultural transformation has been growing steadily. At the same time, many demographers and population geographers have embraced GIS. This has led to some studies and initiatives at various scales that focus on population modeling in a spatial context (Goodchild et al., 1993; Flowerdew et al., 1991; Langford et al., 1994; Moxey and Allanson, 1994; Tobler, 1979). In many countries, demographic and socioeconomic data are often only available at fairly aggregate levels. These polygonal units vary greatly in areal and population size, and contain considerable variation from national means. Clearly, this level of available detail, or geographic scale, is often insufficient for modeling purposes (Deichmann, 1996).

Frequently we wish to know the distribution of a phenomenon inside a vector polygon. Using ancillary data the polygon information can be converted to raster format with an improved distribution inside the polygonal unit. In this investigation we have made use of the common methods for the vector to raster conversion and have applied them to population data of Latin America. We applied the conversion algorithms to a polygonal census map of population of South America (at the municipal level) and data at the village level in Honduras. In this latter case, original methods combining gaussian filtering with night time imagery have been applied to obtain a 10-fold increase in spatial resolution (this approach has been taken by PE-3).

Table 2 shows a classification of the various modeling and visualization techniques that we have applied to population data. The methods here discussed are the last two in the table.

Table 2. Selected methods for modeling population density.

Method	Input data	Data type	Complexity	Ancillary data
Choropleth map	Polygon cover	Municipal: areal	Simple	None
Proportional circle	Point cover	Township: points	Simple	None
Pycnophylactic interpolation	Polygon cover	Smooth surface	Moderate	Smoothing algorithm
Urban areas defined by:				
night-time imagery	Point cover	Surface	Complex	Night images and city-size estimate equation
cost-distance model	Point cover	Surface	Complex	Transport cover and model

Tobler's (1979) interpolation method can be defined as a process that converts polygonal data into a maximally smooth surface but preserves the value within each areal unit. The polygonal data is converted to a regular grid, which is smoothed with a window filter. The value of each cell is determined by its neighbors, regardless of whether or not they are in the same areal unit. Hence the final distribution of the data within the areal unit is dependent upon its neighboring areal units.

The simplest empirical relationship between a city's population and its surface area can be expressed as:

$$\ln A = \ln a + b \ln P$$

Where A is the area of the city, P is its population, and a and b are unknown constants. By using night-time imagery to define urban areas and hence estimate their size, we can perform a regression analysis to extrapolate rural town area given a population figure. The next stage is to assume a population density model within the city area. This is typically a negative exponential function of the form:

$$D = Ae^{-br}$$

Where D is the population density, r is the distance from the city center, and a and b are unknown constants. In this case we have assumed a normal (Gaussian) distribution for population within urban areas, and a normal distribution about a point for rural areas.

The assumptions we make here are: only urban areas (defined as those having electricity for lighting) are visible in night-time imagery; and population settlements have a normal distribution about their center.

A simple way to improve population distributions within municipal boundaries is to assume that population is directly related to accessibility. We would expect that more people live in areas where road networks are dense and fewer people live where there is little development.

Therefore, if we have information on road networks in relation to urban areas we can use these data to estimate populations within a municipality. We applied this assumption to the Latin America population data by using an accessibility surface to redistribute municipal populations within their administrative unit.

The methodology requires the use of an accessibility surface, a map of populated places, and the population data. The accessibility surface was based on towns with over 10 000 people and the road network from the Digital Chart of the World (DCW) (Eade, 1997). The surface is modeled by assuming **expected** travel times over roads and all areas that are not roads. Movement is faster over paved roads compared to gravel roads or trails. This method is common and algorithms for cost-distance analysis exist in many software packages.

To redistribute the population for each administrative district we used the following equation:

$$\Sigma (A_{ij} / A_k) x P_k$$

Where A_{ij} is the accessibility for each cell ij, A_k is the sum of accessibility inside the administrative unit k and P_k is the population within the administrative unit k.

We summed the accessibility values for the raster cells of each municipality. Next, we divided each cell by the total for the municipality to give an accessibility potential throughout the municipality. The potential surface is then multiplied by the population surface to produce the accessibility map.

The methods used in this project incorporate ancillary data and statistical models to characterize the population. Each method presents advantages and disadvantages depending on: scale or geographic resolution of the data, ancillary data available, and distinct factors of location.

The pycnophylactic interpolation is useful as a first pass for improving on the standard thematic representation. The assumption that population density is better represented as a smooth surface provides a base for future refinements. The cost-distance model improves the population distribution based on the transportation network. Clearly this method improves upon the thematic representation, although verifying its quality without a detailed case study is difficult.

The Gaussian model made with night-time imagery appears to give a better representation of urban areas. This representation is much more intuitively appealing from a visual point of view.

Two serious difficulties are related to transformations of these datasets in a GIS. First, GIS transformations produce effects that have direct implications on the data quality. For example, the sum of all values in a raster surface may be different from the source data from which it was derived. Second, GIS literature and software documentation lacks in-depth discussion of transformation effects, nor does adequate information exist on controlling the transformations.

Many processes alter the statistical and geometric properties of the digital map. Often users must make important decisions regarding the selection of an algorithm or transformation. These choices affect the data quality and precision. Rarely does the analyst have sufficient information about the consequences of the choices. In all cases we need to evaluate the models to determine if the data satisfy the requirements of a given application.

<u>Contributors:</u>
Andy Nelson
Glen Hyman
Grégoire Leclerc

PE-4 Activity 2.4: Identification of critical situations and major opportunities for sustainable land use.

Activity: Using Radar Imagery to Assess the Presence of Improved Pasture Systems and to Detect Degradation in Savannas

✓ *First images identifying degraded areas*

To improve the management of the Colombian lowland savannas, we must develop methodologies for monitoring this environment. Our study area is located in the Colombian lowlands, Meta Department, and encompasses the *municipio* of Puerto Lopez, between the cities of Puerto Lopez and Puerto Gaitán. The Meta River limits the study area to the north.

Acquiring clear optical imagery is difficult because of cloud cover and the haze produced by burning native pastures, a situation typical of the humid tropics. Even when a clear image can be acquired in the dry season, a single optical image is of limited use in drawing a complete picture of the type of pastures and their levels of degradation. Contrasts between improved and native pasture can diminish because of generalized water stress. The burning of native pastures can erase differences between degraded and healthy pastures. Combining images acquired during different parts of the year is desirable, but during the rainy season acquiring optical imagery is virtually impossible in the Colombian lowlands.

These problems decided us on exploring the possibility of using radar imagery to help distinguish between land uses in the study area. Radar sensors can acquire images through cloud cover, thus allowing multiseasonal studies. For this application, we chose to use images from the Canadian RADARSAT satellite, using C-band (with a wavelength of 5.6 cm). We wanted to study the possibility of using multiseasonal radar images from RADARSAT together with electro-optical imagery to distinguish native from improved pastures, and to identify areas of severe degradation within each of these two types of vegetation. Here we present the first results of the study of two RADARSAT images acquired near Puerto Lopez, on May 2nd and May 26th, 1997. This research constitutes CIAT's participation in the Colombian chapter of the Canadian GLOBESAR-II project, developed by the CCRS.

