SOIL EROSION AND CONSERVATION AS AFFECTED BY LAND USE AND LAND TENURE, EL PITAL WATERSHED, NICARAGUA

A Thesis

by

MATILDE DE LOS ANGELES SOMARRIBA-CHANG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 1997

Major Subject: Rangeland Ecology and Management

SOIL EROSION AND CONSERVATION AS AFFECTED BY LAND USE AND LAND TENURE, EL PITAL WATERSHED, NICARAGUA

A Thesis

by

MATILDE DE LOS ANGELES SOMARRIBA-CHANG

Submitted to Texas A& M University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE

Approved as to style and content by:

Thomas L. Thurow
(Chair of Committee)

Robert C. Maggio
(Member)

James E. Christiansen
(Member)

Douglas Loh
(Member)

Robert E. Whitson
(Head of Department)

December 1997

Major Subject: Rangeland Ecology and Management

ABSTRACT

Soil Erosion and Conservation as

Affected by Land Use and Land Tenure,

El Pital Watershed, Nicaragua. (December 1997)

Matilde de los Angeles Somarriba-Chang, B.S., National Agrarian University, Nicaragua

Chair of Advisory Committee: Dr. Thomas L. Thurow

Erosion by water is a serious problem threatening the sustainability of steep land agricultural production throughout the tropics. The El Pital watershed is typical of the many regions within Nicaragua where the effects of erosion are increasingly evident.

Analysis of aerial photographs taken in 1968 and 1987, and comparing them with conditions in 1996, indicates that erosion has increased throughout this period and is substantially above the expected geologic "natural" erosion rate for the area. This trend is associated with increased fragmentation of farms associated with the agrarian reform activities of the 1980's, during which many of the large land-holdings were confiscated and redistributed to many peasant families. Also the increasing population and inheritance customs have contributed to the proliferation of smaller farming units. Small farming units (< 4 ha) are linked to increased erosion because small farms tend to emphasize production of annual crops necessary to meet the subsistence needs of the

farm family. Annual crop production is a land use that has a high erosion risk because the soil is more exposed to raindrop impact and there is less vegetative obstruction to overland flow than if the land use was forest, range, or a perennial crop with high cover characteristics, such as coffee. The trend within the watershed toward increased emphasis on annual crop production is greatest on the steep lands where the erosion risk is naturally high. The increase of small farms on the steep land is a function of political and economic considerations, which make these lands most available for settlement.

Most of the institutions working in the watershed to encourage soil conservation have targeted the beneficiaries of agrarian reform. The result has been that adoption of soil conservation practices tends to be greater on these farms than on the lands that were traditionally privately owned. This illustrates that extension activities do make a significant difference in adoption of soil conservation practices. Because the trend within the watershed is toward an increase in small farms, and because the trend on small farms is to select crops with a high erosion risk, there is a need to design and implement programs that enhance adoption of soil conservation technologies by these small farmers.

DEDICATION

I dedicate this thesis to my family, especially to my husband, Abraham, my sons, Eduardo and Allan, and my daughter Natalia; for their love and understanding of having a wife and a mother engaged in her career and education.

ACKNOWLEDGMENTS

My sincere gratitude goes to Dr. Thomas L. Thurow for his opportune guidance, and effective advice. He was a source of motivation and strength through all my work.

Special thanks are due to Dr. James Christiansen and Dr. Douglas Loh for their criticism and suggestions, and the final review of this document.

Particular acknowledgment must be given to Dr. Robert Maggio for his technical supervision and support regarding use of GIS tools as part of this thesis. I am grateful to the personnel and graduate students working in the Mapping Science Lab of the Forest Science Department for their cooperation and assistance during the analysis of information using the GIS facilities - thank you Andrew, Damon, Michelle, Ramash, Ran Tao, and Todd.

I thank US Agency for International Development for funding my education and I thank the Academy for Educational Development for the helpful administration of these funds. I thank the Soil Management Collaborative Research Support Program of USAID (LAG-G-00-97-00002-00) for funding the research associated with this degree.

Recognition is given to my colleagues at the National Agrarian University (UNA) in Nicaragua for their assistance during my field work, and their helpful response to information I requested during analysis of data.

I give my sincere thanks to the 132 farmers who kindly responded to the interviews. They were patient and friendly. Hopefully, this work will guide the institutions working with them to address more effectively their concerns and assist them to improve their standard of living.

I extend recognition to the staff in the Nicaraguan institutions who cooperated with me during my field work. Directors and technical personnel of the Agroforestal Project El Pital, the Nicaraguan Agricultural Technology Institute (*Instituto Nicaraguense de Tecnologia Agropecuaria* - INTA) of the Masatepe headquarters, the National Union of Farmers and Cattle Ranchers (*Union Nacional de Agricultores y Ganaderos* - UNAG) in Masaya and Granada, the Union of Nicaraguan Coffee Producers (*Union Nicaraguense de Caficultores* - UNICAFE) of the Masatepe headquarters, and the European Economic Community (*Comunidad Economica Europea*) CEE-ALA Project in Region IV.

Special gratitude is given to my mother, Angela, for the time and effort she spent on constituting my basic education and values.

Finally, I wish to express my absolute appreciation to my husband for his patient and emotional sustenance throughout the two years of study and to give special recognition to my daughter Natalia for her understanding of my spending all this time away from her.

TABLE OF CONTENTS

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

FIGURE | Page

FIGURE | Page

FIGURE Page

FIGURE Page

INTRODUCTION

Nicaragua is the largest Central American country (130,682 km^2), with one of the highest annual population growth rates (3.3 to 3.5%) and one of the lowest per capita annual incomes (US $420 to US $600) in the Western Hemisphere (IRENA-ECOT-PAF 1994). Agriculture is the largest sector of the economy. The major crops produced for local consumption are staple crops such as corn (*Zea mays* L.), beans (*Phaseolus vulgaris* L.), and sorghum (*Sorghum bicolor* (L.) Moench). The principal crops grown for export markets include tropical fruits, vegetables, coffee (*Coffea arabica* L.), cotton (*Gosipium spp* L.), and peanuts (*Arachis hypogea* L.). Much of the coffee and many of the locally consumed staple crops are cultivated on small farms (1 to 4 ha). Many of the small farms are located on hillsides with slopes ranging from 10 to 40%. These farms are very vulnerable to runoff and erosion that causes degradation of their production potential and results in downstream flooding and siltation.

Approximately 7.7 million ha of Nicaragua have been degraded to varying degrees by water erosion (IRENA-ECOT-PAF 1994). There have been many soil conservation projects initiated in Nicaragua during the 1980s and 1990s, but most do not reach their potential because few efforts have been made to address simultaneously the environmental and socioeconomic relationships necessary to achieve soil conservation (Obando and Montalvan 1993). Failure to do so often results in attempts to

---

This thesis follows the style and format of the Journal of Soil and Water Conservation.

implement technical solutions that are not sustainable within the socioeconomic context. Also, failure to consider spatial linkages within the landscape may result in an activity having insufficient scope to be sustainable, such as when an activity at one location is interdependent with activities in other location. The inherent energy flow patterns associated with a drainage make a watershed a useful level of resolution for soil and water conservation activities because a watershed scope integrates consideration of interrelated biophysical, socioeconomic, and institutional factors that influence natural resources management (Thurow and Juo 1995).

The watershed approach

Traditionally, erosion costs are measured in terms of on-site reduction of future crop production potential. Loss of crop production potential is typically associated with the loss of soil, water, and nutrients. However, loss of production potential represents only a portion of the costs of erosion since it also negatively affects the surrounding environment. Off-site problems include drainage disruption, gullying of roads, eutrophication of waterways, siltation of dams and channels, loss of reservoir storage capacity, increased flooding risk, loss of wildlife habitat, damage to public health, and/or increased water treatment costs (Pimentel et al. 1995). When the associated off-site economic costs of soil loss and degradation are conservatively estimated and included in the cost/benefit analyses of soil conservation, it makes sound economic sense to invest in programs that control erosion (Pimentel et al. 1995). The off-site and societal costs of erosion are great; therefore soil erosion should be a concern to social groups other than the farmers (Alfsen et al. 1996). To implement more effectively soil conservation programs, government cost-sharing, access to credit, access to technical information on a continuing basis, and consistency of national agriculture, development and conservation policies affecting subsistence farmers should be considered (Napier 1991). To maximize the effectiveness of these incentives, it is important that the soil conservation activities be targeted to meet the needs of the farmers who will be installing and maintaining them.

GIS as a tool for land use planning

Land use planning is the systematic assessment of land and water potential, alternatives for land use, and economic and social conditions in order to help to identify land use options. The purpose of land use planning is to identify land uses that will best meet the needs of the people while safeguarding resources for the future. The driving force in planning is the need for improved management or the need for a quite different pattern of land use dictated by changing circumstances (FAO 1993). Geographic Information Systems (GIS) is a useful tool to integrate consideration of a variety of societal and natural resources conditions. GIS technology can aid land use planning by (1) generating efficient and effective views of databases that describe land records, (2) integrating the land data in ways that foster understanding of relationships, and (3) handling transactional updating of land data to maintain current information (Dangermond 1989). GIS provides a way to rapid access of large volumes of updated data, selection of information by area or theme; and to display that information in a context that will facilitate analysis of spatial and temporal pattern (Selman 1991; Brown et al. 1994). The use of GIS as a land management tool was recognized very early in its development (Scott 1992).

Factors affecting the adoption of soil conservation

Socioeconomic conditions affecting hillside farms in developing countries constrain adoption of soil conservation technologies. Lack of secure land tenure understandably negatively impacts farmers' decisions as to whether to invest time, money, and effort without assurance that they will reap the benefits of the investment (Sheng 1989). Poverty is another factor that affects small farmers' disposition to invest in soil conservation. Small subsistence farmers focus on meeting their immediate survival needs. They may not feel they can afford to reduce the intensity of land use in order to protect soils for future generations, or to protect downstream areas (Sheng 1989). Also, government policies may encourage activities that are contradictory to soil conservation, thus limiting the effectiveness of soil conservation initiatives. For example, emphasis on production of export crops to earn foreign exchange as rapidly as possible may undercut the long-term need for investment in installing and maintaining soil conservation structures (Sheng 1989). Other factors limiting the efficiency of adoption of soil conservation practives are the lack of well-trained staff to provide quality technical assistance and the lack of practical methodologies and technologies suitable for use in subsistence agriculture farming systems.

