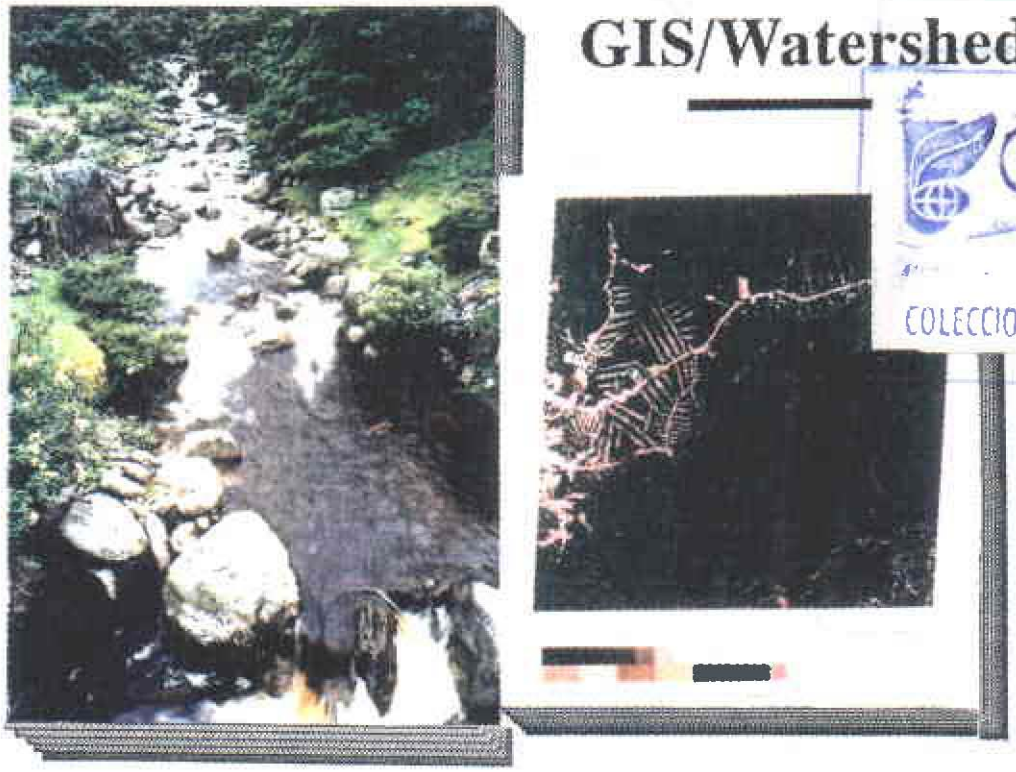
Improving Natural Resource Management for an Andean Watershed Using an Interactive Coupled GIS/Watershed Model



A Proposal for:

Bundesministerium für Wirtschaftliche Zusammenarbeit (BMZ)

Special Project Funding

Submitted by:

CIAT
Centro Internacional de Agricultura Tropical
Cali, Colombia

Collaborating Partners:

Institute of Plant Production in the Tropics and Subtropics
University of Hohenheim

August 1993

IMPROVING NATURAL RESOURCE MANAGEMENT FOR AN ANDEAN WATERSHED USING AN INTERACTIVE COUPLED GIS/ WATERSHED MODEL

QUANTIFYING AND PREDICTING THE EFFECT OF LAND USE PRACTICES ON EROSION, WATER QUALITY, AND CROP PRODUCTION FOR THE OVEJAS WATERSHED, COLOMBIA, USING AN INTERACTIVE, COUPLED GIS/WATESHED MODEL

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Acronyms

AGDIA	Commercial company
asl	above sea level
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit (BMZ)
CETEC	Corporación para Estudios Interdisciplinarios y Asesoría
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIPASLA	Consorcio Interinstitucional para Agricultura Sostenible en Laderas
CREAMS	chemicals, runoff and erosion from agricultural management systems
CVC	Corporación Autónoma Regional del Valle del Cauca
DSS	Decision Support System
DTM	Digital Terrain Model
ESRI	Environmental Systems Research Institute
FDDI	Fiber Distributed Data Interface
FEDECAFE	Federación Nacional de Cafeteros de Colombia
FUNDAEC	Fundación para la Aplicación y Enseñanza de las Ciencias
GIS	Geographic Information System
GO	Governmental Organization
GPS	Global Positioning Satellite
GTZ	German Agency for Technical Cooperation
IFDC	International Fertilizer Development Centre

Acronyms Cont'd

IGAC	Instituto Geográfico Augustín Codazzi
INCORA	Instituto Colombiano de la Reforma Agraria
IPM	Integrated Pest Management
mbs	megabits/sec
NGO	Non-Governmental Organization
SWRRB	Simulator for Water Resources in Rural Basins

1.0 Summary

Title of Research Proposal

Quantifying and predicting the effect of land use practices on erosion, water quality, and crop production for the Ovejas watershed, Colombia, using an interactive, coupled GIS/watershed model.

Short Title

Improving natural resource management for an Andean watershed, using an interactive, coupled GIS/watershed model.

Objective of Research:

The overall objectives of the project are:

1. To develop a prototype diagnostic resource management tool that will improve ecological impact assessment and decision making about resource management in hillside watershed systems.

2. To quantify and predict in the short and long terms the impact of current and alternative management practices on soil erosion, sediment and water yields, and pesticide behavior within the Ovejas watershed using an interactive GIS/ watershed model.

This project proposal is a result of the CIAT "Project Identification/ Development of Area-Based Strategic Management Research", which was approved as a Special Project by BMZ in October 1992.

Abstract

Efforts to improve the use of fragile soils in the hillside ecosystem have been encouraging. Conservation measures to reduce erosion and maintain crop productivity have been researched on and off farms at the plot level. There has been relatively little research completed on the soil water balance component of this ecosystem and at the watershed level.

The use of a watershed model coupled to a geographic information system (GIS) will be invaluable for assessing the ecological impact of current and alternative land use practices on the watershed ecosystem and in identifying thresholds in vital biophysical processes that otherwise would not be readily perceived.

Currently, no GIS/watershed model operates in CIAT or in Colombia that can be used for spatial and temporal ecological impact analysis. The CIAT Hillsides and Land Use Programs, in cooperation with the Department of Plant Production in the Tropics and Subtropics, University of Hohenheim, therefore recommends this proposed research, which would last three years, with possible future extension. The budget would be US $333,720 for CIAT and US $307,800 for the University of Hohenheim.

Cooperating Partners:

The proposed project will be carried out jointly by:

1. Centro Internacional de Agricultura Tropical (CIAT), Colombia.

2. Institute for Plant Production in the Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany.

Names of Principal Scientists:

1. Senior staff from the Land Use Program at CIAT: Dr. William C. Bell, Land Use Program.

2. Senior Staff from the Hillsides Program at CIAT: Dr. Edwin Bronson Knapp

3. Prof. Dr. Bruce Allison, Institute for Plant Production in the Tropics and Subtropics, University of Hohenheim.

Names of Staff to be Financed:

1. ***CIAT staff:*** Directed by Dr. William C. Bell, Land Use Program

2. ***German staff:*** Post-Doctoral Scientist (3 years).

3. Two Diploma students, Germany
   M.Sc. student, Colombia

Budget *--in US Dollars:*

The total budget of the project is US$***641,520*** broken down as follows:

Budget	Year 1	Year 2	Year 3	Total
U. of Hohenheim	135,000	82,700	90,100	307,800
CIAT	142,800	108,840	82,080	333,720
Total Request	**277,800**	**191,540**	**172,180**	**641,520**

2.0 Background and Justification

Soil degradation is a threat to agricultural sustainability throughout Latin America

There is an urgent need to understand better the ecological impact of current and alternative practice on watershed dynamics

Soil degradation is currently a threat to agricultural sustainability in many Latin American countries, especially in the Andean region. Changing land use practices have apparently reduced the amount of arable farmland, because many farmers are now forced to cultivate crops on steep, infertile soils. Techniques to improve crop productivity, enhance erosion control, and increase water infiltration and water-holding capacity in tropical hillsides have been researched and incorporated into soil conservation practices in hillside farming systems. In the proposed project research site, this research endeavor has been the focus of cooperative research between the Centro International de Agricultura Tropical (CIAT) and University of Hohenheim, Stuttgart, Germany, on cassava-based cropping systems.

Collaborative CIAT-Hohenheim research has concentrated on characterizing the soil erosion process at the plot level for two Andean locations in Colombia (on and off station), where cassava has become a staple cash crop. Additional testing and evaluation of the potential of improved soil conservation and fertility management practices are being initiated together with the CIAT Hillsides Program. The cooperative CIAT/Hohenheim erosion research has provided insight into soil erosion process in cassava based cropping systems and the effect of soil conservation methods on productivity. However, the interaction between cassava-based cropping systems and other important components (coffee, perennial, and annual crops) needs to be assessed in order to better understand the ecological impact of current and alternative conservation practices on watershed dynamics.

A research area that has had relatively little directed focus is the effect of conservation measures and cultural practices on the soil-water balance components in the hillside ecosystems. The research completed to date has been at the plot level. The next logical step would be to move from plot level research (on and off farms) to ecosystem or watershed level research.

The proposed approach is a significant advancement over plot level research

The methods and results of this research will be relevant to the majority of Latin American hillside agroecosystems

One way to accomplish this would be through an interactive/coupled GIS/modelling approach. This proposed approach to resource management is a significant advancement over plot level research because:

- it can utilize any information available from plot level studies;
- it more effectively uses and analyzes all available data;
- the scaled up analysis places emphasis on a systems approach to resource management problems;
- systems scenarios can be run and analyzed quickly;
- it is time and cost effective; and
- it encourages interdisciplinary research.

The methods and results of this research should be relevant to the majority of the Latin American hillside agroecosystems. Generalization at this scale requires reducing reliance on statistical prediction for it is doubtful if the quantitative data exist or can be gathered for the whole of the Latin American hillside ecosystem. The GIS/Modelling decision-support tools developed for this study are innovative in that hypotheses related to the cost effectiveness of different sampling frames and the efficacy of compound and complex environmental indicators can be tested by experimenting with the system boundaries and variables during simulation runs. This type of analysis should benefit future study areas by identifying a few efficient sampling frames for a specific scale of study and providing a sense of the sensitivity of the model outputs to changing physical inputs such as soil characteristics or climate.

Based on the above and on the long-term research interests and needs in CIAT's Resource Management Research Division (Hillside and Land Use Programs), a research project focusing on the use of an interactive GIS/ watershed model is required. Further research needs to be

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interdisciplinary, and to holistically assess the effect of management practices on soil erosion, watershed hydrology and crop production in the short and long term at the watershed scale of analysis.

As a result of this strategic research, policy and decisions makers will be informed about the effects of soil degradation on productivity

One major contribution of CIAT's strategic research, with regard to land degradation in hillside farming/watershed ecosystems, will be to inform policy and decision makers concerned with land use issues about the effects of soil degradation on short- and long-term potential productivity and the potential benefits of alternative sustainable scenarios. At present, operational tools to assist decision makers require the development of methodologies which quantitatively assess this situation over time and space. Computer-based techniques for building interactive decision-support systems for multiobjective, multiuser land use planning represent a rapidly moving scientific frontier. It is important for the centers of the Consultative Group on International Agricultural Research (CGIAR) such as CIAT to develop a core competence in this new scientific area in order to effectively interact with advanced university based scientists from industrialized countries and to develop effective programs for information dissemination down to the farmer.

This project aims to provide a prototype diagnostic management tool for decision making

Currently, no such resource management tools are being used at CIAT for tropical Andean hillside farming systems. The purpose of this research is to provide a prototype diagnostic management tool for facilitating decision making among numerous cooperating institutions and interest groups, i.e. scientific institutions, policy makers, extension workers, and farmers.

The approach will be tested in detail for the Río Ovejas watershed

This approach needs to be tested in detail for one watershed. The Rio Ovejas was chosen because its physical characteristics are typical of many hillside farming areas in the Andes. In addition, an extensive infrastructure of governmental organizations (GOs) and non-governmental Organizations (NGOs) exists, which has collected a wide variety of data, making model testing and verification easier and allowing us to run many "what-if" scenarios. There are well over 100,000 watersheds in the region and obviously

An interactive GIS/ watershed model will be useful for the assessment of resource management and ecological impact

The research will help prioritize long term research thrusts and suggest long-term conservation solutions to critical sustainment problems

very few of them can spend over $1 million on a detailed study. The modelling process will allow us, with additional work, to extend our methodology in a cost-effective manner to those other watersheds and allow educated decisions to be made about the natural resource management of these areas.

The development of an interactive GIS/watershed model is needed to assess spatial and temporal resource management, predict crop production/environmental hazards and assess ecological impact . Furthermore, indicators of thresholds in biophysical processes, which are currently unknown and cannot be readily perceived, need to be established and correlated with observable phenomena (where possible). Finally, a usable understandable GIS output format is needed to show land use planners, policy makers, resource scientists, and local farmers the tangible benefits or serious damage that may result from land and soil management practices. This proposed project will aid in identifying critical sustainment problems, prioritizing long term research thrusts, suggesting conservation practices that offer long-term solutions and analyzing more thoroughly existing data.

3.0 Overall Project Objectives

The project purposes aim to improve the livelihood of the hill-farming community and the environmental quality of watershed systems in the Andean region

3.1 Goal

To improve the welfare of the hill-farming community and the environmental quality within hillside watershed systems in the Andean region.