The RADARSAT images acquired in May are in the ascending S6 mode, covering most of the study area. The May 26th image was planned to be the only image to be acquired during May. Radarsat International, the company commercializing RADARSAT images, acquired the May 2nd image as a backup in case acquisition or processing of the later image should fail. Because a rainstorm occurred on the evening of May 26th, we decided to request the May 2nd image for comparison purposes. The Santa Cruz meteorological station (4° 09′ N, 73° 11′ W, 230 m) measured 63 mm of rain on May 26th, and no rain on May 1st and 2nd. As complementary information, we are using a Landsat-TM half-scene acquired in January 1996, which has a cloud cover of about 20% and is affected by haze. Although we are planning to purchase an additional TM image, this one allows us to make general observations on the possible combined use of electro-optical images for monitoring the area.

We synchronized field measurements with the acquisition of the May 26th image. Field recognition and measurements began on May 23rd and extended to June 20th. We chose to make detailed observations on a limited number of relatively homogenous plots and on relatively flat terrain. We studied 14 plots in the *serranía* and over 40 plots in the *altillanura* landscape. The corners of the plots have been measured with a 12-channel, hand-held GPS.

Observations taken for each plot include identification of land use, description of the dominant species, measurements of vegetation height, evaluation of ground cover by dead and live vegetation, qualitative evaluation of soil roughness, orientation of periodic features, and a qualitative evaluation of the soil's drainage capacity. For each field, we took five samples of vegetation biomass, each for a 1 m x 1 m area, from which we measured moist and dry biomass. For bare soils, we made a more quantitative evaluation of roughness. We measured maximum and average size of soil aggregates and maximum variation in height, and estimated the standard deviation of height. We also measured the distance between both ends of a fixed-length chain laid on the ground, to follow the soil's irregularities. The short distance is an indicator of roughness that can give a strong signal to the 5.6 cm radar. On the evening of acquiring the May 26th image, we took five samples of the first 5 cm of the soil surface in each of 14 plots, for which we calculated the volumetric and gravimetric soil moisture. For all studied plots, we complemented observations with numerous photographs.

We took GCPs to georeference the image to the local projection, using vectors of the stream network digitized from 1:25 000 scale maps. Instead of georeferencing the images, we projected the polygons of the plots onto the image geometry. This allowed image parameters to be extracted while avoiding the effect of resampling on image radiometry and variance. We calibrated the images using the gain values and the geometric parameters included in the image header files. The average and standard deviation of the backscattering power was calculated for each plot and for each image, and the averages then converted to decibels. For this stage of the analysis, the images were not radiometrically corrected for the effect of topography. We chose the plots in the flattest areas possible, but some have a slight inclination so a topographic correction would be necessary to develop more precise relationships between backscatter and vegetation parameters.

Most of the native savanna plots appear darker than the improved pasture, except the ones presenting high grass growth or invasion by shrubs. The darker tone of the native savanna is attributed to finer leaves and stems, and to lower biomass in many cases. Because most native savannas are burned each year (although a delay of 14 months is recommended to allow all species to flourish) we expect that acquiring a multitemporal radar image would allow us to distinguish native from improved pastures. In addition to tone, improved pasture plots in the flatter *altillanura* sector present smaller rectangular shapes whereas the native savanna areas are often larger and present irregular boundaries, although exceptions occur. In the more dissected *serranía*, improved pastures are often introduced in the narrow valleys and their limits follow the landscape rather than geometric alignments. We have limited our test plots in the *serranía* landscape to flatter and higher areas, and expect that radiometric variations caused by the slope will complicate identifying improved pastures with radar in this area.

Identifying degraded areas is more complicated. In improved pastures, mismanagement can either result in loss of vegetative cover, caused by overgrazing, or in invasion by shrubs and native savanna species. The latter can be caused by undergrazing, in which case transitional vegetation starts to develop. It can also be caused by a lack of fertilization. Although shrub and weed-invaded pastures are expected to appear brighter than poorly covered plots in a radar image, the overgrazed, improved pasture fields appeared bright in both radar images because of the presence of clumps of grass and the roughness of the soils. The role of electro-optical images such as those from Landsat TM will be important in assessing pasture degradation; radar imagery will be a useful complement.

Contributors:
Nathalie Beaulieu
Patrick Hill

Activity: Using JERS-1 SAR Images to Locate Weaknesses in the Riparian Forest in the Tropical Lowlands of Colombia

✓ *Environmentally critical areas identified*

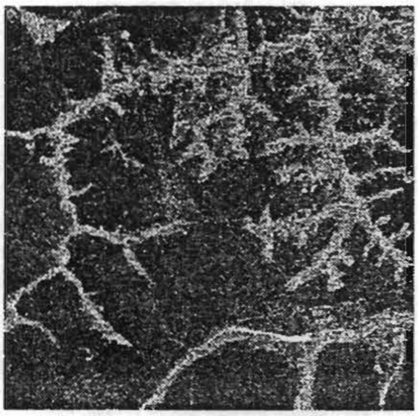
We used remote sensing to determine the distribution of riparian forests. A supervised classification of a 1996 Landsat TM image yielded a forest cover of 16% for the Yucao watershed. We are analyzing radar images taken in 1997, which are particularly useful for delimiting forest boundaries and possibly forest types. Apart from the percentage cover of forests in the landscape, describing and quantifying their distribution is important. Spatial analysis shows that forests are indeed limited to a narrow strip along the streams, where forest cover remains almost continuous. An interruption of forest cover immediately leads to fragmentation, with the risk of isolating plant and animal populations leading to a loss of biodiversity. Forest width is in many cases less than the 30-m-wide strip on either bank that Colombian legislation requires to protect streams (Beaulieu et al., 1997). Although part of this is probably because of limitations that the soil conditions and fire management impose, the legal width could be useful in enforcing the preservation of the riparian forest's continuity.

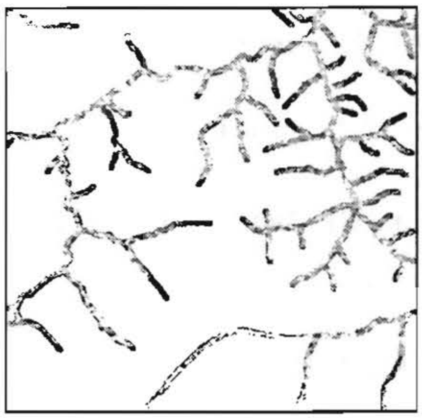
This study aims to locate sections where the riparian forest is either discontinuous or excessively narrow, in an area of savanna dominated by livestock agriculture. Our study area is located south of the Meta River, between the cities of Puerto Lopez and Puerto Gaitán, in the Meta Department, Colombia.

The L-band (wavelength of 23.5 cm) used by the SAR aboard the JERS-1 satellite provides excellent contrast between forest and either natural or improved pasture, independent of cloud or haze from burning. Two SAR images, acquired in March 1996, were georeferenced to an Arc/Info database of the area containing streams digitized from 1:25 000 scale topographic maps, derived from aerial photographs. NASDA made the SAR images available to CIAT for research purposes, under the GRFM Program. For the analysis of the narrow rivers draining the study area, a study buffer with a total width of 87.5 m, corresponding to 7 pixels of the JERS-1 images, was derived from the watercourse vectors, to examine an area slightly wider than that required for protection. A median filter was applied to the image mosaic to reduce speckle (a grainy noise typical of radar imagery); the image was then classified into forest and non-forest. Pixels of non-forest falling into the study buffer constitute the areas that potentially need reforestation, and that should be ground-checked.