Risk aversion and short-term investment perspectives of farmers are primary constraints to the adoption and use of conservation practices, most of which are not profitable in the short-term at the farm level (Stonehouse and Protz 1993). The resistance of farmers to adopt soil conservation practices does not appear to be associated with lack of awareness of damage by erosion. Rather the long-term impacts of erosion on future agricultural productivity and the environment has lower importance to subsistence farmers than meeting their short-term food and cash needs (Napier 1991).

Objectives

The objectives of this study were to :

1. Estimate how soil erosion risk has changed in the El Pital watershed between 1968, 1987, and 1996.

2. Determine the types of soil conservation practices that have been introduced and the factors that have influenced the degree to which they have been adopted within the various land use/land tenure categories.

Hypotheses

The hypotheses formulated to be tested as related to the objectives were:

1.1. Farm size and security of land tenure is related to decisions about crop selection.

1.2. Crop selection on small holdings and on sites without secure land tenure emphasize annual crops (which pose a great erosion risk) than agronomic perennial crops, rangeland, or forestland (which pose a low erosion risk).

1.3. The erosion risk within the watershed increased as the population density and land use intensity of the watershed increased between 1968 and 1996.

2.1. The decision to adopt soil conservation practices is correlated with land erosion risk, land tenure, and farm size.

2.2. Credit availability, market regulation, and technical assistance are related to adoption of erosion control practices by farmers.

There are many interrelated socioeconomic and environmental factors that determine the degree of adoption of soil conservation technology. However, the goal of this research was to estimate the potential soil erosion associated with various portions of the landscape and determine the various factors that influence farmers decisions regarding the type and extent of soil and water conservation activities they apply. Understanding how various site characteristics are interrelated to erosion vulnerability and the adoption of soil and water conservation practices will help project designers to better target their activities.

CHARACTERIZATION OF STUDY AREA

Location

The study area was the El Pital watershed located in the Pacific Region of Nicaragua between 11°42' 48'' and 11° 54' 47''N; 85° 55' 12'' and 86° 09' 12''W (Figure 1). The El Pital watershed has an area of approximately 165 km^2 and is located in the southern part of the Department of Masaya. The watershed is comprised of two sub-basins, Mombacho and Diriomo. The Mombacho sub-basin has a discharge area of 77 km^2. The drainage pattern is classified as sub-dendritic with 4 ephemeral streams; the water in these streams usually infiltrates into the pyroclastic depositions of Mombacho volcano. Therefore, runoff exits this sub-basin only during extreme flood conditions. The Diriomo sub-basin constitutes 88 km^2 of the El Pital watershed. The drainage pattern has about 7 ephemeral streams (MARENA 1993). Seventeen percent of the watershed area has slopes greater than 10%; and 5% of the watershed has slopes greater than 20%.

Climate

The watershed has a "humid and dry tropic" climate, as characterized by the Koeppen Climatic Classification (MARENA 1993). Annual precipitation averages about 1,500 mm. The rainy season occurs from May to October. The altitude varies from 160 to 1,100 m asl. Elevation has a great influence over mean daily temperature which varies in the watershed from 13°C in December to 25°C in April at the highest elevation, and from 26°C in December to 32°C in April at the lowest elevation (Lopez

Figure 1. Location of the study area

and Gonzalez 1994). The rainy season (May to October) is divided into two growing periods; *primera* (May to August) and *postrera* (September to November). There is a dry period from mid July to mid August, which is known as the *canicula*.

Geology and soils

The watershed area is part of the southwest Nicaragua depression flank. The geomorphology characteristics fluctuate from the valley to the mountains with ten soil series identified in the watershed. The basin has mostly moderately to well-drained soils. The parental material of the soils varies from basaltic rocks, volcanic ashes, alluvial sediments, or limestone. The topsoil depth ranges from deep (> 80 cm) in lowlands and on well vegetated hillsides to shallow (< 30 cm) on intensively used steep lands. The two dominant soil texture types within the watershed are sandy loam and clay loam. The organic matter content ranges from 3% to 9% (MARENA 1993). This characteristic facilitates creation of a stable soil structure.

Socioeconomic facts

The study area has a population of approximately 58,505 inhabitants. They belong to the municipalities of Catarina, Niquinohomo, San Juan de Oriente, and San Jose de Masatepe within the Masaya department and to the municipalities of Diriomo, Diria, Granada, and Nandaime within the Granada department. About 62% of the population lives in small communities within the watershed. The remaining 38% (about 22,500) live on their farms. The population density is 148 inhabitants/km^2 (Espinoza 1994).

The land tenure in the watershed is distributed between private landowners (79% of the farmer population) and Beneficiaries of Agrarian Reform (BAR) who live on farm cooperatives. There are 60 cooperatives within the watershed to which about 21% of the total farmer population belongs. The area covered by the cooperative sector occupies about 6,457 ha, which is about 33% of the total area devoted to agricultural activities (MARENA 1993).

CROPPING SYSTEMS INCLUDED IN THE PREDOMINANT CROP EMPHASIS CATEGORIES

There are five distinct categories of agricultural activity present within the watershed: grain production on the plains, grain production on the hillsides, production of a diverse array of crops, coffee production, and livestock production. The types of cropping systems practiced in each of these categories are discussed below:

Grain production on the plains

There are three types of cropping systems commonly used in the plains region: 1) rotation or intercropping of corn and beans, 2) monoculture of sorghum, and 3) monoculture of rice (*Oryza sativa* L.). Generally, the land is plowed using a tractor and the crop is planted using oxen to make a furrow for the seed.

In the case of corn and beans rotation system, the farmers begin to clear the land in early April. Seed is planted when the first rains of the *primera* begin in May. The distance between rows of corn is typically about 80 cm; within the row, two seeds are planted per hole, spaced about 30 cm apart. The rate and timing of fertilizer and pesticide application depends upon perceived need and the availability of cash. Weed control is done using a machete or herbicides. The corn harvest generally takes place during the *canicula*. During harvest, the corn stalks are chopped and taken to feed livestock or piled and burned. Farmers remove the corn stalks in an attempt to reduce the likelihood of pest infestation of the next corn crop. The field is cleared and plowed (usually using an ox or tractor) after the harvest. Beans are planted at the onset of the *postrera*. The row width for beans is about 40 cm; two seeds are planted per hòle at a distance of about 10 cm within each row. The bean harvest takes place at the end of the *postrera*.

For sorghum production, seeds are planted at the onset of the *primera*. Like corn, sorghum is produced for commercial purposes; therefore, farmers use fertilizers, herbicides, and pesticides to manage this crop. The farmers harvest only the follicle at the end of the *primera*. The stalks are left in the soil and a second grain crop is harvested at the end of the *postrera*.

For rice production, the *secano* system is used. This system is dependent on rainfall only; farmers in the watershed do not use irrigation. Land is plowed with a tractor and the seeds are planted in continuous rows, usually at the beginning of the *postrera*. Fertilizers and pesticides are usually applied at several intervals during the growing season. Herbicides are usually used to control weeds. The rice crop is mainly sold in local or national markets; little is kept for family consumption.

Grain production on the hillsides

On hillsides, the land is plowed using an ox or the vegetation is cleared using a machete, herbicides, or fire. The cropping system includes crop rotations or intercropping of corn-beans, corn-beans-cassava (*Manihot esculenta* Crantz), or corn-beans-rice. With regard to the corn-beans rotation, farmers commonly cultivate corn in *primera* and beans in *postrera*. The crops are planted in rows made by an ox-drawn plow or in holes made throughout the field with a digging stick (*espeque*). Seeds in the corn-bean intercropping system may be planted either in alternate rows or in a randomized scheme. In the alternate row system, the distance between the rows is 80 cm, the spacing of plants within a row is 30 cm between corn and 20 cm between beans. In the *espeque* system the distance between holes is about 1 m. The cultivation of rice is done using either the row system or the espeque system. Farmers habitually do not apply agrochemicals in the *espeque* system, generally because farmers who use this labor-intensive system tend to be poor. Depending of the availability of cash, some farmers apply chemical fertilizers and spray to control insects or diseases. The cultivation of cassava is generally configured with a distance between rows of 80 cm and a spacing of 50 cm within a row. Cassava is primarily produced for self-consumption, with the occasional surplus for sale in a local market.

Diverse crops production

Some farms specialize in the production of a variety of crops including fruits, medicinal plants, ornamental plants, and vegetables. The products obtained are utilized for both family consumption and for sale in the local market. The main fruits produced are lemon (*Citrus limon* (L.) Burm.), sweet orange (*Citrus sinensis* (L.) Osbeck), tangerine (*Citrus reticulata* Blanco), mango (*Mangifera indica* L.), avocado (*Persea americana* Mill), guava (*Psidium guajava* L.), pineapple (*Ananas comosus* (L.) Merr.), papaya (*Carica papaya* L.), granadilla (*Passiflora quadrangularis* L.), passion fruit (*Passiflora edulis* Sims), pithaya (*Cereus sp.*), melon (*Cucumis melo* L.), and various types of bananas or plantains (*Musa spp.*). The prevalent vegetables produced are water squash (*Sechium edule* (Jacq.) Sw.), summer squash (*Cucurbita pepo* L.), tomato (*Lycopersicum esculentum* Mill.), taro root (*Xanthosoma sagittifolium* (L.) Schott), and cassava. Some medicinal plants that are commonly produced include chamomile (*Anthemis nobilis* L.), lemon grass (*Cymbopogon citratus* L.), aloe (*Aloe vera* (L.) N.L.Burm), and sour orange (*Citrus aurantium* L.).

The cropping system used to produce these crops is either a monoculture or a home garden. A home garden is an array of plants grown on a small piece of land (usually less than 1 ha) next to the home of the farmer. The primary emphasis is to produce a variety of food crops for consumption by the family and for supply of cash between crop harvest when cash flow decline. Many of the farmers apply organic fertilizer prepared by themselves. This is due to the ease of cultivating small areas with a profitable crop (a 0.06 ha plot of passion fruit). The monoculture system is market-oriented. This system requires intensive use of fertilizer, herbicides, and pesticides. Depending of the life cycles of crops included in the diverse crop system, the land is occupied all year long by one single crop or by rotation of two crops.