3.2 Project Purpose

To develop a prototype diagnostic resource management tool that will improve ecological impact assessment and decision making about resource management in hillside watershed systems.

To quantify and predict in the short and long terms, the impact of current and alternative management practices on soil erosion, sediment and water yields, and pesticide behavior within the Ovejas watershed, using an interactive GIS/watershed model.

The **specific objectives** are:

1. To better understand relationships among variables that operate at plot and system levels so as to model and quantify complex watershed dynamics through study of the Ovejas watershed, Colombia.

2. To process information by using GIS and watershed modelling techniques from strategic research in the form of a decision support system (DSS). The information can be continuously updated to assist consensus building among stakeholders for formulating plans for agricultural land use and the environmental protection of watersheds, through a case study of Rio Ovejas.

3. To determine the impact of current and alternative management practices on soil erosion, sediment and water yields and pesticide behavior with subsequent effects on short- and long-term productivity and environmental quality.

4. To couple the Simulator for Water Resources in Rural Basins (SWRRB) model to the Environmental Systems Research Institute (ESRI) Arc Info Geographic Information System (GIS) to facilitate easier yet more complex spatial and temporal analyses of land use scenarios.

5. To cooperate with GOs, NGOs and farming groups in data and map exchange for the GIS database.

6. To train scientists and disseminate information about the methodology among decision makers at different levels.

3.3 Outputs

The proposed research has clerly defined outputs

The expected outputs from fulfilling the above objectives can be summarized as follows:

1. An interactive, state-of-the-art, computer-based DSS that builds analytical models of multistakeholder, multiobjective land use at the watershed level.

2. Interface between the SWRRB simulation model and GIS for a more effective DSS.

3. Applied methodology for modelling watershed dynamics.

4. Evaluation of land use practices on watershed water quality with regard to sediment yield and pesticide contamination.

5. Estimates of the effects of representative crop, pasture, and woodland use in the hillsides on the partitioning, regulation, and quality of water in hillside catchment water courses due to soil erosion.

The scientific components of the research will contribute broadly to the improvement of agricultural security in the project area

6. Establishing an effective link between researchers, farmers, and regional institutions so that useful information and viable technologies are better used and adopted.

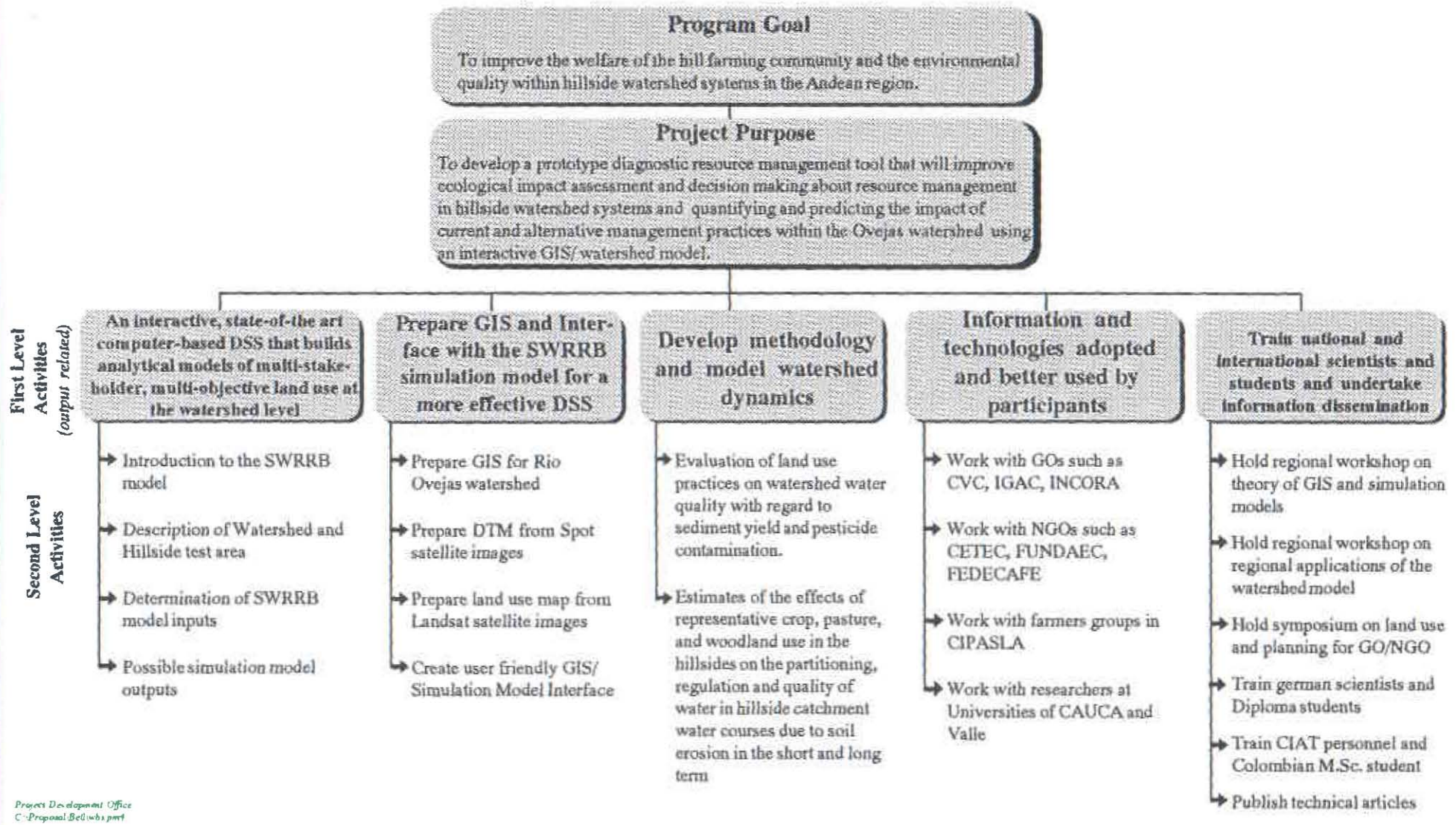
7. Trained national and international scientists and students.

The relationship between objectives and outputs is clarified in Figure 1.

The expected outputs from fulfilling the objectives represent the major components of the overall project strategy. Collectively, the scientific components contribute broadly to improving agricultural security, not only in the project area, but also potentially for Colombia and Andean hillsides in general. This proposed scientific endeavor results in the development of an interactive diagnostic tool that allows assessment of the ecological impact of management practices on watershed dynamics.

The outputs will contribute to the establishment of a more effective link among policy makers, land use planners, resource and environmental scientists, and farmers. Furthermore, contacts between scientists from industrializing and industrialized countries will occur throughout the duration of the project. The outcome of the project will provide an effective springboard for future cooperative interdisciplinary, interinstitutional projects that focus on issues that currently threaten local and national sustainability.

Figure 1. Work Breakdown Structure



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4.0 Work plan

The major activities and subactivities of the project as they relate to the project's outputs are graphically illustrated in Figure 1. The implementation schedule (Gantt chart), showing the commencement and duration for each main project activity is shown in Appendix A. Figure 2 shows the project organization for the technical reporting and financial management of this project.

The execution of the project will require a first phase of three years with a possible second phase for testing extrapolation of the model to additional watersheds. In collaboration with the Land Use and Hillsides programs at CIAT, German students and scientists will participate extensively in executing the project throughout its duration. The Land Use and Hillsides Programs will provide administrative and technical assistance for the project.

Colombian and German scientists and students will participate in the project

The methodologies and specific "on-farm" and "on-watershed" research activities to be implemented and conducted during the three years are outlined in more detail as follows:

4.1 Watershed Model Background and Description

4.1.1 Introduction

The SWRRB model was developed for the primary purpose of simulating the effects of management practices on ungauged rural basin hydrology, erosion, water and sediment yields, crop growth, and pesticide behavior.

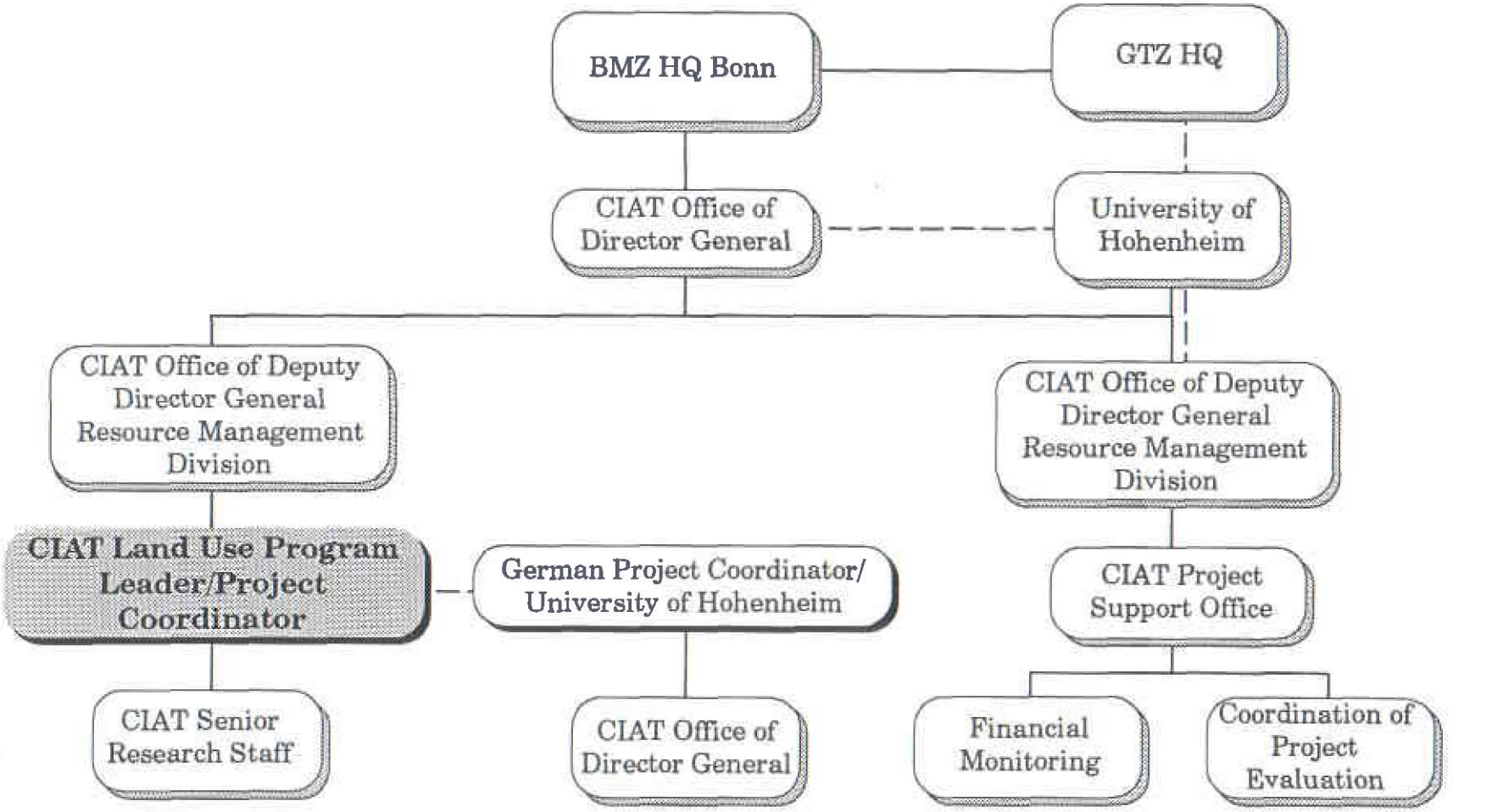
The SWRRB model selected for the project has clear comparative advantages

The SWRRB model was selected for this project because:

1. it is computationally efficient,
2. the required inputs are generally available or can be estimated by the model,
3. relates runoff to soil type, land use and management,
4. output is predicted separately for each microbasin (user defined), routed to obtain the total runoff for the entire watershed, and
5. long term (100 year) simulations are possible.

Figure 2

Project Organization Chart



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Project Development Office

The SWRRB model is a physically based model that has used much of the basic model structure of the CREAMS (chemicals, runoff, and erosion from agricultural management systems) (Knisel, 1980) and the EPIC (Shapley et al., 1990) models. The CREAMS model was modified for application to complex watersheds. The major modifications to the CREAMS model were:

- Improved methods for calculating peak runoff rate.
- A water flow and sediment routing (among microbasins) subroutine was incorporated.
- A weather simulation model was added to provide a method for long-term simulations (100 years).
- The effects of farm ponds and reservoirs on water and sediment yield can be determined.
- Simultaneous computations on several microbasins can be calculated.

The crop models (inclusive crop rotations), soil tillage and soil conservation practices (i.e., tied ridging and furrowdiking) subroutines from the EPIC were modified and integrated into the SWRRB model.

The SWRRB model has been field evaluated on geographically different watersheds

The SWRRB model has been field evaluated on geographically different watersheds (Arnold et al, 1990). The model gives good representations of the hydrology, erosion/ sediment yield, maximum annual peak run off rates, crop and range growth, and the effect of management decisions on water and sediment yields. The resulting SWRRB model is a comprehensive watershed model that can be used to evaluate the long term effects of current and alternative management systems.

The major components of the SWRRB model are:

- Hydrology: surface runoff, peak runoff rate, percolation, lateral subsurface flow, evapotranspiration, and transmission losses.
- Weather: long-term (100 years) precipitation, temperature, and solar radiation can be simulated with a minimum of 5 years of actual data.
- Flood routing.
- Sedimental yield and routing.
- Crop growth: potential growth, yield, and growth constraints.
- Tillage and residue.
- Pesticide behavior.
- Irrigation.