Figure 9A shows a close-up of the unfiltered JERS-1 SAR image over an area of 6.4 km x 6.4 km southwest of Puerto Gaitán; the riparian forest appears white. Figure 9B shows, in black, the areas potentially needing reforestation, overlaid onto the filtered SAR image, only shown in the 7-pixel-wide strips following the river courses. Areas not falling into the study buffer areas appear in white. Clusters of black on the extremities of streams are critical, because they show areas that allow contamination and sedimentation to directly enter the stream network. In Colombia, farmers can benefit from economic incentives for reforestation. The Corporacion Colombiana de Investigación Agropecuaria (CORPOICA), the national institution in charge of agricultural development, will use the results of this study to focus reforestation and conservation initiatives towards the most environmentally critical areas.

Contributors:
Nathalie Beaulieu
Erik Veneklaas
Peter Jones





(A) (B)

Figure 9. Close-ups of the unfiltered JERS-1 SAR image with riparian forest (in A) appearing white and areas (in B), potentially needing reforestation, showing black.

Activity: Relating Riparian Forest and Image Characteristics for Images from Landsat TM, RADARSAT, and JERS-1 SAR

✓ *Transects and images added to geographical database*

This component of the study is in its initial phase, and is conducted in collaboration with the Land Management project, which has coordinated acquiring field measurement data to characterize the riparian forest of the Yucao watershed. Twenty-nine transects have been studied along which forest parameters and the distribution of species has been determined in many 400 m^2 plots. These transects and plots have been added to the geographical database of the area. Images from Landsat TM (Jan 1996), RADARSAT (May 1997), and JERS-1 SAR (June 1996) have been georeferenced and also added to the geographical database.

Contributors:
Nathalie Beaulieu
Erik Veneklaas, PE-4 project

GIS SUPPORT TO PE-5

PE-5 Output 1: Improved targeting for technology and management innovations.

PE-5 Activity 1.2: Integrate information into GIS and other databases.

Activity: Building the GIS Database for Pucallpa

✓ *GIS base maps database for Pucallpa near completion*

This work aims to generate a high-quality digital database with basic information for the collaborative research area near Pucallpa, Ucayali.

The GIS database has been processed by combining resources from PE-4, PE-5, IS-GIS, and the Instituto de Investigaciones de la Amazonía Peruana (IIAP). CIAT and IIAP have formally agreed on free interchange of digital GIS data, exchange of experiences, and collaborations. Table 3 shows what the database will contain when fully completed.

Table 3. The GIS database for Pucallpa, with CIAT and IIAP[a] contributions.

CIAT	IIAP
Contour lines and spot elevations	Forest zoning[b]
Roads 1989	Deforestation 1955-1995[b]
Rivers 1989	Land use 1993-1994[b]
Digital Elevation Model	
Individual houses 1989	
Land cover 1985,1989, and 1996[b]	

a. IIAP = Instituto de Investigaciones de la Amazonía Peruana.
b. To be obtained or processed by January 1998.

Remote sensing images have been obtained and are being processed to produce land-use and land-cover maps and to analyze the changes that have occurred since 1985. Three Landsat MSS images of 1985 have been georeferenced and mosaicked to cover the research area and its surroundings. The control points for this georeferencing have been identified digitally on features digitized from 1:100 000 scale, topographic maps. Four SAR images from the JERS-1 SAR of June 1996 (obtained through GRFM) have also been georeferenced to form a mosaic of the area. However, drawing conclusions from the comparative study of optical and SAR imagery is difficult, therefore the PE-4 project has purchased a set of two Landsat TM images of September and October 1996. These images will help determine if the changes noted between the 1995 MSS and the 1996 JERS-1 SAR are attributable to changes in land use or to differences in the sensitivity of the sensors.

Figure 10 shows a subset of the mosaic achieved with the Landsat MSS images of 1985. The green frame presents the area covered by CIAT's GIS database. The red frame represents the area of collaborative research, delimited after consultation with the Consorcio para el Desarrollo Sostenible de la Región Ucayali (CODESU), the International Centre for Research in Agroforestry (ICRAF), the Center for International Forestry Research (CIFOR), Instituto Nacional de Investigación Agraria (INIA), the Ministerio de Agricultura (MAG),and the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA).

Contributors
Grégoire Leclerc
Javier Puig
Nathalie Beaulieu
Marta Aguilar
Silvia Castaño, PE-4 project

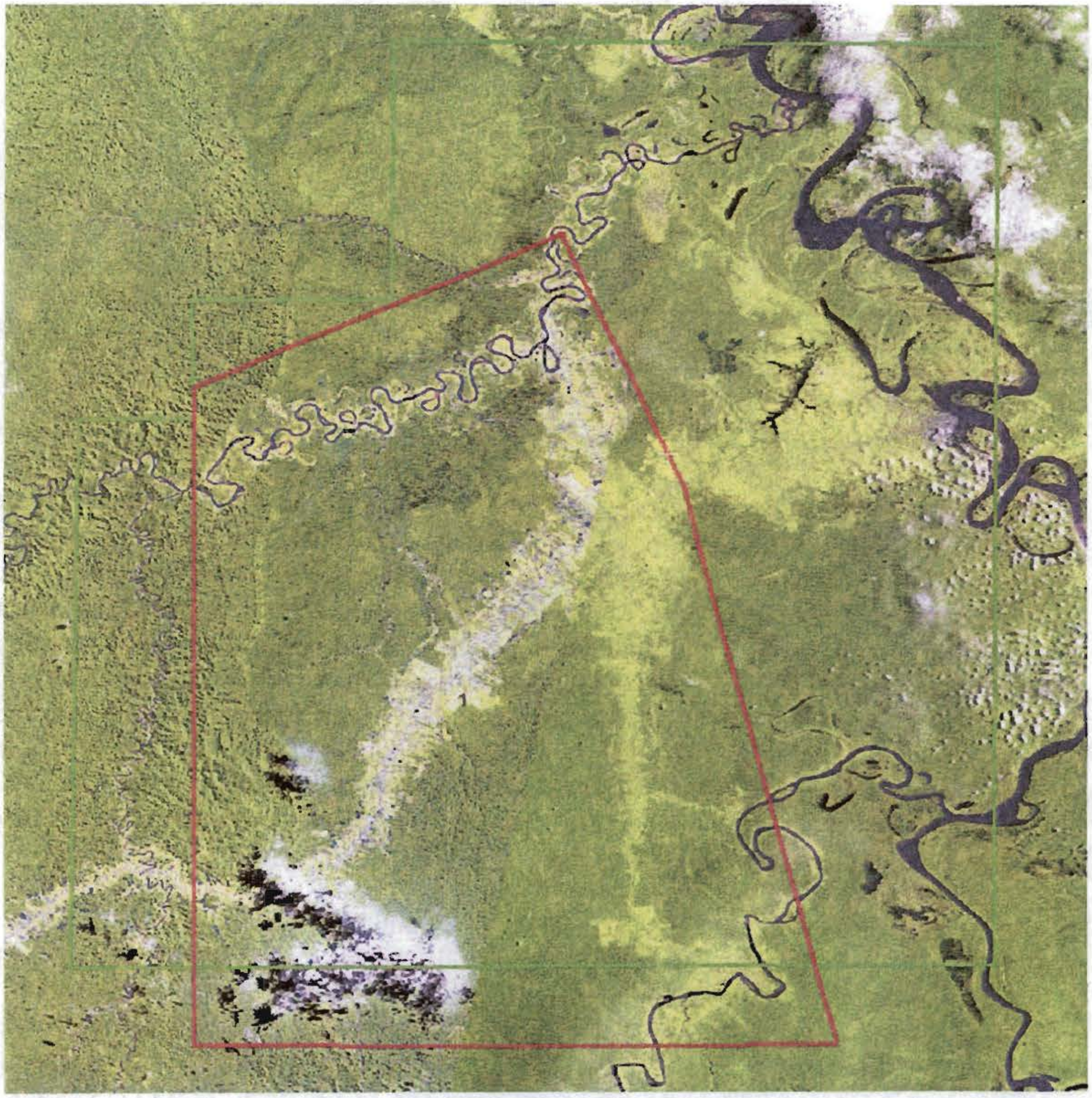


Figure 10. Subset of the mosaic achieved with the Landsat MSS images of 1985.