Coffee production

Coffee plantations are found at the higher elevations of the watershed. There are two types of coffee production systems, the traditional shadow coffee system and the new shade-free coffee system.

The shade trees used in the traditional shadow coffee system are divided into two types of trees: fruit trees or timber trees. The primary purposes of the shade is to 1) allow the beans to mature slowly giving them a richer taste and 2) spread the period during which beans ripen, thereby allowing fewer laborers to be employed over a longer time rather than competing for scarce labor during an intense several-week harvest period that occurs if coffee is grown in full season. Besides these functions, the shade trees provide products such as fuelwood, timber, fruits, and spices. Some help to maintain soil fertility through nitrogen fixation (Jimenez and Gonzalez 1991). The cover also dissipates raindrops energy and thereby reduces erosion hazard.

Trees typically grown in traditional shadow coffee plantations include cedar (*Cedrela odorata* L.), acetuno (*Simarouba glauca* L.), laurel (*Cordia alliodora* L.), guaba (*Inga densiflora*), genizaro (*Pithecellobium saman* (Jacq.), chilamate *(Ficus isophlebia*), guanacaste (*Enterolobium cyclocarpum* (Jacq.) Griseb.), and fruit trees like avocado, oranges, lemon, zapote (*Pouteria sapota* (Jacq.H.E. Moore*)*, tamarind (*Tamarindus indica* L.), and various banana species. The dominant trees tend to be tall timber species that also fix nitrogen. The canopy of traditional coffee plantations creates a micro-climate that has a more stable temperature and humidity. The litter from these trees is maintained as a mulch covering the soil surface. The farmers prune the trees at the beginning of the *primera*. The pruned leaves and small branches also contribute to the mulch.

The new coffee production system tends to use more fruit trees, mainly banana, plantain, oranges, lemon, and papaya rather than taller timber species. Consequently, the shade in the new coffee system is less dense than in the traditional systems. Some of farmers using the new system plant live barriers of trees such as madero negro (*Gliricidia sepium* (Jacq.) Steud)), leucaena (*Leucaena leucocephala* (Lam.) de Wit), and acacia (*Acacia siamea*). The purpose of these barriers is to reduce the exposure of the coffee trees to dry winds or direct sunlight, in addition to providing a barrier to soil erosion and supplying a source of organic fertilizer.

The El Mombacho region is mostly characterized by the traditional coffee system in which Caturra, Catuai, and Mundo Novo coffee varieties are dominant. The other *comarca*s that have coffee plantations have an approximately equal mix of traditional systems and new-style plantations. These *comarca*s usually grow Caturra and Bourbon varieties.

Livestock production

Farmers practice animal husbandry for milk and meat production. Two scales of livestock production are practiced in the area: 1) small farms which typically have a few cattle (up to 10) primarily for family consumption and occasional sale, and 2) large farms, which have hundreds of cattle raised for commercial purposes.

Farmers with small land holdings rely on grain crops rather than livestock for the primary farm income. Generally, these farms range in size from 5 to 15 *manzanas* (3.5 to 10.5 ha). The purpose of including cattle in the farming system is often for milk production. The management of the system is basically to feed cattle with available grass and, if necessary, to rent or obtain free access to fallow land of neighbors. In contrast, some large farms rely on milk and/or meat production to provide the primary source of income. In this case, the farm size ranges from 100 to 500 manzanas (70 to 350 ha). Most beef cattle farms are extensive production systems where cattle graze on native pasture. In contrast, a milk production system is more intensive and operates using more inputs, such as use of feed supplements, than beef cattle farms. In both kinds of farm systems, the pasture may be native grassland or introduced grasses. The grassland is usually grazed in the field, but in the more intensive operations hay will be made for use in the dry season and sometimes fresh grass is cut and carried to feed the animals in stables. The predominate grasses in the area to be grazed are bermuda grass (*Cynodon dactylon* (L.) Pers), pata de gallo (*Digitaria sanguinalis* (L.) Scop.), and buffel grass (*Cenchrus ciliaris* L.). Elephant grass/napier grass (*Pennisetum purpureum* Schumach.) and gamba grass (*Andropogon gayanus* Kunth) are used in cut-and-carry feeding systems. The farmers also use some leguminous forage such as tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.) and cowpea (*Vigna sinensis* L.). Trees are dispersed in the grassland and are used as forage, shade, fuelwood, wood, and as posts. These trees were established by natural regeneration in the pasture or were left when forest was cleared.

SOIL CONSERVATION PRACTICES

There are many soil and water conservation techniques practiced in the El Pital watershed. Some have been introduced as local projects by outside agencies while others are traditional practices done by the farmers themselves. For the sake of discussion, these practices are grouped as agronomic conservation practices or mechanical practices. Agronomic practices have proven to be most cost-effective on gentle slopes below 12 to 15 percent (Sheng 1989). On steep slopes in the tropics, agronomic practices should be used in conjunction with mechanical conservation structures because neither is likely to be very effective if used separately.

Agronomic conservation practices involve the use of cover crops, multiple cropping, vegetative barriers, mulching, contour cultivation, and different levels of conservation tillage.

Cover crops and green manure

Cover cropping and green manure are combined practices in the area. The cover crops are planted after an annual crop either had a chance to become well established or has been harvested. Cover crops protect the soil from direct raindrop impact and later are often plowed into the soil to improve structure and fertility. Many leguminous species, such as velvet bean (*Mucuna pruriens* L.), and tropical kudzu, are grown as a cover crop and then plowed into the soil as a green manure.

Vegetation barriers

Vegetation barriers are usually planted in association with terraces. The vegetation used to form the live barriers may be either woody species, grasses, or cash crops. The objective is for the base of the plant to obstruct overland flow and to stabilize the bunds in terraces. The most common vegetation barriers used in the study area are *madero negro*, leucaena, pigeon pea (*Cajanus cajan* L.), napier grass, or sugar cane.

Surface mulching

Surface mulching practices vary with the type of material used to cover the soil and thereby dissipate the erosive energy of raindrop impact and overland flow. Some farmers leave crop residues over the surface while others apply vegetation material from the pruning of live barriers or live fences. Traditionally farmers cut, piled, and burned crop residues to eliminate pests and weed seeds. The increased use of mulch in the watershed reflects adoption of soil conservation practices disseminated by projects and institutions working in the watershed.

Multiple cropping

Multiple cropping is a traditional practice that ranges in application from a simple intercropping association of corn and beans to the complex, heterogeneous mix of species used in a home garden. The crop association can take the form of several spatial or temporal patterns such as intercropping, where strips of each crop are alternated, mixed cropping, where rows of plants of both crops are associated, and relay cropping, when one of the crops is planted first, and when it flowers, the other crop is then planted. The most common annual crop associations are corn-beans, corn-beans-cassava, beans-plantain-cassava. The home gardens have a variety of crops and trees as earlier mentioned in the description of the diverse crops production system. The objective of multiple cropping is to keep the soil protected by crop cover and to enhance the amount and diversity of production.

Contour tillage

Contour tillage is more difficult than the up-and-down slope tillage method when using an ox to plow a furrow for the seed row. Cultivation of crops following the contour of the land supplements other practice, such as terraces and live barriers, by minimizing rill formation that would occur as runoff flows down the furrows or crop lines. Merely planting crops along the contour will not significantly reduce soil loss and runoff in steep slopes (Sheng 1989).

Conservation tillage

Conservation tillage has different variants; some are traditional methods practiced by the farmers from generation through generation and others are relatively new to the area. Three types of conservation tillage are practiced in the region: the *espeque* method, minimum tillage and no-tillage. The *espeque* method is traditional and the latter two have been introduced by personnel in conservation projects working in the area. The *espeque* method consists of slashing the weeds with a machete and leaving the residues on the field. Some farmers used to burn the weeds before or after they were cut, but this practice left the soil uncovered and more susceptible to erosion caused by the intense rains at the beginning of the *primera* (Smith 1997). Therefore, conservation projects have strongly discouraged use of fire. Crops are then planted by using a stick to make a hole in the ground to plant the seeds. The minimum tillage method refers to the practice of using as few passes of plow as possible to plant the crop (as opposed to the conventional plowing practices). The no-tillage method refers to slashing or applying herbicide to the weeds, leaving the residue on soil, and using special seeding equipment to plant the crop. This seeding equipment must usually be pulled by a tractor although a seeder has recently been introduced that can be manually pushed. Also, this practice requires frequent application of herbicides. The *espeque* method is most commonly used by subsistence farmers on steep slopes whereas the no-tillage method with the tractor-pulled equipment is restricted to communes or large farms located on gentle slopes.

Mechanical practices in the watershed involve mainly two types of terraces, contour terraces and individual basins. These are discussed below.

Contour terraces

Contour terraces are bunds of soil, often used in combination with live barriers. The terraces can built using either a tractor or an ox. The terraces are laid out on a level-grade and raised by excavating soil from the uphill side. They are low bunds that will progressively enlarge with sediment accumulation behind the live barriers. This accumulation of soil is aided by the practice of placing branches and vegetation residues on the uphill side of the live barriers.

Terracing is an old practice found throughout all the Pacific region of the country. There are farms that have had terraces since the 1960s, when the agricultural area of the Pacific region underwent the cotton boom and received all of the accompanying technological packages that went with it.

Individual basins

Individual basins are mainly used in coffee plantations. They help to retain runoff, therefore improving soil moisture content and nutrient retention. Usually cover cropping, mulching, and/or use of compost is combined with the use of individual basins. This practice has been applied for many years in the traditional coffee systems. Coffee producers experience their advantage by keeping soil moisture, and preventing fertilizer from washing away.

MATERIALS AND METHODS

Estimating erosion in the El Pital watershed using the Universal Soil Loss Equation (USLE)

Soil texture, slope degree, and land use data were obtained by field visits. Other sources (MARENA 1993; Mendoza and Rivas 1996).) provided information on some physical and climatic characteristics such as rainfall, soil characteristics, topography, and land use/land cover of the study area.