A detailed description of the model, output interpretation, sensitivity analysis, and model evaluation is given by Arnold et al. (1990).

The weather simulation model has been found inadequate for tropical weather systems. New research (Jones and Thornton, 1993) suggests using a third order markov chain with resampling for simulation to greatly improve accuracy. CIAT/IFDC (International Fertilizer Development Center) (Jones and Thornton) are continuing to refine their spatial model and this will be incorporated into the SWRRB model by Jones to improve accuracy for tropical areas.

4.1.2 Watershed and hillside farming test area

Within the existing framework of ongoing research activities in the CIAT Hillsides and Land Use Programs a suitable watershed site (Ovejas) was selected in the Cauca Region (*see* maps 1 to 5 in Appendix B). Test areas consisting of up to six plots in three typical hillside land transects (approximately 100 ha each) will be selected at three elevations (2,000 m, 1,700 m and 1,400 m) within the watershed. The watershed and hillside plots were selected because (1) Relatively good database for the watershed model and the GIS is available, (2) The region is agroecological diverse, and (3) Good accessibility exists for field research purposes.

The three elevation test areas will focus on the following crops:

1. High altitude (2,000-1,800 m) Pasture and agroforestry components

2. Medium altitude (1,800-1,600 m) Cassava, beans, maize, coffee, pastures and agroforestry components

3. Low altitude (1,600-1,350 m) Coffee, cassava/pastures and maize/fallow rotation

Conservation practices that will be investigated include contour barriers, legume cover crops, green manure crops, and conservation fertility management.

Maintenance and collection of data at the three hillside research on-farm sites will be the responsibility of the CIAT Hillsides Program (Drs. J. Ashby and B. Knapp). Data will be made available for the GIS and watershed databases throughout the duration of the project.

4.1.3 Determination of SWRRB model inputs

Model inputs have been determined jointly by CIAT and the University of Hohenheim

The SWRRB model inputs are detailed. However, based on the availability of existing satellite images and information from maps, and on completed, ongoing and published research at CIAT and University of Hohenheim (Cooperation with CIAT), the majority of the required inputs have been determined. The remaining inputs that drive the model will be field determined at the beginning of the project or will be monitored throughout the test period. The breakdown of duties for determination of inputs are as follows:

1. Hydrology (work group Dr. William Bell, CIAT). General watershed hydrology data, routing data (subbasin to watershed outlet), pond data (if required), and reservoir data (if required) will be either field determined or GIS calculated. The work will be done by a Research Associate Hydrologist (CIAT). We will also collaborate with the regional watershed authority, Corporación Autónoma Regional del Valle del Cauca (CVC), and the University of Cauca's Hydrobiology project who together are conducting an impact study of the Ovejas watershed.

2. Required soil inputs not already available will be determined by a Diploma Student (University of Hohenheim) as part of his/her diploma thesis graduation requirements. Additionally, soil and erosion data available from completed and ongoing CIAT/Hohenheim cooperative research will be used as inputs to the model where possible.

3. Crop data for the hillside farming test sites (work group Dr. Bronson Knapp, CIAT). Estimates will be available on loss of yield potential from soil quality degradation, and the effects on soil quality and crop productivity of soil improvement practices for the main crops.

4. Vegetation data (work group Dr. Bell, CIAT). The vegetation data will be obtained by image analysis of Landsat images. This analysis will be followed with ground truthing. A Colombian M.Sc. student from the University del Valle will do this work.

5. Pesticides. The CIAT Hillsides program will have a project in the Rio Ovejas study area jointly with the CIAT integrated pest management (IPM) working group to assess pesticide use and abuse, and evaluate IPM practices suitable for hillside farming systems.

6. Watershed model initialization will be completed by a Diploma Student (University of Hohenheim) as part of his/her diploma thesis graduation requirements.

7. Verification of all models inputs [postdoctoral (University of Hohenheim) and Prof. Dr. B.E. Allison].

Trial simulations will help determine if the inputs are representative of the watershed

Once all model inputs have been determined, trial simulations will be necessary to determine if the inputs are representative of the watershed. This phase will be an interwork group evaluation.

4.1.4 Model simulations

A complete description of all pertinent simulation output possibilities is beyond the immediate scope of this project proposal. We have therefore given examples that show the versatility of the model and they fit well with the overall CIAT Hillside and Land Use Programs. There is an urgent need to develop methodologies which spatially and temporally analyze homogenous and heterogenous landscapes both in the short and long terms. The interactive GIS/SWRRB model is one such methodology. Once the model inputs have been defined, the watershed and microbasin simulations outputs are:

- Water and sedimentation yield.
- Soil erosion.
- Percolation.
- Root zone water balance.
- Crop growth and yield (grain crops, legumes, roots and tubers)

- Runoff.
- Pesticide behavior.

The SWRRB calculates each output parameter for individual microbasins and that output is routed to neighboring microbasins, depending on the natural drainage. This type of simulation will ultimately be useful in evaluating the ecological impact of different management decisions on the watershed. The model simulations will be initialized on five microbasins within the watershed (Diploma Student, University of Hohenheim) (Map 6, Appendix B). The German postdoctoral will then be responsible for the remaining microbasin/watershed simulations.

The model will permit the evaluation of the ecological impact of different management decisions on the watershed

4.2 Preparation of the GIS and Integration with the watershed model

The research program under this topic aims at creating a GIS for the Rio Ovejas watershed by using satellite imagery, air photos, topographic maps and other relevant maps such as soils, vegetation, geology, climate, hydrology, and transport, supplemented by field data where necessary. The SWRRB model will be used for modelling the watershed dynamics.

Programs will then be written to interface the SWRRB with the ESRI Arc Info GIS system.

The Augustin Codazzi Geographic Institute (IGAC) is working closely with us on this and has supplied us with air photographs and topographic maps of the watershed. The CVC (Corporación Autónoma Regional del Valle del Cauca) has also supplied us with various thematic maps of the area such as historical land use and population which we will incorporate in the GIS.

The following describes the tasks for this section in greater detail:

4.2.1 Preparation of the GIS for the Rio Ovejas watershed

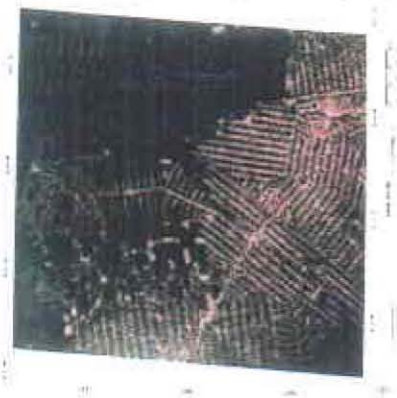
The GIS will store all maps, air photos, satellite images, and images in digital format with their attributes in an associated relational database.

The ESRI Arc Info GIS will be used for the GIS. Data will be stored in an associated Oracle relational database. The Erdas image analysis system with the ESRI live link will be used for image mapping and interpretation. All will reside on a Sun 2000 server with access through Sun Sparc 10 work stations over a 100 mbs fiber distributed data interface (FDDI) ring. *(See Appendix E)*

Colombian 1:10,000 topographic maps will be used to build the database where possible. In the small areas where 1:10,000 mapping is not available, 1:25,000 maps will be used. These maps will be hand digitized or scanned and vectorized (using Cadcore or Arc Scan) as appropriate and a base map will be built of the watershed area, showing all contours, spot heights, hydrography, roads, and settlements. A digital terrain model (DTM) of the watershed will be constructed. Slopes will be derived from the DTM. Because of the importance and sensitivity of the SWRRB model to slope, these slopes will be compared with slopes derived from stereo spot imagery (*see* 4.2.2) and to field samples collected using the "Total Station" to create the most accurate slope map possible.

The "Total Station" is a theodolite, which can accurately measure horizontal and vertical angles, and has built-in, electronic, distance-measuring equipment. This allows in-field verification of elevations and slopes calculated from 1:10,000

Measurement methods will be compared according to their accuracy and cost



topographic maps of unknown accuracy, and from digital orthophotography from stereo spot imagery. Comparison of these results will allow us to pick the best method with respect to accuracy and cost.

All other appropriate maps of soils, geology, transportation etc. will be digitized into the GIS. Field data will be collected, using Sony portable global positioning satellite system (GPS) receivers to facilitate their location to within 30 to 50 meters for subsequent entry to the GIS. Photographs of soil profiles, erosion, and land use will also be located, using GPS, and scanned into the GIS database on the Sun server for easy extraction, using the GIS.

The purchase of a work station for the University of Hohenheim will enable Arc Info GIS files and overlays to be worked on at Hohenheim. This purchase will facilitate the data analysis process. Professor Dr. Bruce Allison currently does not have this capability.

4.2.2 Analysis of satellite images

1. Prepare DTM

Stereo panchromatic Spot Image satellite images will be acquired for the Ovejas watershed to facilitate the construction of a digital terrain model accurate to < 10 meters in the horizontal and < 17 meters in the vertical. GPS receivers will be used to establish suitable ground control. The Erdas digital orthophotography module Orthomax will be used with a Sun work station to carry out this mapping. Other data such as roads and rivers will be extracted as appropriate. Checks on elevations and slope will be made with the total station while positional accuracy will be verified, using GPS technology to < 1 meter.

2. **Prepare Land Use Map**

Seven-band Landsat Thematic Mapper imagery will be acquired for the Ovejas watershed. Image analysis will be performed to extract land use types, using the Erdas software. One recent scene will be acquired, as well as one historical scene, to allow us to look at land use change. The classified image data will be transferred to the GIS for analysis.

Research outputs will enable decision makers to choose appropriate interface and level of detail

4.2.3 Create GIS model interface

The GIS/Model interface will be written so that data can be extracted from the Arc Info vector coverages of the area and transparently converted into a grid-based raster system in Arc Info. These data will then be passed transparently to the SWRRB model, which is also grid based and referenced to the same real world coordinate system. Simulations can then be run, using these parameters and any other data in the Oracle database. Thesimulation results from the model will also be able to be passed back to the Arc Info vector coverages for display and further querying and analyses.

The real power of the system will lie in the user interface. Bell (1992) has extensive experience in preparing easy-to-use menu-driven interfaces to generate complex, yet flexible, queries transparently. Scientists and decision makers will be able to choose an appropriate interface and an appropriate level of detail. Parameters can be readily passed back and forth between the GIS coverages and the SWRRB model for processing and subsequent display on the GIS. The querying system and display capabilities will be designed to make the system usable by scientists and policy makers who have no computer experience.

4.3 Model applications and interpretation

The interactive GIS/SWRRB model can be applied in numerous ways to quantitatively assess the dynamic status of the hillside farm/watershed ecosystem and to determine downward, static, or upward trends related to sustainability. In our analysis we propose to investigate:

- The long- and short-term changes in crop productivity as influenced by soil erosion.
- The interaction between runoff, erosion, and sedimentation (in the microbasin and the watershed) and soil type, vegetative cover, and management practices (current and alternative).
- The interaction between land use practices and watershed water quality in the short and long terms.
- The long- and short-term changes in crop productivity as influenced by current and alternative management practices.

The assessment will create a better link between agencies concerned with land issues and resource management

These four points do not comprise a comprehensive list of application possibilities but do offer insight into pertinent issues that need to be addressed in the CIAT Hillside and Land Use Programs. Once these four areas have been investigated, a baseline for assessing the potential benefits of new management strategies and determining future research priorities will have been achieved. Furthermore, this type of assessment will better create a link between planning/policy agencies concerned with land use issues and agricultural/ environmental scientists.

Ultimately an environmental impact statement can be formulated for the watershed. The overall analysis and interpretation will be the primary focus of work for the German postdoctoral. However, this section will be coordinated among the Hillside (CIAT), Land Use (CIAT), and Soil and Water Management (Hohenheim) Work Groups.

4.4 Project management

Project management will be done by Dr. William C. Bell who has extensive experience in this area. Microsoft Project will be used for tracking tasks and the budget.

4.4.1 Prepare/submit progress reports to donor

Annual reports will be filed for the first two years.

4.4.2 Submit end-of-project report to donor

. A final report will be submitted at the end of the third year.

4.5 Description of the River Ovejas watershed

4.5.1 Study area characteristics and natural resource use

See Maps 1 and 2 in Appendix B.

The headwaters of the Ovejas River are located 3000 m above sea level (m.a.s.l.) in the rocky reaches of Pitayó in the municipality of Silvia, Department of Cauca in southwest Colombia. The river empties into the Cauca River at 1100 m. a.s.l. just below the Salvajina hydroelectric dam. Major subcatchments are the Ovejas River, Mondomo River, Pescador River, and the Cauca River. A major study and data collection area for a consortium of GOs, NGOs and the CIAT Hillsides Program is the microcatchment area of the Cabuyal River *(Map 6, Appendix B).*

The Ovejas catchment (106,000 ha) is comprised of six administrative districts called municipalities: Caldono, Piendamó, Morales, Santander, Buenos Aires, and Silvia with 37%, 12%, 16%, 12%, 8% and 16% of the area, respectively. The total population of the catchment is about 85,000 of which 40% are located in the main urban centers of the municipalities.