DONORS

Because a large part of the GIS Facility's budget comes from CIAT's core budget, we are indebted to all of CIAT's donor agencies and countries. We are also indebted to the donors who fund the CIAT projects that contribute to our operation by covering part or all of the salary of the staff member supporting these projects. Among others, we would like to mention organizations that fund the PE-3 project, the Interamerican Development Bank (IDB), the International Development Research Centre (IDRC), Canada, the Swiss Agency for Development Cooperation (COSUDE), and the Royal Danish Ministry of Foreign Affairs (DANIDA).

We receive direct funding from IDB for our work on poverty mapping (in collaboration with the PE-3 and PE-4 projects), and from the Eco-Regional Fund to Support Methodological Initiatives (Dutch government) for our work on integrating data from different scales (in collaboration with the PE-3 project). We will also receive funding from the Bundesministerium für Wirtshaftliche Zusammenarbeit (BMZ), Germany, for our work on the dynamics and sustainability of farming and regional systems in the South American savannas.

We received free imagery from NASDA and from the CSA. We received funding for field work and imagery from CIDA through the CCRS's GLOBESAR-II project. Training contracts for the GLOBESAR-II project were funded by IDRC, CIDA, and CSA's User Education and Training Initiative (UETI).

REFERENCES

Beaulieu, N.; Veneklass, E.; and Bell, W. 1997. Using SAR images to locate gaps in the riparian buffers of Colombian tropical lowlands. Example 16, GIS Awareness Package in Agricultural Research. United Nations Environment Program (UNEP)/DEIA/TR.97-9. http://www.grida.no/cgiar/htmls/awpack.html

Brunt, A. A.; Crabtree, K.; Dallwitz, M. J.; Gibbs, A. J.; Watson, L.; and Zurcher, E. J. (eds.) 1996. Plant viruses online: descriptions and lists from the VIDE database. Version 16 Jan. 1997. URL http://biology.anu.edu.au/Groups/MES/Vide.

Caballero, R. 1992. Whiteflies (Homoptera:Aleyrodidae) from Central America and Colombia including slide-mounted pupal and field keys for identification, field characteristics, hosts, distribution, natural enemies, and economic importance. MSc thesis, Kansas State University, KS. 201 p.

Deichmann, U. 1996. A review of spatial population database design and modeling. United Nations Environment Program (UNEP), Global Resource Information Database, (GRID). 58 p.

Eade, J. Feb 21 1997. The accessibility surface. < jeremy@epac.norway.ibm.com > < afarrow@gis.ciat.cgiar.org > (Accessed Feb 21, 1997)

Flowerdew, R.; Green,M.; and Kehris, E. 1991. Using areal interpolation methods in geographic information systems. Papers in Regional Science, 70:303-315.

Goodchild, M.; Anselin, L.; and Deichmann, U. 1993. A framework for the areal interpolation of socioeconomic data. Environ. Planning 25:383-397.

Heberlein, C. and Desforges, M. 1997. Mapping poverty in West Africa. Example 11, GIS Awareness Package in Agricultural Research. United Nations Environment Program (UNEP)/DEIA/TR.97-9. http://www.grida.no/cgiar/htmls/awpack.html

Langford, M.; Maguire D. J.; and Unwin, D. 1994. Generating and mapping population density surfaces within a geographical information system. Cartogr. J. 31:21-25.

Leclerc, G. and Beaulieu, N. 1996. Two simple methods to correct radiometric distortions due to the slant-range projection in an airborne radar image. In: Procs. Second International Airborne Remote Sensing Conference and Exhibition Technology, Measurement and Analysis. Vol. 1. San Francisco, CA. p. I305-314.

Martin, J. H. 1987. An identification guide to common whitefly pest species of the world (Homoptera: Aleyrodidae). Trop. Pest Manage. 33:298-322.

Morales, F. 1996. Rice stripe necrosis virus – the importance of early and correct diagnosis for emerging plant diseases. http://www.agric.org/pmp/1996/rsn 9604.html

Mound, L. A. and Halsey, S. H. 1978. Whitefly of the world: a systematic catalogue of Aleyrodidae (Homoptera) with host plant and natural enemy data. British Museum (Natural History). 340 p.

Moxey, A. and Allanson, P. 1994. Areal interpolation of spatially extensive variables – a comparison of techniques. Internat. J. Geog. Inf. Syst. 8:479-487.

Peet, R. K. 1974. The measurement of species diversity. Annu. Rev. Ecol. Syst. 5:285-307.

Puig, J. 1997. Modificaciones del recorrido del río Amaime. Technical Report for Ingenio Providencia. CIAT, Cali, Colombia. 3 p. 6 maps.

Shannon, C. E. and Weaver, W. 1949. The mathematical theory of communications. Illinois Press, Urbana, Ill. 117 p.

Simpson, E. H. 1949. Measurement of diversity. Nature 163:688.

Tobler, W. R. 1979. Smooth pycnophylactic interpolation for geographical regions. J. Amer. Stat. Assoc. 74:519-530.

MEETINGS AND WORKSHOPS

(NB= N. Beaulieu, WB = W. Bell, GL = G. Leclerc, AN = A. Nelson, and JP = J. Puig)

1996:
Nov 7-8 (GL) Ist National Coordination Workshop of units using GIS in Nicaragua

1997:
Feb 17-19 (NB) GLOBESAR-II/ Colombia's principal investigators meeting, organized and hosted by the Instituto Geográfico Augustín Codazzi (IGAC), Bogotá.

May 24-30 (WB, GL) International Symposium Geomatic in the Era of RADARSAT-GER'97, Ottawa, Canada.

Aug 27-28 (GL, JP) Workshop on Development of a Joint Workplan for Pucallpa, Cali, Colombia.

Sept 23-25 (NB, WB, GL) Fourth Annual Workshop "CGIAR/UNEP Cooperation on the Use of GIS in Agricultural Research", Cali, Colombia.

Nov 2-7 (GL, AN, JP) Sociedad de Especialistas Latinoamericanos en PercepciónRemota (SELPER) conference in Merida, Venezuela.

Nov 4-7 (NB) The GRFM Principal Investigators meeting at the Jet Propulsion Laboratory (JPL).]

Nov 24-26 (WB) TREES, Tropical Deforestation Hotspot Expert Meeting, Joint Research Center, Ispra, Italy.

Training Workshops (NB)
Training given for the GLOBESAR-II/ Central America project, level I workshops: Radar general concepts, RADARSAT image products and applications.

May 12-14: Hosted by the Instituto Geográfico Tommy Guardia, Panama city, Panamá, organized by Dirección general de recursos Minerales, Ministerio de Commercio e Industria.

May 15-17: Hosted by the Universidad de Costa Rica, San José, Costa Rica, organized by the Instituto Geográfico Nacional (IGN).