Parameters of the Universal Soil Loss Equation

Even though the Universal Soil Loss Equation is an empirical model developed for United States conditions, it has been widely used and has become the most commonly used soil erosion assessment tool in the world (Renard et al. 1996). The purpose of USLE is to provide an estimate of the long-term average annual soil loss from segments of arable land under various cropping conditions. This estimate helps farmers and soil conservation advisors to select combinations of land uses, cropping practices and soil conservation practices which will keep the soil loss at an acceptable rate. The USLE was not designed to predict soil loss outside the range of its own data base, for example the slope factor calculation is only valided for slopes between 1% and 16% (Hudson 1995). The USLE estimates the long-term average annual soil loss, assuming that over and under estimates of soil loss in individual storms will balance out over a long period (Wischmeier 1976). Because the USLE is based on soil loss observations in the U.S., where most of this empirical research was based on gentle to rolling slopes, the USLE tends to over-predict erosion on cultivated tropical steeplands. This is because the model was not designed for the high energy rainfall conditions and the types of soils common to the tropics (Smith 1997). Therefore, application of the USLE in tropical conditions is meaningful only if the results are not interpreted as absolute values, but rather as comparative values between land use, cropping systems, and soil conservation practices within a particular study area.

Soil erosion risk assessment

Soil erosion risk was estimated by applying the soil erosion factors established by the Universal Soil Loss Equation (USLE). The USLE equation is A= RKLSCP, where A is soil loss per unit area, R is the rainfall erosivity factor, K is the soil erodibility factor, L and S are the slope length and steepness factors, C is the cover and management factor, and P is the support practice factor (Wischmeier and Smith 1978).

Rainfall erosivity factor (R). Annual rainfall erosivity (R) is the average annual sum of individual storm erosion index (EI_{30}) values for a particular location. The E component is the total kinetic energy for an individual storm and event and I_{30} component is the maximum 30-minute intensity of the storm event (Wischmeier and Smith 1978).

Soil erodibility factor (K). The soil erodibility factor (K) is the rate of soil loss per rainfall erosion index units as measured on a "unit" plot. A "unit" plot is defined as a plot 22.13 m long and 1.82 m wide with a uniform length slope of 9%, in continuous bare fallow, tilled up and down the slope (Wischmeier and Smith 1978). Under these unit runoff plot conditions, K can be calculated directly from soil loss observations by dividing soil loss (A) by storm erosivity (EI_{30}) because LS, C, and P in those conditions are equal to 1.

Slope length and steepness factor (LS). LS is the ratio of soil loss on a given slope length and steepness to soil loss from a slope that has a length of 22.13 m and a uniform steepness of 9%, where all other conditions are the same (Renard et al. 1996). LS is a dimensionless value referenced to a value of one.

Slope length (L) is defined as the distance from the origin of runoff to the point where either the slope gradient decreases enough that deposition begins, or the runoff becomes concentrated in a well defined channel that may be part of a drainage network or a constructed channel (Wischmeier and Smith 1978). Slope steepness (S) incorporates the effect of slope gradient on soil loss. Soil loss increases much more rapidly than runoff as S increases. Soil loss increases more rapidly with S than it does with L (Renard et al. 1996).

Slope length (L) and slope steepness (S) factors can be computed by the following equation (Mitchell and Bubenezer 1980):

$$L\,S = (\lambda/22.1)^m\,(0.065 + 0.045\delta + 0.0065\,\delta^2)$$

where L = slope length factor (dimensionless)

λ = horizontal length of slope in m,

22.1 = unit plot length for USLE in m,

δ = slope steepness in %, and

m = variable slope-length exponent

The following algorithms apply for m (Wischmeier and Smith 1978):

If $\delta < 1\%$ then m = 0.2

If $1\% \leq \delta \leq 3\%$ then m = 0.3

If $5\% > \delta > 3\%$ then m = 0.4

If $\delta \geq 5\%$ then m = 0.5

Cover and management factor (C). C is defined as the ratio of soil loss from land cropped under specific conditions to the corresponding soil loss from clean tilled, continuous fallow (Wischmeier and Smith 1978). The C value is 1 when the soil has no cover and is clean tilled and continuous fallow (bare land). C represents the degree of protection that a particular cover and management provides. The USLE has a factor that can take into consideration land management practices (P). Conservation practices were not considered in the analysis of soil erosion risk due to lack of site specific data regarding the effectiveness of the various soil conservation practices. Quantifying conservation practice effectiveness at a field scale would enable the effectiveness of practices to be estimated. This is an area of research that requires future action.

The factors that determine the soil erosion risk are rainfall erosivity, soil erodibility, slope length and gradient, cover and management, and support practices. Obviously, it is very difficult to change R. It takes long time to transform K. LS can be modified with some soil an water conservation practices such as terraces. Cover and management conversion can make a great difference in the modification of erosion hazard within the watershed. Moreover, the effect of the soil and water conservation practices applied by the farmers in the watershed definitely have a big influence on the reduction of soil erosion risk. The conservation practices applied within the watershed have multiple benefits because they offer soil surface protection, increase soil fertility, improve soil structure, diminish runoff, and increase infiltration rates.

The importance of cover in reduction of soil erosion is demonstrated in many studies (Hudson 1995, Nill et al. 1996, and Smith 1997). In this study, a typical C factor value for the respective land uses was chosen for the calculations. Therefore, if a particular soil and water conservation practice is applied that could improve cover, it would reduce the soil erosion risk. Doing an analysis of practice by practice, it is possible to estimate how much the conservation practices are reducing soil erosion.

The influence of the cropping systems is divided into the following subfactors (Nill et al. 1996):

1. influence of canopy cover (c1),
2. influence of mulch or vegetation close to the soil surface (c2),
3. tillage and residual effects of the former vegetation (c3).

Parameterization of the USLE for the El Pital watershed

There were two different procedures used for the estimation of potential soil erosion. One was done based on the information gathered through the interviews and field visits in 1996, and the other was estimated using information such as black and white aerial photographs from 1968 and 1987, topographic maps, and the MARENA soil survey. Each of those approaches for estimating the USLE parameters will be described separately.

Estimation of soil erosion risk for 1968 and 1987

The estimation of soil erosion risk was done at a resolution of 50 by 50 meters. A mean value by each *comarca* was also estimated from the GIS overlays.

R factor. For both estimation techniques, the R factor was calculated by applying regional observations that correlate mean annual precipitation (mm) to values of rainfall erosivity factor SI-metric unit (Mj·mm/ha/hr/yr) (Smith 1997). The annual precipitation isoheyts of the watershed (MARENA 1993) were used to delimit the rain erosivity factor areas.

K factor. The soil inventory from the CARE Project Document was utilized to obtain soil texture and categorize it at the *comarca* level (MARENA 1993).

Mendoza and Rivas (1996) calculated the K factor for three years in three different runoff plots sites located within the watershed. The study of Mendoza and Rivas established that the Niquinhomo soil series (silty sand) had a K factor equal to 0.032, and those soils from the Diriomo soil series (silty clay) had a K factor equal to 0.016 (SI-metric unit system). The K factor values applied in both estimation techniques were based on these data.

LS factors. The LS factors were calculated using a slope map. A standard length of 100 m was assumed when applying the USLE-LS formula (Wischmeier and Smith 1978).

C factor. The land use/land cover maps of 1968 and 1987 were deliniated into nine different types of land use. Each type was assigned a C value based on C factors determined in similar tropical conditions (Nill et al. 1996). These C factor estimates are similar to those estimated by Mendoza and Rivas (1996) in the watershed. The values of cover and management factor were used accordingly with the portion of land devoted to that particular use. The C factor values were applied according to the distinct types of land use that appears in the aerial photographs (Table 1).

Estimation of soil erosion risk for 1996

The estimation of soil erosion risk was done at farm level and a weighted mean by *comarca* was calculated. For each farm the erosion risk was calculated based on the survey data and field observations.

K factor. Soil texture data were obtained by direct examination of the soil on each farm sampled during the interview process. These observations were used to assign a soil type within each *comarca*. The K factor values applied were based on the study mentioned earlier (Mendoza and Rivas 1996).

Table 1. Cover and management factor values of the Universal Soil Loss Equation for the El Pital watershed, Nicaragua

Land Use	C factor
Forest	0.002
Mixed range	0.004
Bush range	0.01
Grass range	0.05
Perennial crops	0.01
Mixed crops	0.16
Annual crops	0.35
Urban areas	1.0
Streams and Lagoons	1.0
Fallow areas	0.06

LS factors. The LS factors were calculated by applying the mean farm slope gradient by direct examination of each farm sampled during the interview process to a uniform length of 100 m (Wischmeier and Smith 1978).

C factor. The specific land use classification used to estimate the cover factors C were calculated from each surveyed farm crop. The C factor values represent five broad types of land use existent in the watershed: annual crops (grains, vegetables), perennial crops (coffee, citrus, banana, pineapple), grassland, forestland, and fallow. There were five different C factor values applied according to the portion of land devoted to annual crops, perennial crops, range, forest, and fallow for each farm (Table 1). The C values were based on the same references as used for the 1968 and 1987 calculations (Nill et al. 1996; Mendoza and Rivas 1996).

The farmer survey

A field survey was done to collect the biophysical and socioeconomic information needed to analyze the extent to which these factors influence the degree of adoption of soil conservation technology.

Design and application. The survey instrument was designed to gather selected socioeconomic information that may influence the adoption of soil conservation practices. Information of the farm physical characteristics, farming systems, and crops, were also collected. Colleagues of the National Agrarian University (UNA) in Nicaragua who are familiar with the study site and the lifestyle of people in the region reviewed a draft survey instrument and their suggestions were incorporated into the survey. The survey instrument was reviewed and applied in Spanish.

The survey instrument was divided in 4 sections: general characterization, socioeconomic aspects characteristic of the farm family and the farming systems, technological aspects of farming practices used, and soil conservation practices with which the survey participants were familiar and their perspectives regarding adoption considerations (Appendix A). In the general characterization section, the location of the farm (department, municipality and *comarca*), land tenure, farm size, topography, soil texture, and land use partitioning for the current year were recorded. Socioeconomic aspects included labor force used in the farm, time of permanency, crops yields, limiting factors to increase productivity, long-term concerns, long-term hopes, access to credit and market orientation. Technological aspects included use of chemicals (herbicides, pesticides, fertilizer) and provision of technical assistance. Information on soil and water conservation practices were obtained by questions to determine farmer knowledge about the subject and factors farmers considered important regarding adoption decisions associated with specific soil and water conservation practices.