Geomorphologically, three topological zones are recognized: (1) zone of very abrupt escarpments, generally between 2,000-3,000 m.a.s.l. occurs in the highest part of the watershed. (2) The peneplain of Popayán with rolling, dissected terraces of low relief is found between 1,400-2,000 m.a.s.l.. The piedmont alluvial plain comprising the lowest part of the catchment occurs between 1,100-1,400 m.a.s.l..

The principal life zones according to the classification of Holdridge are: premontane dry forest, subtropical humid and very humid forest, and very humid montane and low montane forest.

The soils of the area have been surveyed in some detail and classified into 19 mapping units at the level of associations. The soils are generally young with weak development. Seventy-seven percent of the soils are classified as Inceptisols and another 15% as Entisols. Information exists regarding formation, fertility levels, effective depth, and erosion hazard (IGAC, 1976). Also available are hundreds of soil laboratory analyses that have been carried out over the past 20 years. These analyses have yet to be systematically evaluated at a landscape scale.

The distribution of slopes according to total area and percent area are found in Table 1 (CVC, 1980).

Table 1

Distribution of slopes according to total area and percent area

Class	Slope	Area (ha)	%
I	0-12	35,628	34
II	12-25	12,975	12
III	25-50	11,932	11
IV	50-100	3,437	3
unclassified		42,028	40

Accelerated interrill, rill, and gully erosion are common problems in the area, and in the upper parts of the Ovejas River, landslides are common. The soils on these very steep slopes are mainly Andepts, which are not cohesive. This, in combination with errosive tropical rains and uncontrolled and unadapted land use, is causing accelerated soil degradation (*see* Map 4, Appendix B).

CIAT and the University of Hohenheim have collaborated productively since 1987

Since 1987, a cooperative research project between Hohenheim University and the CIAT Cassava Program and supported by BMZ/GTZ (German Agency for Technical Cooperation) has resulted in characterization of the relationships between different cassava management practices, erosion, and productivity, and has attempted to quantify the factors of the universal soil loss equation.

The deterioration of the natural resource base is associated with the requirements of the type of land utilization and land qualities. According to local knowledge, large- scale clearing of the primary forest began in 1940. Between 1940 and 1970 the production of high quality cassava starch grew rapidly.

In 1940, coffee was also introduced and soon developed into a major export crop. Recently, however, a combination of low international prices, excess inventories, and the spread of "broca", a devastating insect that attacks the coffee berry, led to the perennial coffee crop being replaced by annual crops. Around 1985, a pilot agroindustrial project was initiated to promote the perennial crop, sisal, the fiber of which was to be made into sacks for the coffee industry. Unfortunately, the circumstances that befell the coffee industry have derailed the project.

The trends of degradation of the natural resource base in the Ovejas River watershed have not been scientifically documented. Nevertheless, more than 90% of the population in the Ovejas River catchment generate income from agricultural, livestock and forest products including wood fuel. Table 2 shows the growth of population and family units in the Caldono municipality.

Table 2

Growth of population and family units for the municipio of Caldono.

Year	Population [1]	Families [2]	Ha/family
1920	6,472	1,360	30
1930		1,707	24
1940	10,272	2,143	19
1950		2,691	15
1960	18,296	3,378	17
1970	21,082	4,241	10
1980	30,000	5,323	8
1990		6,683	6

[1] Population from census of 1918, 1938, 1964, 1980

[2] Calculated on the basis of a population growth of 2.3% and 5 persons per family.

Local NGOs, (including farmers' groups) and GOs, together with CIAT have formed a consortium to addres issues of sustainable resource use

What is obvious from Table 2 is that the population has grown rapidly. The question that must be addressed by the residents of the Ovejas River watershed is whether agriculture, livestock, and the forest product industries will be viable income-generating industries in the future. There is a strong desire on the part of the local population and locally involved development organizations to look for answers. Some of the local GOs and NGOs, including farmers' groups, together with CIAT, have formed a consortium of 18 agencies, the Consorcio Interinstitucional para Agricultura Sostenible en Laderas (CIPASLA), to address issues of sustainable resource use. What follows is a brief introduction to some of the collaborating institutions of CIPASLA.

4.5.2 Collaborating institutions

- **CVC** (Corporación Autónoma Regional del Valle del Cauca)

  The CVC is a regional, governmental organization responsible for the management of natural resources (mainly soils and water) in the upper Cauca Valley, including the watersheds of the affluents. The CVC creates and provides information in areas of mapping of actual and potential land use and soil maps. Work is also done in the area of rural education and technical assistance on natural resources management and conservation.

  In 1992, a formal agreement was established among the CVC, CIAT, and others to test, multiply, and validate soil conservation technology in different watersheds. One professional of the institution was appointed to develop these activities in cooperation with the consortia. Cooperation with the CVC is given priority because of its infrastructure, official mandate and its influence on regional environmental policies.

  Main contact: Dr. Juan Gabriel Casas, Director of the Division of Natural Resources.

Local NGOs will take part actively in the project

- **CETEC** (Corporación para Estudios Interdisciplinarios y Asesoría Técnica)

The CETEC is a nongovernmental organization working with rural communities in the northern Cauca Department. It aims to develop small-scale, rural, cassava-based industries and ecologically sound, sustainable farming systems, based on the use of local resources. Studies on the efficiency of new technologies, support of farmers with credit, technical assistance, and field days on specific topics form part of their program. They also cooperate in conducting field trials on erosion measurement plots with different cassava cropping systems. They are also testing cover legumes and other materials from CIAT on their "Green Farm" in San Antonio. Cooperation with CETEC is informal but so far very uncomplicated and efficient. Working so close to the farmers offers good perspectives for continued testing and transfer of technology.

Main contact: Engineer Miguel Serrano

- **FUNDAEC** (Fundación para la Aplicación y Enseñanza de las Ciencias)

The FUNDAEC is a private Foundation working everywhere in Colombia in rural education and development. FUNDAEC gives credit to farmers who participate in specific training courses, i.e., cassava production. The preparation of extension leaflets and other teaching materials also forms part of their program.

FUNDAEC will cooperate with the project to develop of sustainable land use systems and by taking part in the formal agreement with the CVC. Cooperation with CIAT started in April 1992 and FUNDAEC has set up trials with improved cassava cropping systems and the adoption of soil cover/ forage legumes in Mondomo and Pescador.

Main contact: Engineer Martin Präger

- **FEDECAFE** (Regional Office at Santander de Quilichao) will cooperate with the project to find ways of establishing new coffee plantations on hillsides with less erosion by integrating live barriers, legumes, and food crops such as plantains, beans, and cassava in the initial stage of development. Combining profitability with sustainability was the main objective of collaborative trials with CIAT, which started on three sites in September 1992.

  Main contact: Dr. Senen Suárez.

- **INCORA** (Instituto Colombiano de la Reforma Agraria)

  The national land reform institution maintains contacts with farmers' groups who received land from the institution. They are a useful agency for help in contacting local farmers.

4.6 Participation in project evaluation

The project will have both internal and external reviews

There will be both an internal and external review of the project. In the second year we will invite one of the SWRRB model designers to review our work and suggest improvements. We will follow this up in the third year with a formal review, suggestions for further improvement, and, if appropriate, follow up research. An internal review will evaluate effectiveness issues, training courses and the workshop.

5.0 Training Program and Information Dissemination

Training of local GO and NGO, as well as CIAT and German scientists is a key element of this project

Training of regional GO and NGO staff, as well as CIAT and German scientists, is an integral part of this proposal. We will run two workshops, a symposium, and train German and Colombian scientists, the details of which are discussed below.

5.1 Workshops and publications

5.1.1 Regional workshop on the theory of GIS and simulation models

The first workshop will introduce participants to the theory of GIS and simulation models in general and to the SWRRB model, particularly as applicable to natural resource management in Andean hillsides. The model assumptions and types of data required for input will be discussed, as well as ways of estimating data when they are missing or inadequate. Example datasets will be accessed, management scenarios will be simulated interpreted and discussed.

5.1.2 Regional workshop on the regional applications of watershed models

The second workshop will be a hands-on applied workshop for scientists and environmental managers who wish to apply modelling and GIS to their specific area. Participants will be taken through the entire process step by step on computers in our training laboratory. Assumptions, alternatives, sensitivity, and outputs will be discussed.

5.1.3 Symposium on land use and environmental planning for GOs and NGOs

The project includes a symposium for policy and decision makers

This workshop is aimed at key policy makers in the region from agencies such as the CVC and IGAC, and NGOs such as CETEC, FUNDAEC, and FEDECAFE. It will discuss opportunities for using GIS/modelling techniques as a decision support system to aid in consensus building among stakeholders for formulating plans for agricultural land use and the environmental protection of watersheds.

5.1.4 Publication of technical articles

The research findings will be made available through publications

We expect to publish material on an annual basis and will disseminate the information at conferences and in conference proceedings.

5.2 Training of German scientists

CIAT's extensive GIS expertise in natural resource management will be transferred to Hohenheim where there are strong natural resource management modelling skills and emerging GIS skills. Dr. Bell will work closely with Hohenheim to facilitate this.

5.2.1 Postdoctoral fellow (Germany) watershed modelling (duration of project)

The 3-year project period will allow the postdoctoral fellow to gain state-of-the-art experience in GIS methodology and enhance his/her overall modelling background. This opportunity will allow the individual to seek an international position, e.g. within the CGIAR or to pursue an academic position. Additional experience in publication writing is anticipated.

Justification for postdoctoral staff: The proposed project is for 3 years. It is absolutely essential to place an individual in this position who already has acquired skills in computer modelling and simulation, quantitative methods, and field methods associated with collecting and determining model inputs. The training period required to elevate a doctoral candidate to the level necessary for this project is not realistic.

5.2.2 Diploma thesis (planned)

Soil physical characteristics of the Ovejas watershed

5.2.3 Diploma thesis (Planned)

Initialization of the SWRRB watershed model for five microbasins in the Ovejas watershed.

5.3 Training of Colombian personnel

The strong natural resource modelling skills from Hohenheim, along with CIAT's GIS skills will allow a large number of Colombians to be trained in GIS/modelling at the watershed and regional scales through interaction with the scientists and through two workshops and a symposium. In addition, a Colombian M.Sc student will conduct vegetational analysis, using satellite imagery.

Colombian scientists will receive training on the techniques used throughout the research

5.3.1 Enhancement of expertise of CIAT Land Use personnel in GIS/remote sensing/ modelling

At present, no CIAT personnel has the capability of performing integrated GIS and modelling analyses, although this is recognized as a necessary skill. This project will allow us to train several Associates (M.Sc. level) in the methodology. Our research associates and assistants have limited expertise in remote sensing and this project will allow our people to gain solid experience in this area. In addition, our systems analysts and designers, as well as our Arc Info AML programmers, will develop skills in this emerging and vital area. In the future, this training will be exported from the Land Use Program within CIAT to the other Natural Resource Management programs and the commodity programs such as Savannas and Hillsides and Beans, Rice, Cassava, and Tropical Forages, all of which have requested our help to set up a similar GIS/ modelling system. As such, this capability is strategic to CIAT. The links with Hohenheim will prove invaluable in the area of modelling .

5.3.2 Colombian M.Sc. student

A Colombian M.Sc. student from the University del Valle will conduct research on vegetational mapping, using Landsat imagery.

6.0 Dissemination of information and databases

CIAT and the collaborating German Institute for Plant Production in the Tropics and Subtropics at the University of Hohenheim, Stuttgart, support and abide the concept of complete access to research results.

All generated information and viable technologies achieved by the project will be disseminated and made available to target groups without restriction. In this kind of project, none of the expected results would be patentable.