May 19-21: Hosted by the Escuela Nacional de Ciencias Forestales (ESNACIFOR), Siguatepeque, Honduras, organized by the Corporación Hondureña de Desarrollo Forestal (COHDEFOR).

Training given for the GLOBESAR-II projects in Colombia and Central America, level II workshops, Radar image processing and extraction of information.

Oct 6-10: Hosted and organized by the Instituto Geográfico Augustín Codazzi (IGAC), Bogotá.

Dec 1-5: Hosted by the Escuela Nacional de Ciencias Forestales (ESNACIFOR), Siguatepeque, Honduras, organized by the Corporación Hondureña de Desarrollo Forestal (COHDEFOR).

Dec 8-12: Hosted by the Universidad Nacional Autónoma (UNA), Heredia, Costa Rica, organized by the Instituto Geográfico Nacional (IGN).

PUBLICATIONS

Book and Journal

Langford, M. and Bell, W. 1997. Land cover mapping in a tropical hillsides environment: a case study in the Cauca region of Colombia. Int. J. Remote Sensing, 18:1289-1306.

Leclerc, G. and Rodriguez Ch., J. 1997. Using a GIS to determine critical areas in the central Cordillera conservation area, Costa Rica. In: Lacher Jr., T. E. and Savitsky, B. G. (eds.) Conservation policy making using digital mapping technologies: case studies in Costa Rica. Biol. Res. Manage. Tropics Series. Colombia University Press. Forthcoming.

Conference and Workshop

Beaulieu, N.; Leclerc, G.; Bell, W.; Marmillod, D.; and Asch Quirós, C. 1997. Comparison of RADARSAT imaging modes to monitor land use in coastal areas. Procs International Symposium Geomatics in the era of RADARSAT- GER´97, Ottawa May 24-30. CD-ROM. Forthcoming.

Hyman, G.; Nelson, A.; Jones, P.; and Bell, W. 1997. Mapeo de población de America Latina. Procs VIII Simposio Latinoamericano de Percepción Remota, Merida, Venezuela, Nov 2-7. Sociedad de Especialistas Latinoamericanos en Percepción Remota (SELPER). Forthcoming.

Knapp, E. B.; Ashby, J. A.; Ravnborg, H. M.; and Bell, W. C. 1997. A Landscape that unites: community-led management of Andean watershed resources. Paper presented at "Global challenges for Ecosystem Management on a watershed context", 22-26 July, Soil and Water Conservation Society, Toronto, Ontario, Canada.

Langford, M. and Bell, W. 1997. A comparison between an image processing approach and a GIS approach to improving land cover mapping using multi-source satellite imagery. Procs GIS Research UK Conference, Leeds University, Apr 1997. Forthcoming.

Leclerc, G.; Beaulieu, N.; Aguilar, M.; Bell, W.; and Ash Quirós, C. 1997. Comparación de los modos de adquisición S1, S7, EH5, y F5 de RADARSAT para el monitoreo del uso de la Tierra en zonas de manglares. Procs VIII Simposio Latinoamericano de Percepción Remota, Merida, Venezuela, Nov 2-7. Sociedad de Especialistas Latinoamericanos en Percepción Remota (SELPER). Forthcoming.

Nelson, A.; Hyman, G.; Jones, P.; and Bell, W. 1997. La conversión de vector a raster aplicada a datos de población de America Latina. Procs VIII Simposio Latinoamericano de Percepción Remota, Merida, Venezuela, Nov 2-7. Sociedad de Especialistas Latinoamericanos en Percepción Remota (SELPER). Forthcoming.

Puig, J.; Leclerc, G.; and Bell, W. 1997. La cromoestereoscopía aplicada en la percepción remota. Procs VIII Simposio Latinoamericano de Percepción Remota, Merida, Venezuela, Nov 2-7. Sociedad de Especialistas Latinoamericanos en Percepción Remota (SELPER). Forthcoming.

Other:

Beaulieu, N.; Veneklass, E.; and Bell, W. 1997. Using SAR images to locate gaps in the riparian buffers of Colombian tropical lowlands. Example 16, GIS Awareness Package in Agricultural Research. United Nations Environment Program (UNEP)/DEIA/TR.97-9. http://www.grida.no/cgiar/htmls/awpack.html

Crawford, E. 1997. A classifier system prototype for the exploratory analysis of spatial data. Project Report CIAT / University of Edinburgh. 21p.

Leclerc, G.; Nelson, A.; Bell, W.; and Grum, M. 1997. Spatial analysis of intraspecific diversity: a point centred approach. Example 39, GIS Awareness Package in Agricultural Research. United Nations Environment Program (UNEP)/DEIA/TR.97-9. http://www.grida.no/cgiar/htmls/awpack.html

Leclerc, G.; Puig, J.; and Bell, W. 1997. High-resolution remote sensing: getting detailed information for participatory research. Example 8, GIS Awareness Package in Agricultural Research. United Nations Environment Program (UNEP)/DEIA/TR.97-9. http://www.grida.no/cgiar/htmls/awpack.html

Oyana, T. J. 1997. An inventory of existing poverty assessment methods. Working paper. CIAT, Cali, Colombia. 17p.

Oral Presentations:

Beaulieu, N. 1997. Identification of weaknesses in the riparian forest of Colombian tropical lowlands using JERS-1 images. Oral presentation given at the GRFM principal investigator's conference, Jet Propulsion Laboratory, Pasadena, California, November 4-7.

Beaulieu, N. 1997. The use of Remote Sensing for Land Management at the International Center for Tropical Agriculture. Seminar given January 24th at the Applied Physics Laboratory, Johns Hopkins University, Laurel, Maryland., and on February 3rd at the Canada Centre for Remote Sensing, Ottawa, Canada.

GIS STAFF LIST

* Left CIAT during 1996-97
% Time on projects

	%		
William Bell	50	PhD Microclimatology	Manager GIS Facility
Nathalie Beaulieu		PhD Remote Sensing (RS)	Senior Research Fellow
Grégoire Leclerc	25 PE-3	PhD, Physics	Senior Research Fellow
Marta Aguilar	50 PE-4	LIC Geog, spec.RS	Junior Research Fellow
Julie Cox	100 PE-3	MSc RS, MSc GIS	Junior Research Fellow
*Mandy Kingston		MSc GIS	Junior Research Fellow
Justine Klass	50 PE-1	BAH, CGIS	Junior Research Fellow
Andy Nelson	100 PE-3	MSc GIS	Junior Research Fellow
Tonny Oyana	100 PE-3	MSc GIS	Junior Research Fellow
Javier Puig	100 GIS	MSc NRM	Junior Research Fellow
Patrice Couillaud		Ing Electron.	Junior Research Fellow
*Nick Thomas		MSc RS	Junior Research Fellow
Jorge Cardona	50 PE-4	Systems Technician	Programmer 1
Elisabeth Barona		Systems Technician	Programmer 2
Martha Gomez	20 PE-4	Bilingual Secretary	Bilingual Secretary