The surveys were conducted in a manner designed to get a representation of land use/land tenure patterns within the boundaries of the political subdivisions (*comarcas*) of the watershed. The sample was drawn from nine different categories observed throughout the watershed. Fifteen farmers in each of nine land use/land tenure categories (Table 2) were surveyed (135 farmers total) throughout the watershed. These categories were delimited based on the types of land tenure (private or beneficiary of agrarian reform (BAR)) and the predominant crop emphasis on the farm (grains, diverse crops, coffee, livestock) existent in the watershed. Due to the socioeconomic conditions and the management of farming systems, cultivating grain crops on the hillsides is very different from grain crop production systems on the plains. Therefore, grain crops were separated into two categories: grain production on the hillsides and grain production on the plains. The diverse crops category included farming systems dominated by production of vegetables and fruits. The other two land use categories were coffee and livestock production. Originally, it was intended that there be ten land tenure/crop emphasis categories (150 samples); however, during the course of the field work, it was found that there were no BAR groups that were primarily engaged in livestock production. BAR farmers typically own only a few cattle for self-consumption.

The BAR are peasants who received land as a cooperative group, after which the land area was divided for management by individual farmers. The agrarian reform took place during the Sandinista revolution (1979-1990). A transformation in rural areas changed the relations of production and distribution. The agro-export model of the Nicaraguan economy before the decade of revolution consisted of a private, modern sector of relatively few wealthy landowners and a relatively large, poor peasant sector

Table 2. Number of farmers interviewed associated with the different land tenure and predominant crop emphasis categories in the El Pital watershed, Nicaragua

Predominant crop emphasis on farm	Number by land tenure	
	Private	Beneficiary of Agrarian Reform
Basic grains on plains	15	15
Basic grains on hillsides	15	15
Diverse crops	15	15
Coffee	15	15
Livestock	15	-

that farmed using traditional methods on land to which most had insecure or no tenure rights. The 1963 national agricultural census reported that 50.8% of the total number of farms were smaller than 10 *manzanas* (7 hectares), and accounted for not more than 3.5% of the total farm land. On the other hand, farms which were larger than 200 *manzanas* (140 hectares), represented only 4.9 % of the number of farms but occupied 58.8% of the farm land. The Land Reform Law of July 1981 formally legalized the process of confiscating farm land that was judged to not be used to its potential (Spoor 1995). The confiscation mainly targeted on large private farms in possession of the Somoza family (the ruling family prior to the 1979 revolution), and their political allies. The farm land was redistributed to landless peasants in the form of cooperatives. Cooperative holdings of farm land grew from 0 % in 1978, 23.4 % in 1981, and 39.7 % in 1988.

Private ownership refers to land that has been bought or inherited and for which a legal title is possessed. Private land in the watershed has generally been occupied for more than 50 years. The private sector had a significant change in the distribution of land, with large farms of more than 500 manzanas (350 hectares) being gradually reduced from occupying 36.3% of the land area in 1978 to 9.4% in 1988. Agricultural producers owning between 35 and 140 hectares were generally not affected by the agrarian reform, nor were the larger farms of those who were considered as anti-Somoza bourgeoisie or "patriotic" commercial farmers (Spoor 1995). Public investment in the agricultural sector during the 1980s period of the Sandinista government pretty much ignored private farmers and was almost exclusively directed at the state sector and the cooperatives (Spoor 1995).

Cooperation was solicited from different institutions and projects working in the study area to aid in the selection of farmers who owned land within the watershed. The Nicaraguan Agricultural Technology Institute (*Instituto Nicaraguense de Tecnologia Agropecuaria* - INTA), National Union of Farmers and Cattle Ranchers (*Union Nacional de Agricultores y Ganaderos* - UNAG), Union of Nicaraguan Coffee Producers (*Union Nicaraguense de Caficultores* - UNICAFE), the Agroforestry Project El Pital from CARE, and the European Economic Community (*Comunidad Economica Europea*) CEE-ALA Project in Region IV, provided a list of the farmers served by each organization. From the combined list, a random selection of farmers was made within each of the nine categories. To avoid interviewing only farmers receiving technical assistance from one or more institutions, about 25% of the sample population was randomly selected from residents who were not on any of the lists.

Questions regarding land tenure, limiting factors of the farming system, long-term concerns, long-term hopes, application of soil and water conservation practices and a subjective characterization of the quality of conservation technical assistance they received were recorded according to the response of the farmer.

Data analysis . The primary emphasis of the farming system employed by each household was used to characterize the farm in the following land use types:

Annual crops - These crops are planted each year and include corn, beans, sorghum, rice, and vegetables. The cover provided by these crops is limited to the rows, between rows is mainly bare soil.

Perennial crops - Crops planted generally without tillage that can remain for more than one year in the field. There is not fallow period between harvest. The crop cover is generally dense and protects the soil within the rows as well as between rows. They include fruit trees, coffee, plantain, pineapple.

Rangeland - Areas dominated by grass and shrubs and utilized for cattle production.

Forestland - Areas of semi-dense and dense natural forest or reforested areas.

Fallow - Areas with bare land or poor grass cover. Left without cultivation because of its unfavorable conditions or farmer' insufficient funds to cultivate them.

The predominant crop emphasis on the farm (Table 2) were five groups that combined with the land tenure category were used to analyze the different factors influencing the decisions about crop selection and its relationship with soil erosion risk.

An analysis of the relation to farm size, land ownership, access to technical assistance, and other socioeconomic factors was done to test the hypothesis that national agricultural production policies (e.g., credit availability, market regulation, and technical assistance) are related to farmers' decisions regarding implementation of soil conservation practices. The statistical analysis to compare means among the land tenure and crop emphasis of farm utilized the Duncan test at an alpha level of 0.05.

The socioeconomic data were associated with the nine land tenure and crop emphases relates to the farm categories. The factors analyzed assisted in the identification of the barriers that impede the adoption of soil conservation practices. An analysis of the frequency of application of each conservation practice among the nine categories and farm size explored the influence that land tenure, farm size, and quality of technical assistance have over adoption of conservation practices. The limiting factors, long-term concerns, and long-term hopes were examined by the nine groups in terms of the frequency of a particular appointed response by the farmers.

Use of GIS for erosion analysis

The rainfall erosivity, soil erodibility, slope steepness, and the 1968 and 1987 land use were depicted as GIS layers. With the 1996 data, five broad land use types and various socioeconomic factors were used. Table 3 is a summary of the data layers produced as part of the GIS. These maps placed in a GIS data base illustrate the spatial relationship among these variables.

Aerial photograph analysis of land use

Two sets of aerial photographs from the watershed, one set from 1968 (1:30,000) and the other set from 1987 (1:25,000), were used to contrast how land use changed during the period between the photographs dates. Land use/land cover maps of different years were produced. The different land use/land cover characteristics were interpreted and delineated for each of the 72 photographs. Each photograph was analyzed as map traced to paper (mylar), using stereoscopic enhancing. The individually

Table 3. GIS data layers used to classify various characteristics in the El Pital watershed, Nicaragua

Data layer	Classes 1	2	3	4
Mean farm size (ha)	2 - 5	6 - 15	16 - 40	> 40
Land use diversity index	0.40 - 0.50	0.51- 0.65	0.66- 0.79	0.80 - 0.90
Land devoted to annual crops (%)	0 - 10	10 - 20	20 - 40	40 - 60
Land devoted to coffee (%)	0	1 - 10	10 - 40	40 - 64
Land devoted to other perennial crops (%)	0 - 10	10 - 20	20 - 30	30 - 45
Land devoted to range (%)	0 - 10	10 - 20	20 - 30	30 - 76
Mean number of soil and water conservation practices applied per farm	0 - 1	1 - 2	2 - 3	3 - 5
Land use map	Annual crops	Perennial and mixed	Range	Forest
Rainfall erosivity (Mj·mm/ha·hr/yr)	7500	8900	10600	11800
Soil erodibility (Tons/ha /Mj·mm/ha·hr)	0.016	0.032		
Mean slope (%)	0 - 1	2 - 10	11 - 30	> 30
Cover factor (C values)	0.0002 - 0.004	0.01 - 0.05	0.16	0.35
Mean soil erosion risk by *comarca* (Tons/ha/yr)	0 - 10	10 - 20	20 - 40	> 40
Explicit soil erosion risk (Tons/ha/yr)	Negligible 0 - 2	Low 2 - 10	Moderate 10 - 40	High > 40

traced maps were scanned as a run length encoding (rle) file and put into a Geographic Information System (GIS), using "IRASB" from the Modular GIS Environment (MGE) program. The individual rle files were wrapped together, conforming to the watershed mosaic. The watershed mosaic was geo-referenced using scanned topographic maps to fit the land use mosaic and "IRASB" was used to wrap it to the topographic maps. The mosaic was a rle file that needed to be vectorized and converted to a .dgn (design) file, in order to generate polygons which could be measured. The vectorization was done for both 1968 and 1987 mosaic. The land use mosaic .dgn file was exported to ARC INFO and converted to an ARC file. In ARC INFO, the mosaics were transformed into polygon coverages. In ARC VIEW, the attributes of the land use were assigned to the polygon coverage. Nine different classes were used: annual crops, perennial crops, mixed crops, grass range, shrub and bush range, mixed range, forest, streams and lagoons, urban residential and agro-buildings. To obtain the area of each land use class, the land use field was converted to a grid format, and the area for each class of land use was then computed in units of hectares.

Land use diversity was calculated using the survey data by means of the estimation of a diversity index (Simpson 1949). These data were used to create a land use diversity index map.

Generation of the isoheyt and comarcas maps

The rainfall erosivity (R) factor layer was created by scanning the isoheyts map 1:50000 of the watershed (MARENA 1993) and vectorizing the map in MGE to make it a .dgn file. The isoheyts .dgn file was exported to ARC INFO to be converted to an ARC file.

The *comarca*s division in the watershed was performed vectorizing the divisions over the scanned isoheyts map 1:50000, that also contained the names and location of the *comarca*s. The *comarca*s boundaries were delineated using input by the farmers which were collected during the survey. The *comarca*s .dgn file, as well as all the other .dgn files, were exported to ARC INFO.