7.0 Budget

Improving Natural Resource Management for an Andean Watershed using an Interactive Coupled GIS/Watershed Model

TABLE 3 : BMZ – Improving Natural Resource Management for an Andean Watershed using an Interactive Coupled GIS/Watershed Model
Proposed budget (In US$ dollars)

LINE ITEM	YEAR 1	YEAR 2	YEAR 3	TOTAL
REQUESTED FOR CIAT				
1.0 PERSONNEL				
Research associate	20,472	21,496	22,570	64,538
Field research assistant	10,200	10,710	11,250	32,160
M.Sc Student – University of Valle	14,350	15,860	–	30,210
Short term consultant	–	5,200	3,400	8,600
Total personnel	**45,022**	**53,266**	**37,220**	**135,508**
2.0 TRAVEL				
Local	15,000	3,500	2,500	21,000
International	4,000	4,200	4,400	12,600
Total travel	**19,000**	**7,700**	**6,900**	**33,600**
3.0 MATERIALS AND OPERATIONS				
Supplies	3,000	3,000	3,000	9,000
Plotter supplies	3,000	3,200	3,400	9,600
Laboratory analysis	20,000	10,000	–	30,000
Vehicle maintenance	4,500	4,800	5,100	14,400
Communications	1,500	1,600	1,700	4,800
Total materials and operations	**32,000**	**22,600**	**13,200**	**67,800**
4.0 TRAINING AND INTERINSTITUTIONAL COOPERATION				
Training research assistant and collaborators	1,500	1,500	2,000	5,000
Operational costs CVC cooperation	5,000	5,000	5,000	15,000
Cooperative funds for on–watershed research activities	2,500	2,500	2,500	7,500
Total training and instit. cooperation	**9,000**	**9,000**	**9,500**	**27,500**
5.0 CAPITAL (With detailed justification)				
Total station – Complete survey station	15,000	–	–	15,000
Total capital	**15,000**	–	–	**15,000**
6.0 INDIRECT COSTS	24,004	18,513	13,364	55,882
TOTAL FOR CIAT	**144,026**	**111,079**	**80,184**	**335,290**

TABLE 3 : BMZ – Improving Natural Resource Management for an Andean Watershed using an Interactive Coupled GIS/Watershed Model
Proposed budget (In US$ dollars)

LINE ITEM	YEAR 1	YEAR 2	YEAR 3	TOTAL
REQUESTED FOR HOHENHEIM UNIVERSITY				
1.0 PERSONNEL				
Postdoctoral fellow	63,600	67,400	71,500	202,500
Diplom soil characterization	3,000	–	–	3,000
Diplom model preparation	3,000	–	–	3,000
Total personnel	**69,600**	**67,400**	**71,500**	**208,500**
2.0 TRAVEL				
Postdoctoral	3,500	–	3,900	7,400
Supervisor	4,400	4,500	4,600	13,500
Diplom students	0 [1]	–	–	–
Total travel	**7,900**	**4,500**	**8,500**	**20,900**
3.0 RESEARCH AND OPERATIONS				
Remote sensing images				
Spot panchromatic stereo pair	8,000	–	–	8,000
Spot images from 1980s	4,000	–	–	4,000
2 sets landsat TM scenes	16,000	–	–	16,000
Supplies and services	3,500	3,600	3,700	10,800
Literature, translations, publications, copies	2,000	3,000	2,000	7,000
Student helper	4,000	4,200	4,400	12,600
Total research and operations	**37,500**	**10,800**	**10,100**	**58,400**
4.0 CAPITAL				
Workstation	20,000	–	–	20,000
Total capital	**20,000**	–	–	**20,000**
TOTAL FOR HOHENHEIM UNIVERSITY	135,000	82,700	90,100	307,800
GRAND TOTAL	279,026	193,779	170,284	643,090

[1] Provided by University of Hohenheim

GIS1–PPSED
05–Aug–93
PROPOSED

ABRAHAM E. ESPINO
FINANCIAL CONTROLLER

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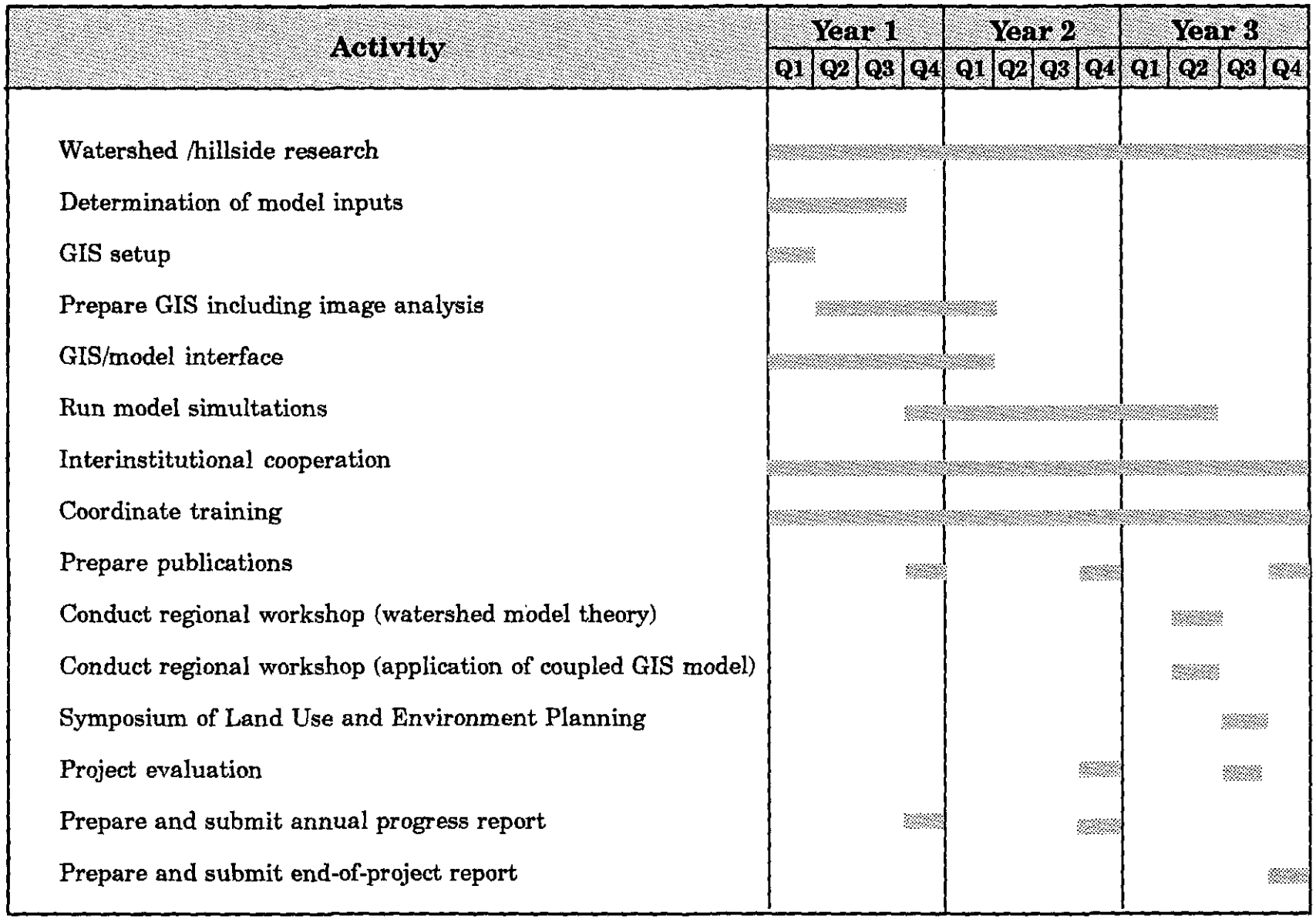
Appendix A: CHRONOGRAM OF PROJECT ACTIVITIES BY YEAR



Appendix B

Maps of Project Research Location

Map 1. Study area within Colombia.

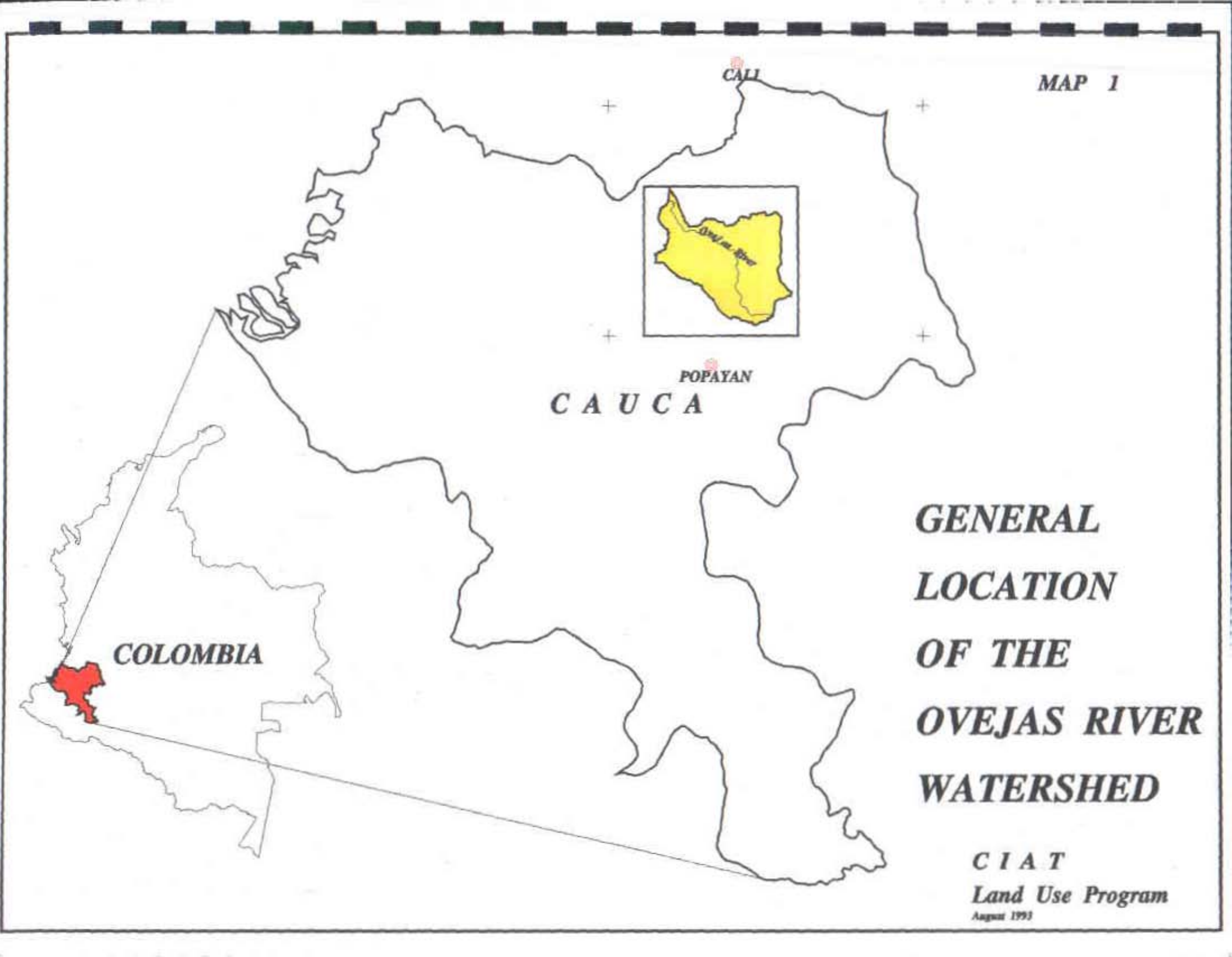
Map 2. Detailed map of the Ovejas River watershed.

Map 3. Population and ethnic composition of Ovejas watershed.

Map 4. Erosion in Ovejas watershed.

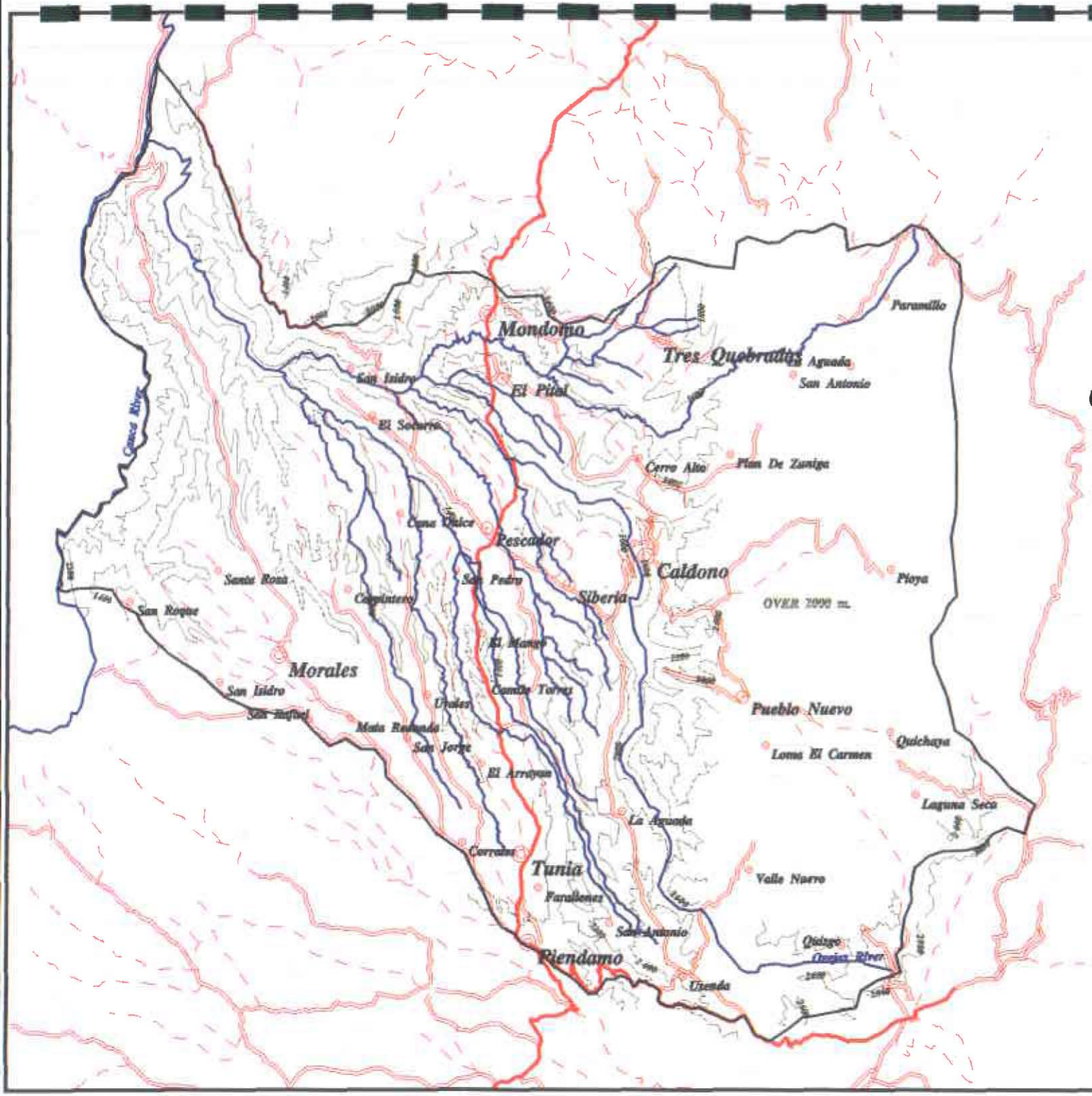
Map 5. Climatic zones of Ovejas watershed.