IS STAFF LIST

Name	Section	Position
William Bell	Information Systems	Chief Information Officer
Ricardo Uribe	Information Systems	Head of Users Support and Network Administration
Carlos Meneses	Information Systems	Assistant to CIO
Carlos Andres Arango	Information Systems	Systems Engineering Student
Angelica Lastra	Information Systems	Systems Engineering Student
Sandra Lopez	Information Systems	Systems Engineering Student
Nathalie Sima	Telecommunications	Telecommunications office staff
Hector Mesa	Micro Support	Supervisor
Fernando Arango	Micro Support	Electronics Technician
Manuel Caldas	Micro Support	Electronics Technician
Susana Cardona	Micro Support	Electronics Technician
Yolanda Gomez	Micro Support	Office staff
Alex Zurita	Micro Support	Electronics Technician
Aura Patricia Villa	Users Support	Engineer
Lewis Araujo	Users Support	Technician
Jairo Castañeda	Users Support	Systems Engineering Student
Alberto Nader	Users Support	Systems Engineering Student
Oscar Bermeo	Network Administration	Network Engineer
Juan Carlos Machado	Network Administration	Network Engineer
Carlos Lopez	Network Administration	Operator
Luis Fernando Cruz	Administrative Systems	Head of Administrative Systems
Claudia Morales	Administrative Systems	Systems Analyst
Maria del Pilar Ospina	Administrative Systems	Systems Analyst
Arturo Franco	Databases	Database Administrator
Fernando Rojas	Databass	Database Administrator
Juan Caros Serna	Databases	Systems Engineering Student
Marlyn Silva	Databases	Systems Engineering Student

ACRONYMS AND ABBREVIATIONS

ADRO	Application Development and Research Opportunity, RADARSAT
BA	beneficiary assessment
BGMV	bean golden mosaic virus
BMZ	Bundesministerium für Wirtshaftliche Zusammenarbeit, Germany
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CCRS	Canadian Center for Remote Sensing
CGIAR	Consultive Group on International Agricultural Research
CIDA	Canadian International Development Agency
CIFOR	Center for International Forestry Research, Indonesia
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico
CIO	Chief Information Officer
CODESU	Consorcio para el Desarrollo Sostenible de la Región Ucayali, Peru
COHDEFOR	Corporación Hondureña de Desarrollo Forestal
CONDESAN	Consorcio para el Desarrollo Sostenible de la Ecoregión Andina
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
COSUDE	Corporación Suiza al Desarrollo
CPM	Capability Poverty Measure
CSA	Canadian Space Agency
DANIDA	Royal Danish Ministry of Foreign Affairs
DCW	Digital Chart of the World
DEM	Digital Elevation Model
ESNACIFOR	Escuela Nacional de Ciencias Forestales, Honduras
FAO	Food and Agriculture Organization of the United Nations, Italy
GCP	ground control point
GDP	gross domestic product
GER	Geomatics at the Era of Radarsat
GIS	Geographic Information Systems
GPS	global positioning system
GRFM	Global Rain Forest Mapping program
GRID	Global Resource Inventory Database, Arendal, Norway
HCI	Head Count Index
HDI	Human Development Index
ICIS	International Crop Information System
ICRAF	International Centre for Research in Agroforestry, Kenya
IDB	Interamerican Development Bank
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agriculture Development
IGN	Instituto Geografico Nacional, Costa Rica
IIAP	Instituto de Investigaciones de la Amazonía Peruana
INIA	Instituto Nacional de Investigación Agraria, Peru
IPGRI	International Plant Genetic Resources Institute, Italy
IS	Information Systems
ISU	Information Systems Unit
IT	Information Technology
IVDN	Integrated Voice and Data Network

IVITA	Instituto Veterinario de Investigaciones Tropicales y de Altura, Peru
JERS-1	Japanese Synthetic Aperture Radar Satellite
JPL	Jet Propulsion Laboratory
Kbps	kilobytes per second
LSMS	Living Standard Measurement Survey
MAG	Ministerio de Agricultura, Peru
Mbps	megabytes per second
NARS	National Agricultural Research Systems
NASDA	National Space Development Agency, Japan
NGO	nongovernment organization
NRM	Natural Resource Management
PPA	participation in poverty assessment
PPP	purchasing power parity
PRA	participatory rural appraisal
RESTEC	Remote Sensing Technology Center of Japan
SAR	Synthetic Aperture Radar satellite
SDA	Social Dimensions of Adjustment
SELPER	Sociedad de Especialistas Latinoamericanos en Percepción Remota
SIMC	Strategic Information Management Committee
UETI	User Education and Training Initiative of the CSA
UNA	Universidad Nacional Autónoma, Costa Rica
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UPS	uninterruptible power supply
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
WWW	World Wide Web

ANNEXE 1

SB-2: Enhancing The Understanding And Use Of Agrobiodiversity Through Biotechnological Methods

Objectives: To contribute to the improvement and use of genetic resources. To promote agrobiodiversity conservation through the integrated application of modern molecular and cellular biotechnologies.

Outputs: Improved understanding of genetic diversity of wild and cultivated species. Exotic or novel genes and gene combinations identified and accessed for broadening the genetic base of crops. Collaboration with CIAT partners in the study of agrobiodiversity and broadening the genetic base of crops.

Gains: Plant breeders and genetic conservation specialists will perform better through the use of information and tools from biotechnology for the characterization of agrobiodiversity at molecular and agroecological levels. By the year 2001, useful genes and gene combinations will be used for broadening the genetic base of CIAT mandated crops. Throughout 1998-2001, diversity conservation and germplasm improvement efforts with CIAT partners will be strengthened through cooperation in capacity building for the application of modern biotechnology.

Duration: Five years.

1998 Molecular linkage maps and DNA-based markers available for assessing diversity of *Phaseolus* and *Manihot*. Core collections developed for beans and cassava. Collaborative activities with CIAT partners implemented.

1999 Gene and gene combinations identified for gene pool enhancement, and methodologies developed for gene transfer in *Phaseolus*, cassava, rice, and *Brachiaria*. Collaborative activities with CIAT partners implemented.

2001 Agroecological, genomic, and socioeconomic information being developed for CIAT mandated crops as models. for other species. Collaborative activities with CIAT partners implemented.

Users: Primarily CIAT and NARS scientists involved in agrobiodiversity conservation in Latin America, but also other scientists involved in germplasm enhancement and use around the world.

Collaborators: IARCs (IPGRI: systemwide program on genetic resources; CIP and IITA: root-tuber crops initiative; IRRI: rice blast). NARS (CORPOICA, EMBRAPA). Specialized research institutions (universities in USA, Europe, Cuba, Brazil, Argentina). Universities in developing countries (UNIVALLE; Nacional-Bogotá, Colombia; Nacional, Costa Rica; Agraria, Peru). Biodiversity institutions (A. von Humboldt, INBIO, Smithsonian). Corporations and private organizations (Corp. BIOTEC, BRL, Sandoz).

CGIAR system linkages: Saving Biodiversity (40%); Enhancement and Breeding (55%); Training (5%).

CIAT project linkages: *Inputs to SB-2:* Germplasm accessions from gene bank project. Phenotyped segregant populations from crop productivity projects. Characterized insect and pathogen strains and populations from crop protection projects. GIS services from land use project. *Outputs from SB-2:* Genetic and molecular information on gene pools, and populations, for gene bank, productivity, and crop productivity projects. Information and material on identified genes and gene combinations for productivity and crop protection projects. Methods and techniques of cloning and conservation for gene bank and productivity projects. Interspecific hybrids and transgenic stocks for crop productivity projects.