Generation of the slope map

Topographic maps (1:50,000) were used to characterize slope in a GIS format. To input the topographic data into a GIS format, the maps were scanned as a rle file in GEOVEC from INTERGRAPH and georeferenced for each sheet designating the latitude and longitude coordinates to each corner of the maps. Subsequently the map contour lines were vectorized for each one of the four topographic sheets that contained the watershed area one at a time, obtaining four .dgn files. When the contour lines were vectorized, the four maps were attached together to comprise the whole watershed area and were saved as a single .dgn file. Next, the .dgn file was transferred to ARC INFO. With ARC EDIT, applying the "UNSPLIT" command, the divided contour lines were connected to create continuous contour lines from the segmented contour lines on the

.dgn file. ARC VIEW was used to assign elevation to each contour line. A slope map was obtained from a query and display front end to ARC INFO grid of the contour lines applying the "Derive Slope" command in ARC VIEW. The watershed boundary was delineated manually over the contour lines of the scanned topographic map in GEOVEC.

Production of GIS layers

All the .dgn files, isoheyts, contour lines, land use patterns, and *comarca* maps were converted to an ARC format and projected to the latitude and longitude coordinates in Transverse Mercator Projection.

The "fields" of the USLE R factor were created using the map polygons table to attach the attribute values. The polygons were converted to a grid with the values of the field R factor.

In each *comarca* polygon, the attributes of the soil erodibility (K) factor were assigned, as well as other socioeconomic variables such as mean farm size, land use diversity index, percent of private ownership, and mean potential soil erosion. To obtain the K factor layer the respective field was converted to a grid format.

The LS factor was calculated with the slope decline value of the slope map and a standard 100 m length using the LS formula previously discussed (Wischmeier and Smith 1978). Cover (C) factors for the nine types of land use were assigned to the land use map for 1968 and 1987. Then a grid was generated with the field C factor. All the grid cell size for the USLE factors are of 50 meters of resolution.

Overlay and generation of results

To link the USLE to the GIS program, an arithmetic overlay was performed for each of the data layers generated by USLE factor. Therefore, there were separate overlays for the erosivity factor (R), the erodibility factor (K), the slope length and degree factors (LS), and the cover factor (C). The arithmetic overlay to apply the USLE was performed in ARC VIEW. The results were in the form of maps of estimated annual soil erosion. The area covered by the different land use type in the watershed were calculated in ARC VIEW. The differences of area by land use type between 1968 and 1987 were computed.

Information from the survey that was input into the GIS included mean farm size, land use diversity index, and mean number of conservation practices.

RESULTS AND DISCUSSION

Characteristics of the watershed used to estimate erosion

The spatial pattern throughout the El Pital watershed for rainfall erosivity (R), soil erodibility (K), and slope (S) were used to estimate erosion in the El Pital watershed associated with the land use patterns in 1968, 1987, and 1996.

Rainfall erosivity (R). The rainfall erosivity pattern within the watershed (Figure 2) was influenced by the orographic characteristics of the watershed. The lowlands received less than the uplands, the central valley in the uplands received more rain than the surrounding upper portions of the valley ridges. It is notable that the lowest erosivity values are located in areas with gentle slopes and the highest erosivity values are located in the areas with steep and rolling slopes. This map was used in the erosion estimates for 1968, 1987, and 1996.

Soil erodibility (K). The soil erodibility pattern within the watershed (Figure 3) was influenced by the distribution of two primary soil groups found within the watershed, one being sandy loam and the other being a clay loam. The detachability and transportability of the clay loam soils made them somewhat more erodible than the characteristics of the sandy loam. This map was used in the erosion estimates for 1968, 1987, and 1996.

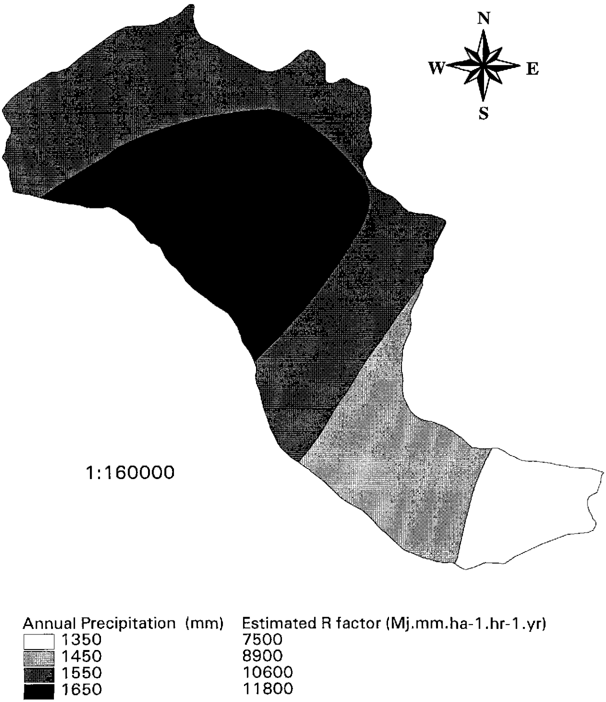


Figure 2. Mean annual precipitation and the associated rainfall erosivity factor map of the El Pital watershed, Nicaragua

Figure 3. Soil erodibility map of the El Pital watershed, Nicaragua

Slope (S). The slope pattern within the watershed is shown in Figure 4. The steepest slopes are in the area around the Mombacho volcano at the east-central edge of the watershed. In the middle upper portion of the watershed rolling slopes of 10% to 40% are found, whereas the lowland portion of the watershed is characterized by gentle slopes ranging from 0% to 5%. The slope has a great influence over the soil erosion risk pattern. This map was used in the erosion estimates for 1968 and 1987.

Cover estimates from aerial photographs

Aerial photographs of the watershed were available for 1968 and 1987. These were used to characterize existing land use at those times (Figures 5 and 6). The cover factor associated with those land use patterns for 1968 and 1987 is displayed in Figures 7 and 8, respectively. The land use in the watershed is shifting to annual crops and grassland at the expense of forest and range. This trend has resulted in reduced cover and increased soil erosion risk between 1968 and 1987 (Table 4). Forest, mixed crops, and mixed range area has been reduced by 51%, 62%, and 67% respectively, whereas annual crops increased 29%, grass range 489%, and perennial crops increased by 14%.