Map 6. Rio Ovejas Microwatershed.


MAP 1
CALI
POPAYAN
CAUCA
COLOMBIA
GENERAL
LOCATION
OF THE
OVEJAS RIVER
WATERSHED
CIAT
Land Use Program
August 1993

MAP 2

DETAILED MAP OF OVEJAS RIVER WATERSHED



LEGEND

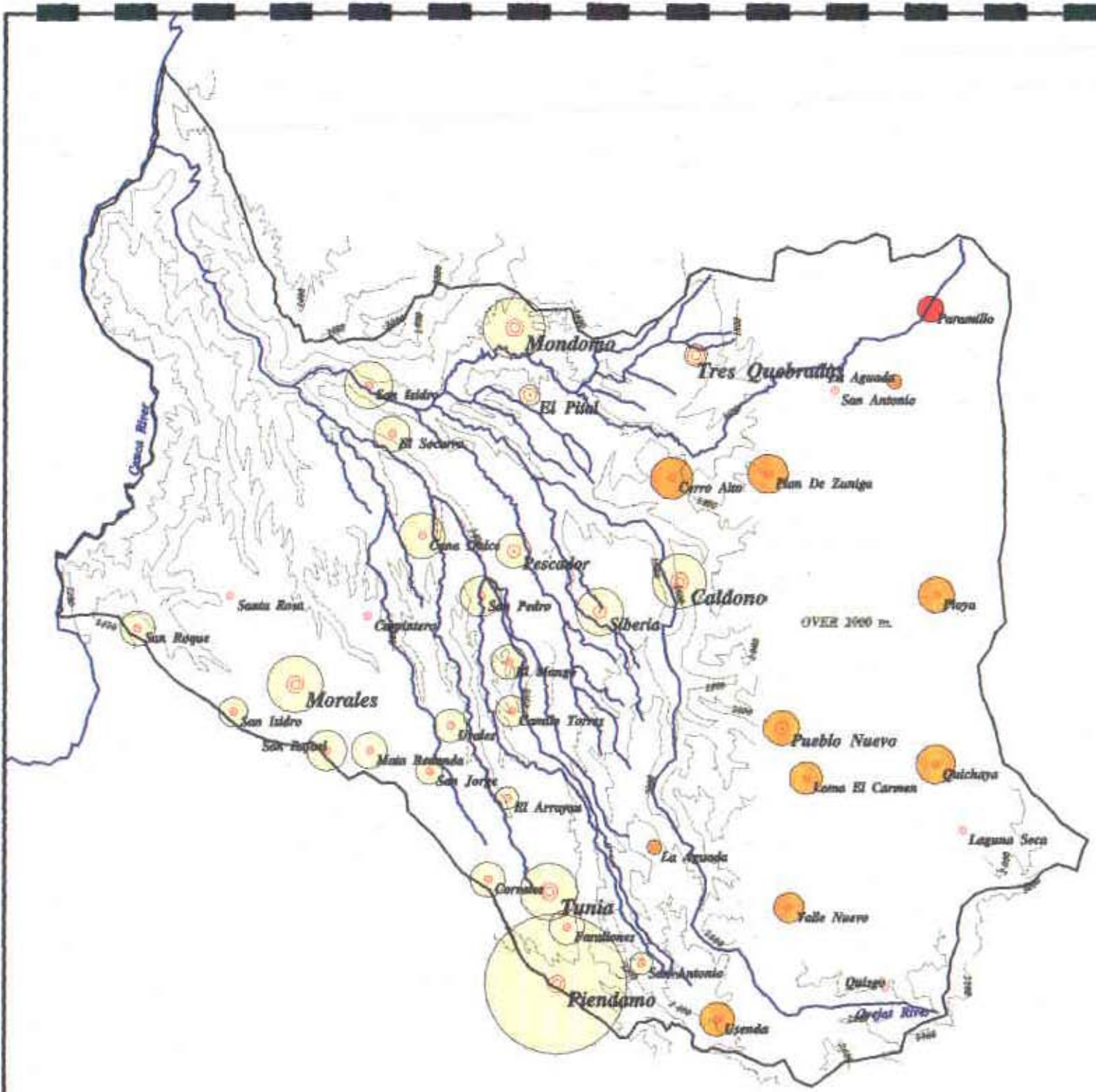
- Rivers
- Paved Road
- Gravel Road
- Track
- Watershed boundary
- Contours
- Towns

CIAT
Land Use Program

August 1993

MAP 3

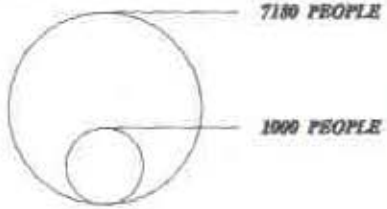
POPULATION AND ETHNIC COMPOSITION OF OVEJAS WATERSHED



LEGEND

- MESTIZO
- INDIGENOUS
- MULTIETHNIC

SIZE OF THE CIRCLES IS PROPORTIONAL TO POPULATION

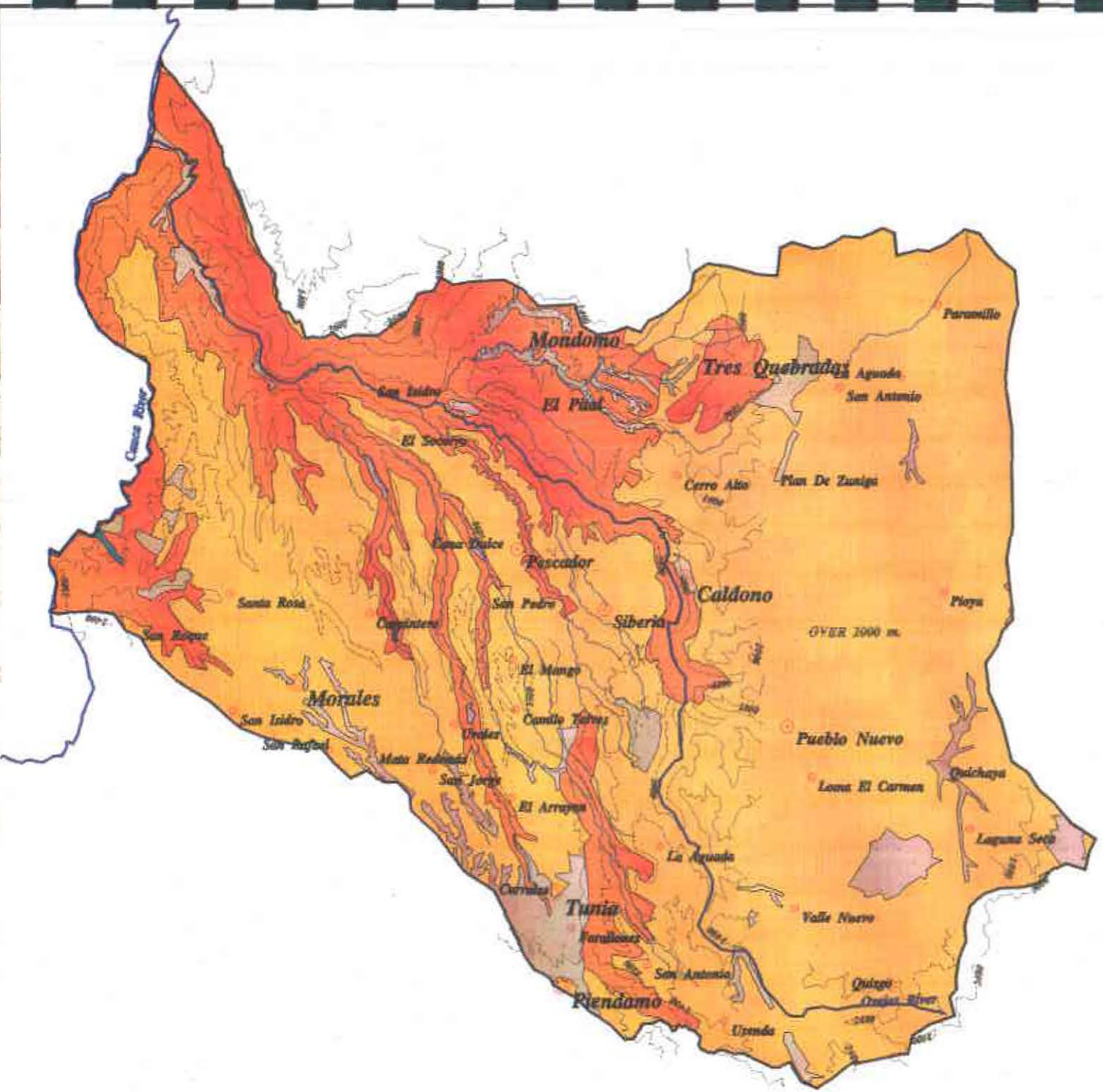


CIAT
Land Use Program

August 1993

MAP 4

EROSION IN OVEJAS RIVER WATERSHED



LEGEND

- WITHOUT EROSION
- SLIGHT
- MODERATE
- SEVERE
- VERY SEVERE

C I A T
Land Use Program
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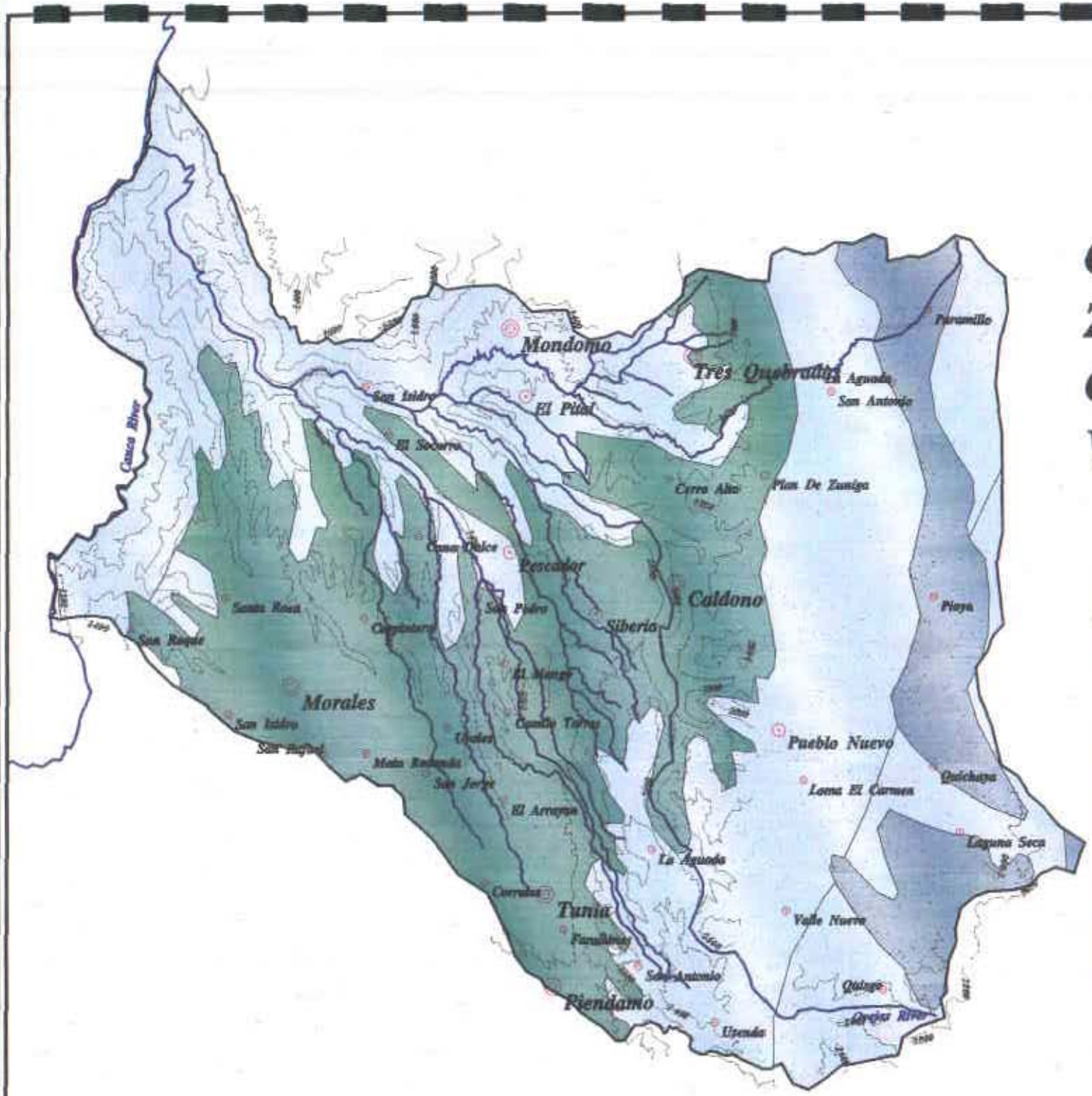
MAP 5