SB-2 Work Breakdown Structure (the GIS Facility contributed to the underlined theme)

	Project objectives		
	To contribute to the improvement and use of genetic resources, and to promote agrobiodiversity conservation through the integrated application of modern molecular and cellular biotechnologies		
Outputs	**1. Understanding of the genetic diversity of wild and cultivated species for the use and conservation of improved genetic resources**	**2. Exotic or novel genes and gene combinations accessed for broadening the genetic base of crops**	**3. Collaboration with CIAT partners to study agrobiodiversity and broaden the genetic base of crops**
Activities	1.1 Enhancement of knowledge of gene pool structure at intra- and interspecific level. 1.2 Identification of useful genes and gene combinations for germplasm inprovement. 1.3 Agroecological, agronomic, and genomic information assembled and integrated. 1.4 Molecular techniques for assessing genetic diversity developed.	2.1 Access exotic or novel genes and gene combinations for broadening the genetic base of cultivated gene pools. 2.2 Generate information on genetic and molecular mechanisms of plant response to biotic and abiotic stresses, and interaction with beneficial and parasitic organisms. 2.3 Improve cellular and molecular gene transfer methodologies for broadening the genetic base of cultivated gene pools.	3.1 Exchange genes, genetic stocks, genomic maps, probes, and cell cultures with CIAT partners. 3.2 Collaboration on modern molecular and cellular techniques for understanding genetic diversity and broadening the genetic base of crops.

PE-1: Integrated Pest And Disease Management In Major Tropical Agroecosystem

Objective: To develop and transfer improved pest and disease management components that increase sustainable productivity for tropical agricultural production systems and reduce environmental damage caused by excessive pesticide use.

Outputs: Improved pest and disease management components and implementation strategies for CGIAR commodity crops. Improved crop management components relevant to IPM strategies. NARS' capacity to design and execute integrated crop management research and development projects strengthened.

Gains: Increased crop yields and reduced environmental damage. Natural enemies of major pests and diseases evaluated. IPM developed, and tested and verified on-farm. Increased knowledge of biology and ecology behavior of pests and diseases and the damage they cause. Molecular characterization of major pathogens and diagnostic kits available. Whitefly biodiversity characterized. FPR methods for IPM developed and implemented. Biological control agents established in new regions.

Milestones:

1998 Whitefly and geminivirus biodiversity partially characterized. Biological control agents of cassava green mite established in Africa and NE Brazil. Additional natural enemies for mites, whiteflies, and other pests identified. Creation of farmer participatory research committees. A PCR diagnostic test developed for cassava bacterial blight (CBB).

1999 Selected natural enemies of whiteflies, mites, burrowing bugs, and mealybugs identified, evaluated, and released in Latin America and Africa. Resistance to cassava frogskin virus identified and diagnostic kit developed. A PCR diagnostic test developed for root-rot pathogens.

2000 Biological control implemented for several arthropod pests and root-rot pathogens. Cassava geminiviruses characterized. Farmers and extension workers trained in the use of diagnostic kits.

Users: Biodiversity of agroecosystems determined and available to researchers. NARS scientists, extension workers, and farmers trained in IPM methodologies. Crop yields for small producers increased and stable production systems identified.

Collaborators: IARCs (IITA, ICIPE, CIP). Advanced research institutes (e.g., CATIE, NRI, universities of Florida, Wisconsin, and São Paulo, John Innes Center, ETH/ORSTOM/CIRAD, Boyce Thompson Institute), NARS (e.g., EMBRAPA, CORPOICA, INIAP, INIVIT, NARO), NGOs, and private industries (COINBIOL).

CGIAR system linkages: Improving Productivity (30%); Biodiversity (20%); Protecting the Environment (40%); Strengthening NARS (10%). Manages Whitefly and Participatory Methods Projects in Systemwide IPM Program.

CIAT project linkages: Collaborates with breeding projects (IP-1, IP-2, IP-3, IP-4, and IP-5) in host-plant resistance. Provides biocontrol agents to project PE-5. Uses inputs from PE-4, SB-2, and SN-3.

PE-1 Work Breakdown Structure (the GIS Facility contributed to the underlined theme)

	Project objective			
	To develop and transfer improved pest and disease management components that increase sustainable productivity for tropical agricultural production systems and reduce environmental damage caused by excessive pesticide use			
Outputs	**1.** **Improved understanding of pest and disease management components and implementation strategy developed for CGIAR commodity crops**	**2.** **Development and integration of pest and crop management components relevant to IPM strategies**	**3.** **NARS' capacity to design and execute integrated crop management research and development projects trengthened**	**4.** **Globalization of IPM research activities on selected pests and crops initiated**
Activities	1.1 Identification and quantification of major arthropod complexes in selected agroecosystems. 1.2 Identification and characterization of fungal and bacterial pathogens; development of rapid detection methods. 1.3 Identification and characterization of major viruses; development of rapid_detection methods. 1.4 Molecular characterization of pest, pathogen, and natural enemy biodiversity. 1.5 Improvement of understanding of pest and disease dynamics.	2.1 Development of effective control measures for selected pests of cassava, beans, vegetables, and other crops. 2.2 Determination of crop management practices that affect pest and disease populations and dynamics. 2.3 Development and evaluation of cultural control practices such as crop rotation and intercroppping for selected pests and diseases. 2.4 Evaluation of alternate, safer, chemical control agents. 2.5 Use and integration of biological control agents in IPM.	3.1 Development and testing of methods for farmer participatory diagnosis and research in IPM and ICM. 3.2 *Ex post* adoption and impact studies on IPM costs and crop productivity. 3.3 Integrated management technologies for cassava planting material. 3.4 Assessment of impact of IPM measures and policy recommendations. 3.5 Dissemination of IPM methodologies through training, workshops, etc. 3.6 Assessment of impact of farmer participatory methodologies, including participation of women in IPM projects.	4.1 Formation of an international whitefly network. 4.2 Diagnosis and characterization of whitefly problem and target areas. 4.3 Exchange of biological control agents. 4.4 Exchange of resistant germplasm for IPM systems.

PE-3: Community Management Of Watershed Resources In Hillside Agroecosystems Of Latin America: Overview.

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

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

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

Milestones:

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

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

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

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

Collaborators: CIMMYT, CIP, IFPRI, IIMI, IICA; universities of Florida, Wageningen, Edinburgh, Guelph, Nacional Agraria (Nicaragua); CURLA (Honduras); DICTA, INTA, CONDESAN, CIPASLA.

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

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

PE-3 Work Breakdown Structure (the GIS Facility contributed to the underlined themes)

Project objective

To develop generic databases, decision-support tools and social organizational models for planning research and development activities for hillside watershed groups

Outputs	**1.** **Procedures established for use of databases to target problems, priority areas, and beneficiary groups for intervention in watershed management**	**2.** **Strategic techniques developed to strengthen capacity for location-specific diagnosis, monitoring, and impact assessment of environmental problems and interventions**	**3.** **Generic interactive decision-support tools produced to strengthen stakeholders' capacity to evaluate location-specific innovations and to negotiate action plans**	**4.** **Institutional capacity to use decision-support tools established for community-managed development of watershed resources**
Activities	1.1 Revision, edition, consolidation, and georeferencing of data into user-friendly biophysical and socioeconomic databases, including for gender. 1.2 Development of a step-wise framework for increasing the precision and resolution of spatial data ("successive refinement"). 1.3 Characterization of key parameters ("indicators") of land use change at plot, farm, catchment, and watershed scales. 1.4 Development of strategic procedures for applied policy impact analysis for use by local interest groups, including women's groups.	2.1 Development of field techniques for local monitoring of soil and water indicators of susceptibility to change. 2.2 Development of natural resource evaluation techniques, both financial and nonfinancial. 2.3 Identification of internal system indicators and their calibration with external system health and sustainability indicators. 2.4 Incorporation of indigenous indicators into knowledge-based decision-support tools, and their consolidation with spatial (GIS) analysis. 2.5 Testing methods and tools for agroecosystem health planning and technology testing at a landscape scale with community leadership, including women.	3.1 Development of techniques for simplifying extensive database queries by "non-experts." 3.2 Benefit-sacrifice assessment for upstream and downstream stakeholders, e.g., erosion, pollution, and water demand trade-offs. 3.3 Simulation of potential impact of current and exploratory technologies within the context of political environments. 3.4 Development of knowledge-based models to complement "databased" process models for decision support. 3.5 Cost-benefit analysis of requirements for alternate decision-support tools.	4.1 Development of organizational principles and procedures for watershed user associations and institutional consortia. 4.2 Participatory research on organizational development and collective action. 4.3 Use of decision-support tools to develop preferred scenarios with stakeholder organizations, including women's groups. 4.4 Development of computer-assisted training materials for negotiating collective action plans and for managing "change", using decision-support tools and techniques. 4.5 Conduct training with research networks (e.g., ICASA and commodity and NRM networks). 4.6 Management of project reporting, documentation, and information exchange.