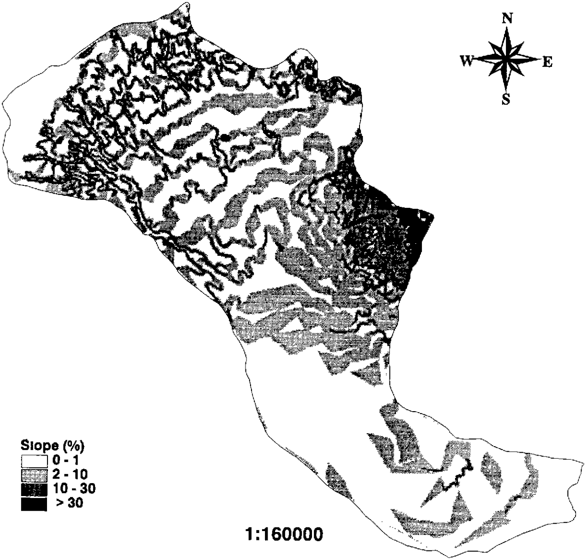


Figure 4. Slope map of the El Pital watershed, Nicaragua

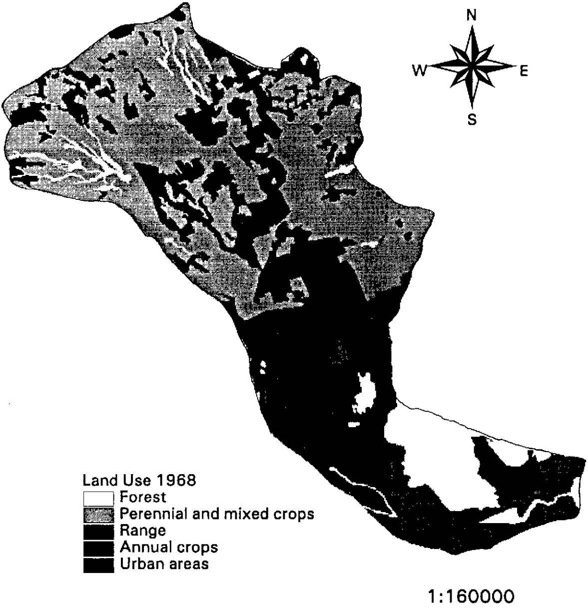


Figure 5. Land use map for 1968 within the El Pital watershed, Nicaragua

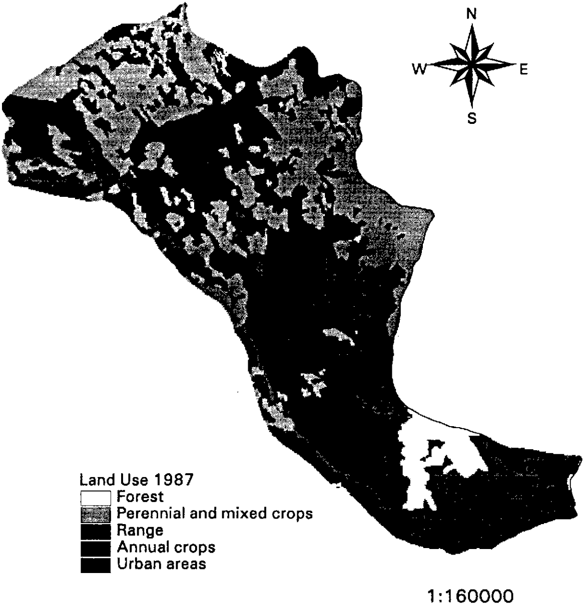


Figure 6. Land use map for 1987 within the El Pital watershed, Nicaragua

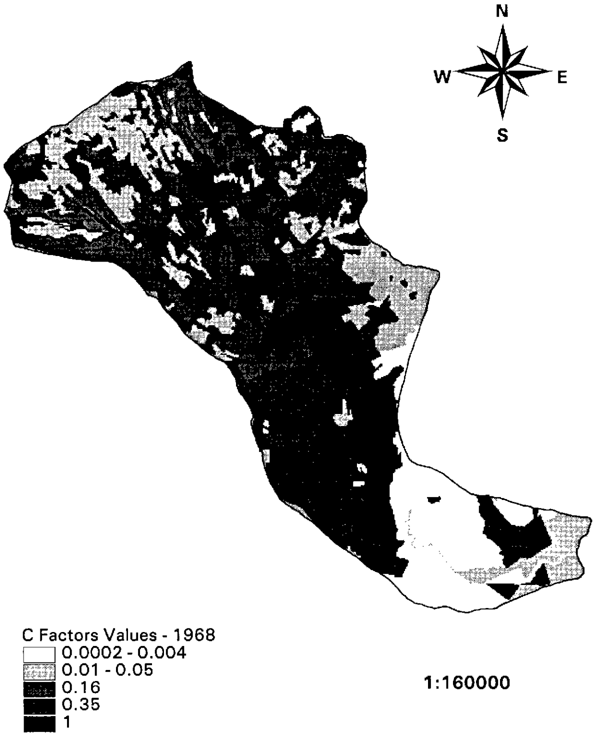


Figure 7. C factor values for 1968 within the El Pital watershed, Nicaragua

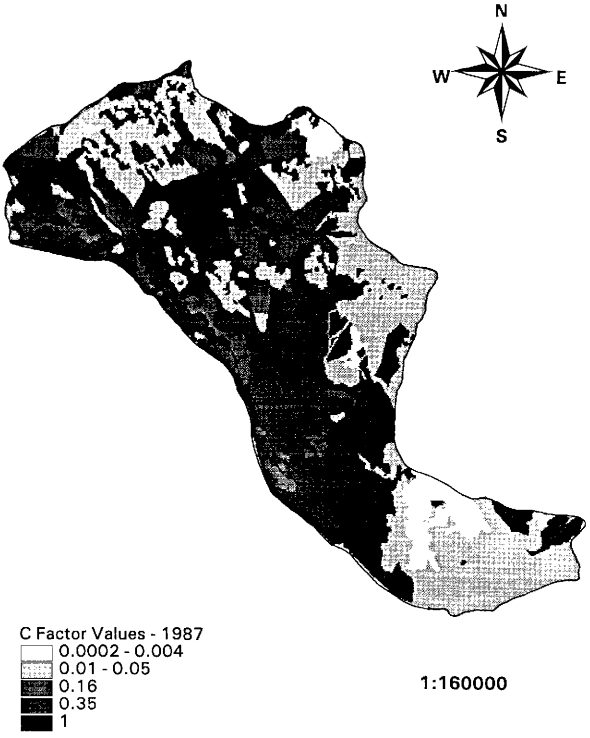


Figure 8. C factor values for 1987 within the El Pital watershed, Nicaragua

Table 4. Land use change between 1968 and 1987, El Pital watershed, Nicaragua

Land Use	Area (ha)		Difference between years (ha)	Difference between years (%)
	1968	1987		
Forest	1,637	803	- 834	- 51%
Annual crops	8,599	11,105	2,506	29 %
Perennial crops	3,354	3,813	459	14 %
Mixed crops	5,628	2,132	-3496	- 62%
Grass range	413	2,432	2,019	489%
Bush range	318	453	135	42 %
Mixed range	1,116	364	-752	- 67 %
Streams	418	358	-60	- 14 %
Lagoons	12	15	3	27 %
Urban-residential	152	182	30	20 %
Agro-buildings	24	14	-10	- 42 %
Sum	21, 672	21, 672	0	

Erosion estimates from aerial photographs

The estimated potential soil erosion for 1968 and 1987 was displayed in Figure 9 and 10, respectively. The soil erosion risk pattern shows that the area with greater erosion has increased between 1968 and 1987. A map query technique was used to estimate that the area with potential soil erosion greater than 40 Tons/ha/yr in 1968 was 4,538 ha. whereas in 1987 it increased to 4,752 ha. In addition, an estimate of erosion was made as if the entire watershed was still covered with native vegetation unimpacted by human activity. This estimate represents the geologic "natural" erosion that would occur in the absence of man (Figure 11). This estimate provides a benchmark against which the 1968 and 1987 erosion estimates can be compared (Figure 9 and 10). The difference between these estimates and the geologic erosion estimate is considered accelerated "human-induced" erosion. Doing a map query, it was found that the soil erosion greater than 40 Tons/ha/yr under natural vegetation is only 220 ha in the whole watershed.

Cover from 1996 survey data at the comarca level

A map with the *comarca* boundaries and names is displayed in Figure 12. The land use change in 1996 continued to follow the same trend that was evident from 1968 to 1987, namely that the portion of land devoted to annual crops was increasing in the middle and upper portion of the watershed (Figure 13). Unfortunately, much of this land is also inherently more susceptible to erosion because of the associated greater values for R and S (i.e., San Diego, Jose Benito Escobar, Hoja Chigue, Palo Quemado, and El

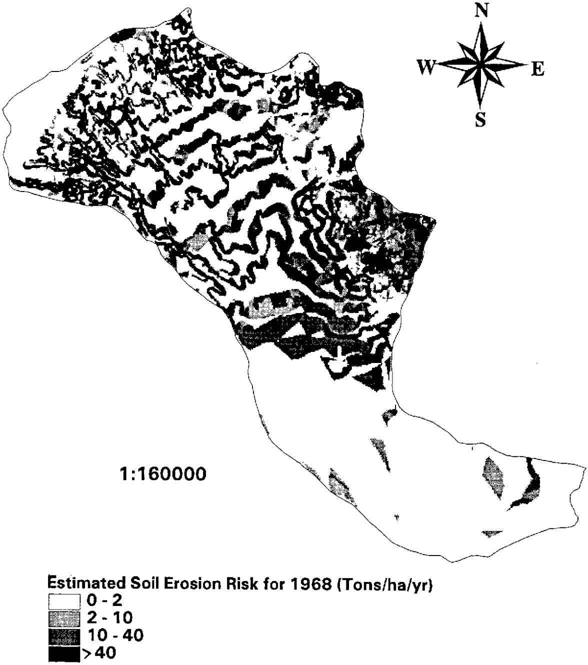


Figure 9. Universal Soil Loss Equation estimates of the soil erosion pattern within the El Pital watershed in 1968

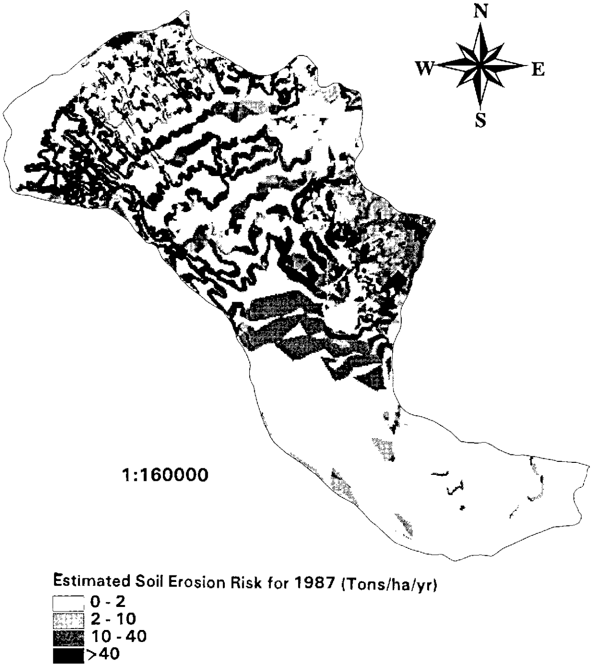


Figure 10. Universal Soil Loss Equation estimates of the soil erosion pattern within the El Pital watershed in 1987

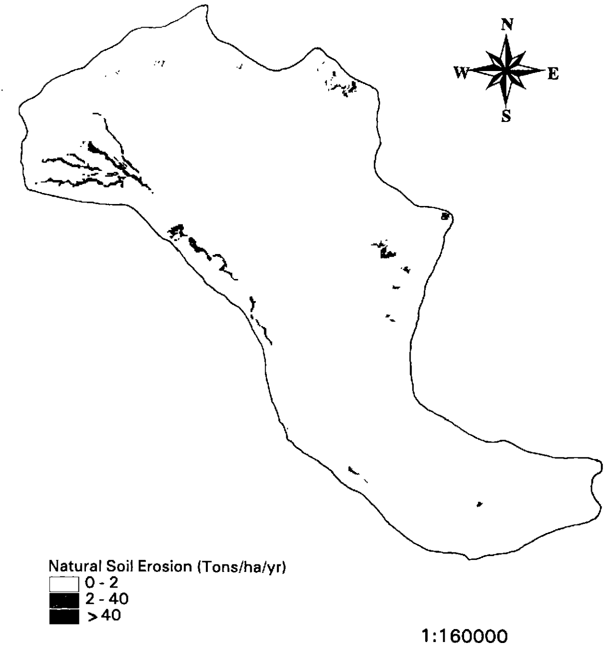


Figure 11. Estimated geologic erosion that would occur under natural vegetation uninfluenced by human activity, El Pital watershed, Nicaragua

Figure 12. Comarcas within the El Pital watershed , Nicaragua

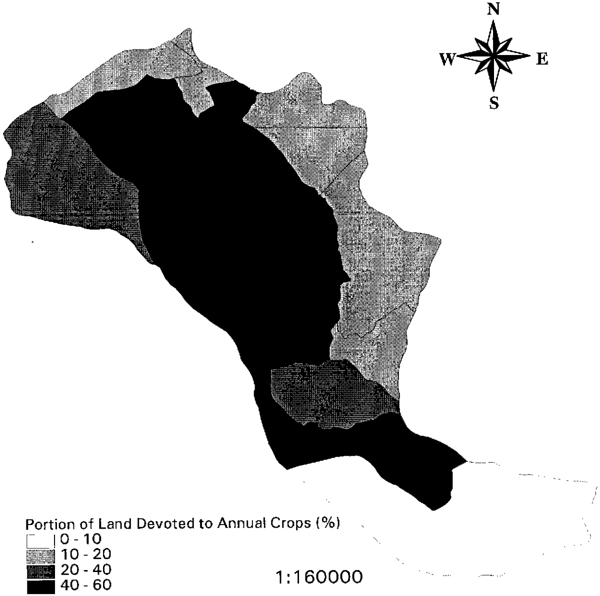


Figure 13. Portion of the land devoted to annual crops by comarca, as determined by the 1996 farmer survey, El Pital watershed, Nicaragua

Portillo comarcas). This differs from other *comarca*s that have high R and S values too, but the predominant land use is coffee (Figure 14), such as in Niquinohomo, El Mombacho, San Jose de Masatepe, and Veracruz where the soil risk is half of the first mentioned. *Comarca*s in the lowland part of the watershed, such as Dolores, los Ranchones, and Cuatro Esquinas, still have a great amount of land devoted to rangeland (Figure 15).