CLIMATIC ZONES OF OVEJAS WATERSHED

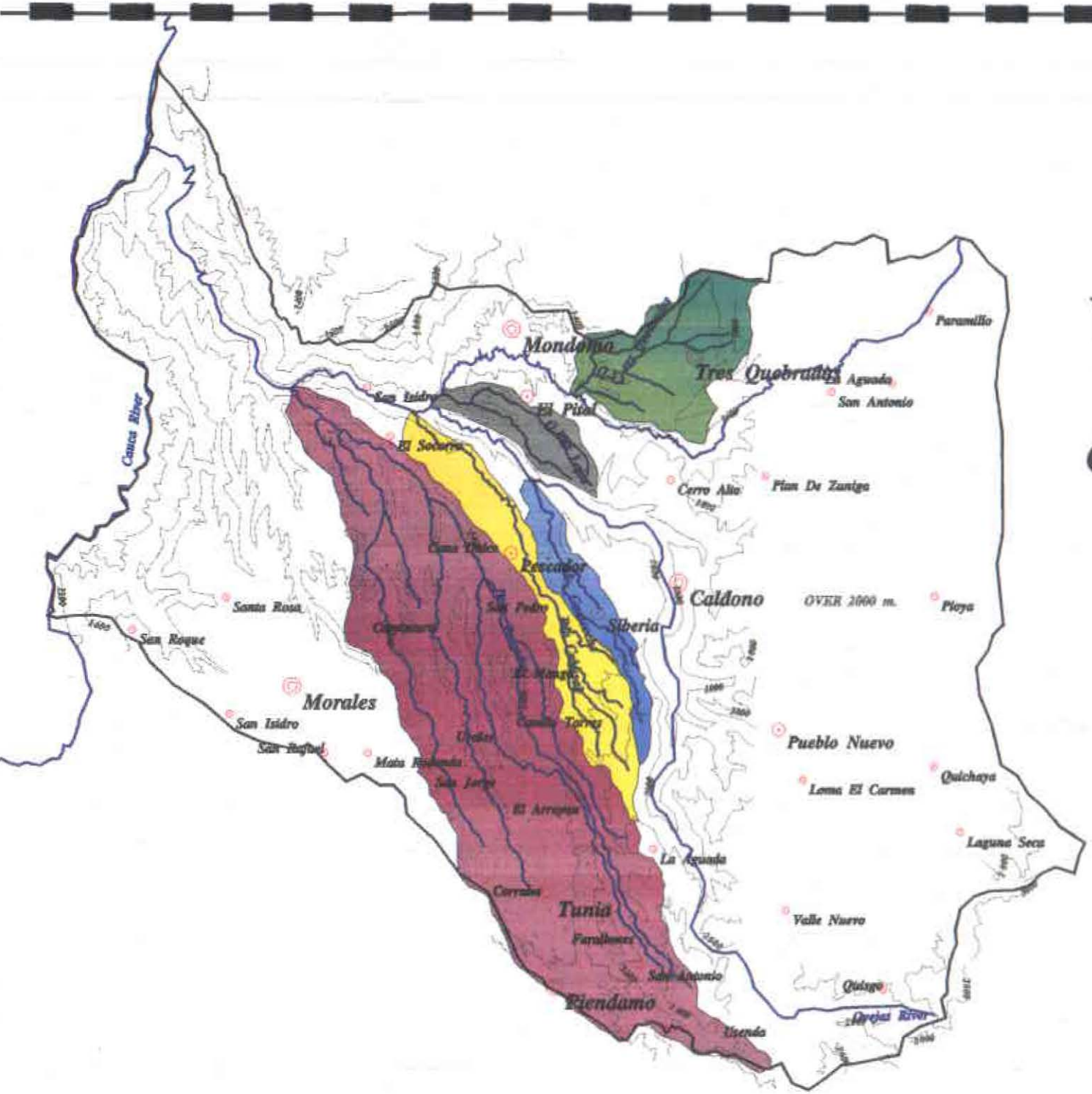
LEGEND

- Bleak Plateau
- Very cold/humid
- Moderatly cold/Very humid
- Mild/Very humid
- Moderatly hot/Very humid
- Hot/Sub-humid

CIAT
Land Use Program
August 1993

MAP 6

MICRO - WATERSHEDS OF THE OVEJAS RIVER



LEGEND

- Q. Tres Quebradas
- Q. Las Lajas
- Rio Pescador
- Rio Cabuyal
- Q. Guaicoche

C I A T
Land Use Program

August 1993

Appendix C-1

CIAT C.V.

Centro Internacional de Agricultura Tropical

Name:	**William C. Bell**
Position in Project:	Project Coordinator
Citizenship:	Canadian
Country of Residency:	Colombia
Education:	Ph.D. Geography-Micro-Climatology/Applied Computing University of Edinburgh, 1974 M.A. Major: Soil Science, Biogeography, Surveying. University of Edinburgh, 1966.
Languages:	English -Native Spanish -Conversational
Management & Administrative Experience:	**Centro Internacional de Agricultura Tropical** (CIAT) Cali, Colombia GIS and Database Specialist, Land Use Program, 1992 to present **University of Georgia.** Institute of Government and *Government Information Systems Laboratory* Director. 1991 to 1992 **Linnet Graphics International**, Winnipeg Vice-President Operations 1989 to 1990 **University of Winnipeg** Land Information Systems Laboratory Director. 1987-1990

University of Manitoba
Plant Science Department
Adjunct Professor
1979-1985

University of Winnipeg
International Contracts Officer
1985-1987

University of Winnipeg
Lecturer to Professor
1966-1990

International Research Experience:

Project Manager of 3 Canadian International Development Agency Projects
1983-1988 in Egypt

- In Resource Management, Applied Computing and Remote Sensing.
- As University of Winnipeg International Contracts Officer, I prepared numerous projects on Asia and the Middle East.

Project Management Experience:

Received and supervised $13 M of contracts in last 8 years.

Relevant GIS contracts include:

1992	Georgia Department of Transport. GIS Base map preparation $1,800,000
1992	Forsyth County assessment map $140,000
1991	Cobb County GIS System, Phase I $1,589,000
1990	City of Winnipeg Phase II. Assessment mapping $450,000
1989-90	Project Manager Manitoba Land Related Information System Phases I - III $4,000,000

Teaching and Thesis Supervisory Experience:

Supervision of various graduate and undergraduate thesis in Agriculture, Engineering and Geography.

Selected Publications

Bell W. C., 1992. GIS design document for Georgia Department of Transport.

Bell W. C. et al., 1992. Phase II, Final Report, Cobb County GIS System, Information Services Division, Cobb County, Marietta, Georgia. Report, maps and computer software.

Bell W. C., 1992. Final Report on Forsyth County Assessment Mapping Conversion, Forsyth County Assessment Department. Report, maps and software.

Bell W. C., 1991. Implementation Plan and Cost Benefit Analysis for Cobb County GIS, Final Contract Report 1992, Information Services Division, Cobb County, Marietta, Georgia 114pp.

Bell W. C. et. al., 1990. User Needs and Cost Benefit Analysis for Manitoba Land Related Information Systems Project. Linnet Graphics International, 1991. 7 volumes.

Bell W. C. and Purves P., 1990. Final Contract Report, City of Winnipeg Assessment Mapping Project, Linnet Graphics International, Winnipeg. Report, maps, and software.

Bell W. C., 1988. Final Report, Land Resource Development of the Western Desert, Egypt. CIDA, Ottawa, 1988.

Books and Book Chapters

Bell W. C. and Brown M., 1993. Computer Based Information Systems -: A Public Management Tool. Chapter 18 in "Handbook for County Commissioners" University of Georgia Press. pp 201-210

Bell W. C. and Brown M., 1993. Geographic Information Systems Chapter 19 in "Handbook for Georgia Mayors and Council members" University of Georgia Press. 210-224pp.

Bell, W.C., et al., 1988. Neighborhood Atlas of Winnipeg. City of Winnipeg. 138pp.

Appendix C-2

CIAT C.V.

Centro Internacional de Agricultura Tropical

Name:	**Edwin Bronson (Ron) Knapp**
Position in Project:	Soil scientist, cropping systems specialist
Citzenship:	USA
Country of Residency:	Colombia
Education:	Ph.D., Soil Biochemistry/physics, Washington State U., Pullman WA. April 1980 M.S., Soil Biochemistry, Washington State U., Pullman, WA. Dec. 1978 B.A., Economics, Dartmouth College, Hanover, N.H. June 1965
Languages:	English -Native Spanish -Conversational
International Research Experience:	**Centro Internacional de Agricultura Tropical, (CIAT)** Research on the sustainability of agricultural systems in Hillside Agro-ecosystems focusing on defining relationships for productivity - degradation, market cost - soil equilibrium Nov. 1992 to present **Centro Internacional de Mejoramiento de Maíz y Trigo,** (CIMMYT), Cali-Colombia Developed detailed crop management, climate and soil databases and maize dot density distribution maps; developed

stochastic yield gap analyses using OFR results, crop modelling and GIS analysis; carried out geostatistical spatial analyses to improve selection in abiotic stress breeding nurseries affected by pronounced variability over short distances; studied sustainability mechanisms related to fertility and soil acidification resulting from maize cultivation in one acid soil savanna ecosystem.
Jan. 1987 - Nov. 1992

Centro Internacional de Mejoramiento de Maíz y Trigo, (CIMMYT), Texcoco (El Batan), Mexico
Designed, managed and taught a seven month field oriented, in-service production training course for university graduate agronomists from LCD's. Supervised graduate students and organized short term, in-country courses. Consulted for the World Bank.
Oct. 1980 - Jan. 1987

Professional Memberships:

- American Society of Agronomy
- Crop Science Society of America

CV -3-
Edwin Bronson (Ron) Knapp

Publications

Journals:

Knapp,E.B.,L.F.Elliot,and G.S.Campbell.(1983).Microbial Respiration and Growth During the Decomposition of Wheat Straw. Soil Biol.Biochem.15,No.3,319-323.

Knapp, E.B.,L.F.Elliot, and G.S.Campbell.(1983). Carbon, Nitrogen and Microbial Biomass Interactions During the Decomposition of Wheat Straw: A Mechanistic Simulation Model. Soil Biol. Biochem.15,No.4,455-461.

Published Proceedings:

Knapp,Ron [E.B.] and Compton Paul.(1985). Establecimiento de Normas: Un Paso Crucial en el Arte de Fijar Prioridades de Investgacíon y Produccíon. In: El Sorgo en Sistemas de Produccíon en America Latina. ICRISAT-INTSORMIL,p199-205.

Osmanzi,M.,S.Rajaram, and E.B.Knapp.(1987). Breeding for Moisture-stressed Areas. In: Drought Tolerance in Winter Cereals. ed. J.P.Stivastava, E.Porceddu, E.Alcevedo, and S.Varma. 1987 ICARDA. John Wiley & Sons Ltd.

Knapp,E.B. and A. Violic.(1989). Manejo de Experimentos en Fincas Bajo el Sistema de Labranza de Consevación. In: XI Seminario. Labranza de Conservación en Maíz. Ed. H.Barreto, R.Raab, A.Tasistro y A.D. Violic. IICA-BID-PROCIANDINO.1989. Quito,Ecu. PROCIANDINO. 195p.

Knapp,E.B., O.Urdinola M., O.Carmen C., and A. Ramírez V.(1990) Diagnosticando Prioridades de Investgación y Extensión: Un Estudio de Casos en la Zona de Ladera, Valle del Cauca, Colombia. In: Memorias XIII Reunión de Maiceros Zona Andina. Chiclayo, Peru. 25-30 Sept. 1988. INIPA, Lima Peru. p180-194.

Knapp,E.B., S.Pandey, and H.Ceballos.(1990). El Programa Regional Suramericano de Maíz del CIMMYT 1989-1990. In: Memorias XIV Reunión de Maiceros de la Zona Andina. Maracay, Venezuela. 17-21 Sept.1990.

Knapp,E.B.(1990). La Formulación de Recomendaciónes a Patir de Datos Agronómicos o: Datos son Datos, Información es Poder. In: VII Curso Corto. Sistemas de Producción: Investigación en Campos de Productores (Caso Maiz). IICA-BID-PROCIANDINO.1990. Quito,Ecu. PROCIANDINO.191p.

Knapp,E.B., S.Pandey, and H.Ceballos.(1992). The Use of Spatial Analysis in Nutrient Stress Maize Breeding. In: International Symposium on Environmental Stress: Maize in Perspective. Belo Horizonte,MG,Brazil. 8-13 March 1992. EMBRAPA-CIMMYT. in press.

Knapp,E.B.(1992). Uso de Modelos de Simulación en el Diagnostico de Riesgos y la Formulación de Dominios de Recomendación. In: Memorias XXXVIII Reunión PCCMCA. Managua, Nicaragua. 23-27 March 1992. PCCMCA, Managua, Nicaragua.

in press

Knapp,E.B., H.Ceballos, and S.Pandey.(1992). Uso del Análisis Espacial en Viveros de Mejoramiento de Maíz en Condiciones de Estrés por Nutriementos. In: Memorias XXXVIII Reunión PCCMCA. Managua, Nicaragua. 23-27 March 1992. PCCMCA, Managua, Nicaragua.

Published Abstracts

Knapp,E.B., and H.H.Cheng.(1979). Inorganic nitrogen status in the Soil in Lysimeters Simulating No-Tillage Wheat. Agronomy Abstracts 1979.p.158.

Knapp,E.B., L.F.Elliott, and G.S.Campbell.(1980) The Interrelations of Carbon, Nitrogen and Microbial Biomass During the Initial Decomposition of Wheat Straw. Pacific Division Am. Assoc. for the Advancement of Sci. Abstracts. 1980. [This paper was awarded as the best paper presented at the 61st annual AAAS Pacific Division meetings.]