PE-4: Land Use Studies: Reconciling The Dynamics Of Agriculture With The Environment

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.

1999 A stochastic land-use model developed for at least one of the study areas. Production of a CD-ROM Latin American data sampler, incorporating GIS coverages useful to policy makers. Sustainability indicator systems applied in Central America and within Colombia in the Orinoquia region. First regional report on environmental and sustainability indicators published.

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.

Collaborators: ICRAF, CIP, ILRI, ECLAC, University of Guelph (Canada), IICA (Costa Rica), IILA (Italy), IIASA (Austria), WRI (USA), RIVM (the Netherlands), TCA-Amazonian Cooperation Treaty, the Earth Council (Costa Rica), the World Bank, NARS, GOs and NGOs in Latin America; DNP, IGAC, MinAmbiente, IDEAM, CARDER (Colombia); Ministry of the Environment, EMBRAPA (Brazil); IVITA, INIA (Peru); INIAP (Ecuador).

CGIAR system linkages: Protecting the Environment (60%); Policies (20%); Breeding (10%); Biodiversity (10%). Contribute 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.

PE-4 Work Breakdown Structure (the GIS Facility contributed to the underlined themes)

	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			
Outputs	**1. Environmental opportunities and constraints identified and assessed**	**2. Land use patterns and their spatial distribution classified, and correlated with environmental and socioeconomic data**	**3. Determinants, dynamics, and impacts of land use in Latin America characterized and strategic options assessed**	**4. Environmental policy and sustainability indicators defined and reported**
Activities	1.1 Diagnosis of agroecosystem health in priority areas. 1.2 Perform field characterization of study sites. 1.3 Preparation of digital ecological maps at different scales (local to regional). 1.4 Assessment of alternatives for restoration of degraded land.	2.1 Characterization and mapping of land use patterns in hillsides, forest margins, and savannas. 2.2 Implementation of digital maps of land use, environmental degradation, and poverty for Latin America. 2.3 Perform quantitative analysis of potential sustainable land use for the ecoregion. 2.4 Identification of critical situations and major opportunities for sustainable land use.	3.1 Development of holistic framework for understanding land dynamics in Latin America. 3.2 Analyze historical land use changes. 3.3 Identification of major ecological and socioeco-nomic determi-nants of land use and farmer's decision making. Assessment of ecological impacts of land use. 3.4 Development of explanatory simulation models of land use dynamics. 3.5 Identification and assessment of strategic and policy options for sustainable agroecosystem management.	4.1 Promotion of a network of regional and national institutions that develop or demand indicators. 4.2 Development of conceptual framework in consultation with the network. 4.3 Definition of sets of environmental and sustainability indicators at different scales. 4.4 Development of a digital map of environmental and socioeconomic indicators for Latin America. 4.5 Testing of selected agroecosystem indicators at field level. 4.6 Biannual report produced.

PE-5: Sustainable Systems For Smallholders: Integrating Improved Germplasm And Resource Management For Enhanced Crop And Livestock Production Systems

Objective: To reduce poverty by developing productive crop and livestock technologies and sustainable management practices in smallholder farming systems of Latin America, Asia, and Africa, where beans, cassava, and forages are important commodities.

Outputs: Methodologies for linking resource management with improved germplasm options. Technology components that can be readily integrated to produce productive and sustainable land use systems. Effective partnerships for research and implementation.

Gains: Integration of commodity and natural resource research. New approaches to the development of environmentally sound technologies. Indicators for measuring economic and environmental impact of improved technology at the farm and watershed levels. Methodology to extend results beyond benchmark sites.

Milestones:

1998 Workshop to analyze the effectiveness of FPR in the development of new technology options for smallholder systems.

1999 NARS in Central and South America and Southeast Asia trained in methodology for integrating natural resource and commodity research. Methodology for assessing socioeconomic and environmental impact at farm level.

2000 New crop and livestock technologies for smallholder systems in Latin America, Southeast Asia, and Africa. Use of legumes for soil improvement in cropping systems and as forage alternatives for dry-season feeding. Increased bean production in low P soils. Cassava varieties for mixed cropping system. Demonstrated impact of technologies on increased welfare of poor rural families and sustainable land use. Methodology for more rapid dispersion of productive and sustainable technologies.

Users: The research will benefit low-income farmers in Latin America, Asia, and Africa by increasing available food and cash flow to rural households while providing a basis for more sustainable production systems. Adoption of environmentally sound farming practices will benefit society as a whole.

Collaborators: ICRAF, ILRI, IRRI; linkages with national R&D organizations and specialized research organizations.

CGIAR system linkages: Protecting the Environment (50%); Crop Production Systems (20%); Livestock Production Systems (15%); Strengthening NARS: Training (10%); Strengthening NARS: Networks (5%).

CIAT project linkages: Conservation of genetic resources; germplasm enhancement in beans, cassava, and tropical forages; natural resource management in areas of land use dynamics, soil processes, and watershed management; strengthening NARS through developing partnerships, participatory research, and impact assessment.

PE-5 Work Breakdown Structure (the GIS Facility contributed to the underlined theme)

Project objective To reduce poverty by developing productive crop and livestock technologies and sustainable management practices in smallholder farming systems of Latin America, Asia, and Africa, where beans, cassava, and forages are important commodities				
Outputs	**1. Improved targeting for technology and management innovations**	**2. Integrated technology and management options for production systems**	**3. Enhanced ability to promote adoption of sustainable land use practices**	**4. Known impact and utility of new technologies and strategies**
Activities	1.1 Characterize biophysical and socioeconomic resources and resource use systems. 1.2 Integrate information into GIS and other databases. 1.3 Evaluate potential for new technology, management, and employment options.	2.1 Develop new crop and livestock components with farmer participation through subprojects, e.g., Forages for Smallholders, Cassava Management, and Tropileche. 2.2 Develop integrated management practices with farmer participation. 2.3 Investigate nonagricultural alternatives for natural resource use. 2.4 Integrate results with higher scale studies of land and water use.	3.1 Investigate methods for increasing adoption of environmentally sound practices. 3.2 Develop collaborative research and development partnerships. 3.3 Develop integrated resource model to facilitate extension of results. 3.4 Develop training modules.	4.1 Determine economic impact and market opportunities. 4.2 Assess social impact. 4.3 Measure environmental impact on soil, vegetation, water, and atmosphere. 4.4 Communicate results through networks, workshops, and journals.