Tasistro, A.S.,A.Violic,and E.B.Knapp.(1983). Weed Control Practices in Maiz (Zea mays L.) and wheat (Triticum aestivum L.) in Mexico. In: Weed Sci.Soc. of Amer. Abstracts. 1983.

Other publications:

Knapp,E.B. "Diagnosing Factors Limiting Productivity in Wheat Production". Twenty competency-based tutorial instructional modules.

Appendix C-3

CIAT C.V.

Centro Internacional de Agricultura Tropical

Name:	**Bruce Edward Allison**
Position in Project:	Project Leader (Hohenheim)
Citzenship:	American
Country of Residency:	Germany
Education:	Ph.D., Soil-Plant-Water-Relations/Microclimatology Kansas State University, 1980 M.Sc., Plant, Soil & Water Science University of Nevada, Reno, 1974 B.Sc. Soil Science California Polytechnic State University, Pomona, 1970
Languages:	English German
International Research Experience:	University of Hohenheim, Institute for Plant Production in the Tropics and Subtropics. C3 Professor 1987 to present University of Hohenheim. West Africa Program, Project Leader 1989 to present University of Hohenheim. Department Coordinator for soil and water management in the tropics and subtropics. Department Coordinator for GIS development
Thesis Supervisory Experience:	Directed/directing research programs for several Ph.D. and M.Sc. students

Selected Publications

Allison, B.E., and Thomas Entenmann. 1993. The Use of the CERES-Maize Model in Southwest Germany to Predict Yield and Nitrogen Leaching Potential. Tagungsband, Expert-N und Wachstumsmodelle. TU Muenchen-Weihenstephan (to be published August, 1993).

Lamars, J., K. Michels, B.E. Allison, and Rick J. Vandenbeldt. 1993. Agronomic and socioeconomic aspects of windbreaks in southwest Niger. Proceedings of the 4th International Symposium on Windbreaks and Agroforestry, Viborg, Denmark. July 26-30 1993.

Allison, B.E., J. Fechter, A. Leucht, and MVK Sivakumar. 1993. The Use of the CERES-Millet Model for Production Strategy Analysis. Proceedings of the International Irrigation and Drainage Conference, Den Haag. (to be published September 1993).

Kraemer, F., B.E. Allison, M. Kleber, A. Leucht, T. Entenmann. 1993. Kalibrierung des Simulationsmodelles EPIC auf dem Standort "Naturmessfeld Horkheimer Insel". Mitteilgn. Dtsch. Bodenkundl. Gesellschaft. (veroeffentlicht nach der Tagung, September 1993).

Gong, Y., and B.E. Allison. 1993. Flaechige Abschaetzung des Bewaesserungsbedarfs in der Huabei-Ebene der VR China mit einem Bodenwasserbilanzmodell. Mitteilgn. Dtsch. Bodenkundl. Gesellschaft. (veroeffentlicht nach der Tagung, September 1993).

Michels, K., M. V. K. Sivakumar, and B.E. Allison. Wind Erosion in the southern Sahelina Zone and Induced Damage to Pearl Millet (accepted for publication, Agricultural and Forest Meteorology).

Allison, B.E., and T. Entenmann. 1992. Entwicklung von Modellen zur Abschaetzung des Grundwasserschmutzungspotentiels. Bericht 2. Statuskolloquium PWAB, Kernforschungszentrum Karlsruhe. KfK-PWAB 5:29-48.

Topcu, S., and B.E. Allison. 1992. Evaluierung des Modells COTTAM fuer die Cukurova Region in der Turkei. Verband deutsch-tuerkischer Agrar- und Naturwissenschaftler. Univ. Hohenheim:131-137.

Fechter, J., B.E. Allison, M.V.K. Sivakumar, R.R. van der Ploeg and J. Bley. 1991. An Evaluation of the SWATRER and CERES-Millet Models for Southwest Niger. IAHS Publ. no. 199: Soil Water Balance in the Sudano-Sahelian Zone.

Leucht, A., B.E. Allison, T. Entenmann and R.R. van der Ploeg, 1991. Evaluierung von Evapotranspirationsmodelle am Standort "Naturmessfeld Hirkheimer Insel". Mitteilgn. Dtsch. Bodenkundl. Gesellschaft. 66(1):169-172.

Bley, J., R.R. van der Ploeg, M.V.K. Sivakumar and B.E. Allison. 1991. A Risk-Probability Map for Millet Production in Southwest Niger. IAHS Publ. no. 199: Soil Water Balance in the Sudano-Sahelian Zone.

Appendix D

The International Center for Tropical Agriculture
Centro Internacional de Agricultural Tropical - CIAT

CIAT's MISSION

CIAT was established in 1967. Its mission is to contribute to the alleviation of hunger and poverty in tropical developing countries by applying science to the generation of technology that will lead to lasting improvements in agricultural output while preserving the natural resource base. CIAT pursues this mission through two interrelated approaches: research on germplasm development and research on resource management.

CIAT is increasingly emphasizing strategic research that covers a wide agroecological zone while assisting national and regional research partners to assume major responsibilities for applied and adaptive research that are more location specific.

GERMPLASM DEVELOPMENT DIVISION

CIAT's germplasm development programs (beans, cassava, rice, tropical forages) focus on the development of germplasm-based technology that efficiently uses inputs and is adapted to environmental contraints in tropical and sub-tropical developing countries. Research support is provided for the four commodity programs by the Germplasm Resources Unit, the Virology Research Unit and the Biotechnology Research Unit.

CIAT has a global responsibility for research on cassava, field beans and tropical forage species in acid soils. It has a regional responsibility for research on rice in Latin America and the Caribbean.

RESOURCE MANAGEMENT RESEARCH DIVISION

This new division focuses on research that will improve the management of resources available for agriculture in tropical America such that gains in food outputs and other commodities are compatible with the long-term preservation and enhancement of the resource base.

There are three agroecological and one land use research programs which integrate the work of the division. The agroecosystem programs focus on disturbed forest margins in the humid tropics, mid-altitude tropical hillsides and lowland acid-soil savannas.

CIAT works collaboratively with other institutions in providing an inter-disciplinary approach to the multi-dimensional problem of agricultural sustainability.

STAFF AND FACILITIES

CIAT has a staff of approximately 100 international scientists who work closely with their counterparts in national agricultural research systems.

CIAT's main research facilities are located outside of Palmira close to Cali's airport. CIAT also has research stations in various parts of Colombia including Carimagua, Villavicencio, Popayán and Pivijay. CIAT conducts area-based research in other countries of Latin America, the Caribbean, Africa and Asia in partnership with national and regional institutions.

INSTITUTIONAL RELATIONS

Training

Training at CIAT supports the institutional development objectives of strengthening both national research capacity and the national links between research and development and of supporting the development of sub-regional training systems. In 1991, approximately 150 research scientists from national agricultural research systems in developing countries received specialized training in individualized programs at CIAT.

CIAT has developed a training of trainers program for rice, beans and cassava scientists and extensionists. This is provided at a sub-regional basis in Latin America.

CIAT also provides post-graduate training opportunities to young researchers from developed countries to become acquainted with international tropical agricultural research. In 1991, CIAT supervised both practicums and doctoral research projects for 16 students from universities in North America and Europe.

Undergraduate students from Colombia are also given the opportunity to carry out research projects under the guidance of CIAT scientists, in fulfillment of a partial requisite to obtain their first degree. In 1991, 46 Colombian students completed their theses at CIAT, 52% of these being women.

CIAT has modern desktop publishing and printing facilities for producing highly effective print-based learning materials. In addition, it now has a small television studio for in-house production of audio visual training materials for use with national scientists.

Information Services

CIAT's library collection contains over 40,000 volumes with an emphasis on tropical agriculture; 37,000 specialized documents on common beans, cassava, rice and tropical pastures; 2,500 journals; and 400 technical bulletins; as well as maps, microfilms and audiotutorials. CIAT also has a computerized inventory of over 11,000 slides.

This is an extremely valuable resource for researchers at CIAT and at national research programs.

CIAT relies on the latest information and communications technologies, including electronic mail, compact disc (CD-ROM) and online databases to ensure rapid exchange of current research information with national agricultural research programs in Latin America.

Publications

CIAT publishes technical monographs, journals, working documents, manuals, training materials and research program newsletters. This is an important activity for ensuring widespread dissemination of research findings. CIAT has a worldwide distribution of over 1,600 subscribers for its quarterly abstracts on beans, cassava and tropical pastures research findings.

Conferences and Official Visits

CIAT organizes conferences both at headquarters and in-country. The objectives are to provide for information exchange, technical reviews, institutional strengthening through training, evaluation and inter-institutional planning on collaborative research agendas, thereby reducing duplication of efforts by building on the comparative advantages of individual institutes. In 1991, CIAT held 17 such conferences.

In addition, there are over 3,000 national and international visits to CIAT annually. These visits are encouraged as part of CIAT's public education program to help inform the educational and scientific community, the general public and the donors as to the advances that have been achieved through investments in agricultural research that contribute to sustainable development.

DONOR SUPPORT

CIAT is one of 17 international agricultural research centers sponsored by the Consultative Group on International Agricultural Research.

CIAT's core budget and Special Projects are financed by more than 20 donor countries, international and regional development organizations and private foundations. These include:

- Governments of Australia, Belgium, Canada, Finland, France, Germany, Italy, Japan, Mexico, Netherlands, Norway, People's Republic of China, Spain, Sweden, Switzerland, United Kingdom and United States.
- Regional and multilateral donors such as the European Economic Community, Inter-American Development Bank, the United Nations Development Program and the World Bank.
- Private Foundations such as Ford Foundation, Rockefeller Foundation and the Kellogg Foundation.
- Public corporations such as the International Development Research Center.

Centro Internacional de
Agricultura Tropical (CIAT)
A.A. 6713 Cali, Colombia

Telephone: 57-23-675050
Fax: 57-23-647243
Telex: 05769
Electronic Mail: (CGNET): CGI301

Appendix E

Description of Networking, Hardware and Software in CIAT's GIS Group

CIAT has recently installed extensive facilities for GIS, which are available to carry out the project. The GIS section of the Land Use Program has a mixed interconnect networking environment of SUN work stations, Digital Vax stations, and 486 personal computers running Microsoft windows and X windows.

High speed (100 mbs) FDDI networking facilities are currently being installed to better handle the data volumes associated with image analysis and extensive GIS data input and analysis.

Input facilities include digitizers and large format (90 cms) scanners while output is performed by a 90 cm color, electrostatic, plotter.

In addition CIAT has installed a Centralized SUN 2000 server which the GIS group has access to via FDDI.

SOFTWARE

Consists of the ESRI Arc Info System V7 for GIS and the ERDAS Imagine (V8.0.2) and PCI systems (V5.1) for image analysis. Digital orthophotography is performed with the Orthomax system from ERDAS.

Data input is done manually from digitizing tablets or from the scanner.

Input data is converted from raster to vector, using ESRI Arc Scan or CADCORE software. Data are stored in an Oracle (V7) relational database and linked to the GIS.

HARDWARE

Sun Sparc 690 - 52 dual processor server, 128 MB memory, 13GB disk, 0.5" reel tape, 0.25" cartridge tape, 8 mm Exabyte tape, 19" monitor.

Sun Sparc 10 Model 41, 64 MB memory, 4GB disk, 8 m Exabyte tape, 19" monitor

Sun Sparc 10 Model 30, 64 MB memory, 2GB disk, 19" monitor

Sun Sparc IPX, 64MB memory, 3GB disk, 19" monitor

Digital Vax station 3100/76, 64 MB memory, 3GB disk, 19" monitor, 0.25" tape

10 486/50 and 486/33 Personal computers, 8 MB to 16 MB memory, 300 - 1000 MB disk , 17" color monitors running Windows and X windows in a networked environment under TCP/IP and IPX.

Contex 36" 800 dpi greyscale scanner

Calcomp 68436 36" 400 dpi color plotter

2 x 36" x 48" Calcomp backlit digitizing tablets

QMS 860 11" x 17" 600 dpi networked printer

Several small pen and inkjet plotters

PERSONNEL

In addition, the Land Use Program has several professional GIS AML programmers, systems analysts, system designers; and database, system programming, and data input staff to keep the system operational and to develop effective new end-user applications .

Appendix F

German Confirmation Letter

UNIVERSITÄT HOHENHEIM
Institut für Pflanzenproduktion
in den Tropen und Subtropen
Prof. Dr. Bruce Allison

Postanschrift/Mailing address:
Universität Hohenheim (380), D-70593 Stuttgart

Hausadresse:
70599 Stuttgart
Kirchnerstr. 5
Telefon: (0711) 4 59-27 32
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Telex : 722959 uniho-d
E-Mail : inst380@ds0ruh11
(Bitnet)

Stuttgart-Hohenheim, den 03.08.1993

Statement of project support and committment

The project titled "Improving Natural Resource Management for an Adean Watershed Using an Interactive Coupled GIS/Watershed Model" has been cooperatively developed and proposed by the Hillsides and Landuse Programs (CIAT) and the University of Hohenheim, Department of Plant Production in the Tropics and Subtropics. The project objectives, work plan, distribution of research responsibilities and proposed budget are supported in full by this cooperating partner.

Prof. Dr. B.E.Allison
University of Hohenheim

CIAT has in-house facilities for the production of high-quality training materials and video programs for scientific and extension agricultural activities.

This proposal was produced and published, using CIAT's computer layout and graphic composition facilities and outside low-cost copying services