Comarca-level erosion estimates

Estimation of soil erosion risk using the survey data (Appendix B) was conducted by comparing the mean soil erosion risk of the three years 1968, 1987, and 1996. These results clearly showed a growing area spreading within the watershed with extremely high erosion risk of more than 40 Tons/ha/yr (Figures 16, 17, and 18). To compare the geologic erosion estimated between 1968, 1987, and 1996, a mean estimated by comarca is presented in Table 5. The *comarca*s with greater risk are distinguishable the same for the three years (Table 5). This zone coincides with the years where the major expansion of annual crops is taking place (Figure 5, 7, and 13). If the *comarca*s with a greater portion of land devoted to coffee in 1996 (Figure 13) are compared with the *comarca*s with 40 - 60% devoted to annual crops, it is evident that the soil erosion risk is lower for the coffee-dominated lands (Figure 18), even though the slope inclination is greater in the areas where coffee is the predominant crop (Figure 4).

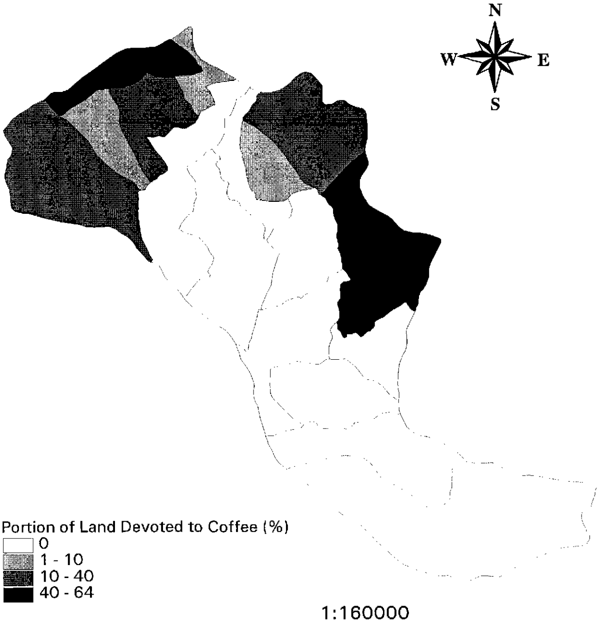


Figure 14. Portion of the land devoted to coffee by comarca, as determined by the 1996 farmer survey, El Pital watershed, Nicaragua

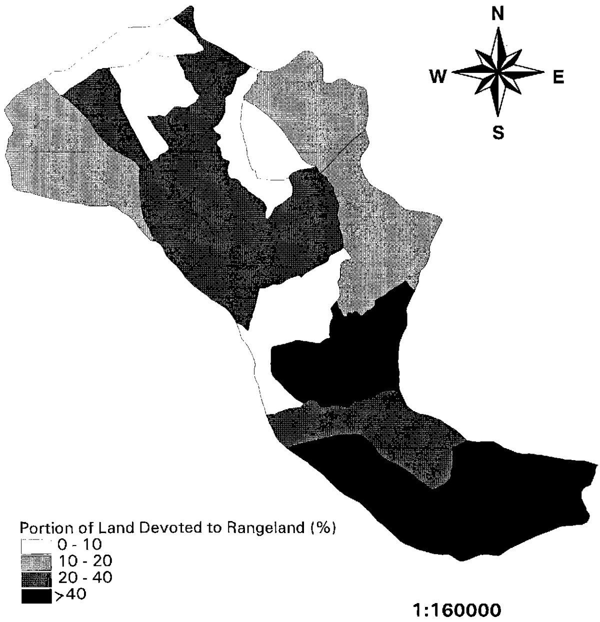


Figure 15. Portion of the land devoted to range by comarca, as determined by the 1996 farmer survey, El Pital watershed, Nicaragua

Table 5. Mean soil erosion risk by comarca. Estimates were calculated assuming no soil and water conservation practices were applied, El Pital watershed, Nicaragua

Comarca	Soil Erosion (Tons/ha/yr)			
	1996	1987	1968	Geologic
Dolores	8	8	8	2
Cuatro Esquinas	21	3	3	1
Los Ranchones	29	30	15	4
El Mombacho	37	31	28	6
La Granadilla	37	28	30	4
Niquinohomo	39	18	14	5
San. J. de Masatepe	42	21	16	10
Agua Agria	43	16	15	0
San. Jn de Oriente	50	36	28	2
El Portillo	51	27	22	5
Veracruz	52	22	16	9
Rolando Espinoza	64	22	20	0
El Coyolar	80	40	36	8
Hoja Chigue	90	33	27	4
Jose B. Escobar	101	56	35	0
Palo Quemado	108	38	36	10
San Diego	132	50	43	2

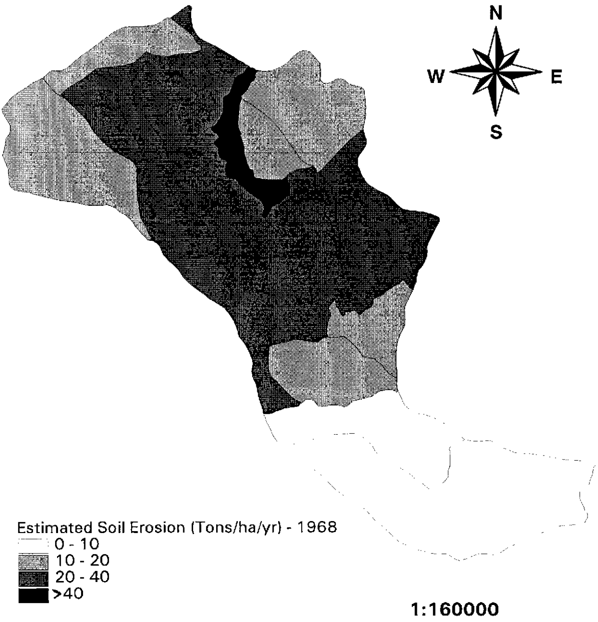


Figure 16. Estimated mean soil erosion by comarca in the El Pital watershed, Nicaragua using 1968 aerial photo cover estimates

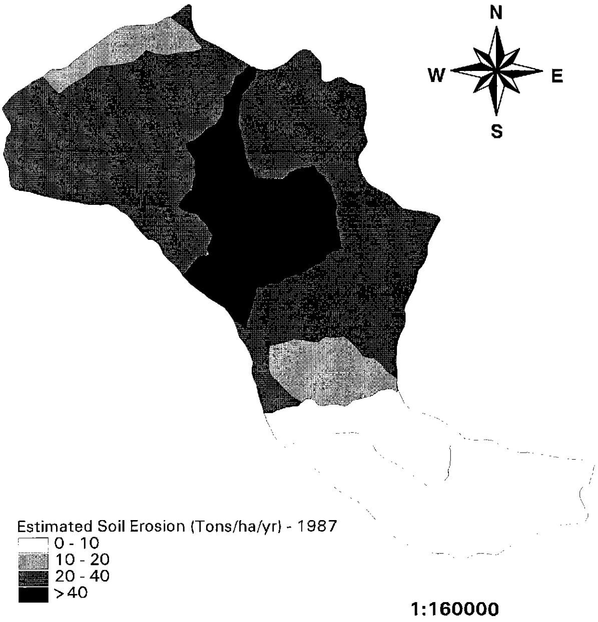


Figure 17. Estimated mean soil erosion by comarca in the El Pital watershed, Nicaragua using 1987 aerial photo cover estimates

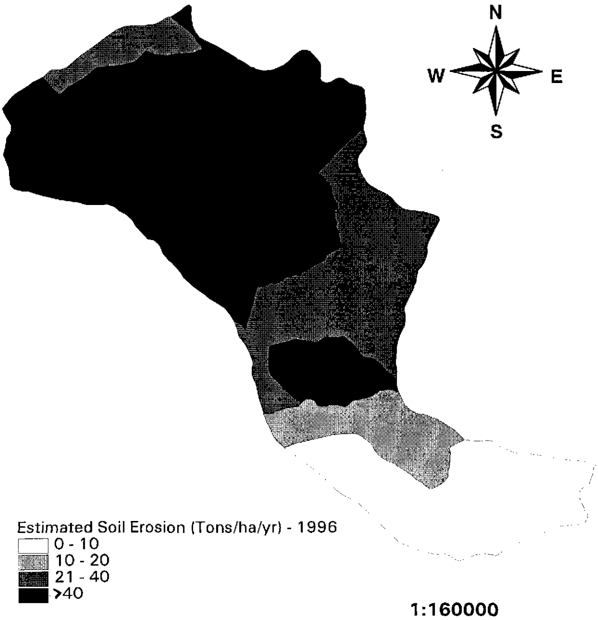


Figure 18. Estimated mean soil erosion by comarca in the El Pital watershed, Nicaragua using farmer surveys to provide cover estimates for 1996

Factors influencing trends in land use and erosion hazard

Farm size. Farm size is related to the type of crops grown and the land use diversity. Small farms tend to be more intensively managed than big farms, therefore small farms tend to have a land use diversity index higher than large farms (Table 6). Figure 19 and Figure 20 illustrate that mean farm size and land use diversity are inversely related.

The relationship between farm size and percent of self-consumption is inversely related with most of the farm production on small land holdings directed to self-consumption (Figure 21). The exception to this trend is the diverse crop category, which shows that even though the mean farm size is 4 ha, most of the production is intended for sale by both land tenure groups. This suggests that the diverse crops category tends to maximize the land use and have greater farm productivity than both grains categories.

The hypothesis that farm size is related to decisions about crop selection is strongly supported by the relationship between portion of land devoted to a particular type of land use and mean farm size. The portion of the farm devoted to annual crop production tends to increase in curvilinear fashion as farm size decreases, regardless of whether the land tenure history is private or BAR. Although BAR farmers tend to keep a considerable portion of farm cultivating annual crops (about 40%) even at a large farm size, private farmers tend to reduce the amount of land devoted to annual crops to almost 0% when the farm size increased above 10 ha (Figure 22). A possible explanation is that the large BAR farms that are grouped as cooperatives are in fact

Table 6. Land use diversity index and mean farm size by *comarca*, El Pital watershed, Nicaragua

Comarcas	Land use diversity index	Mean farm size (ha)
Dolores	0.40	347.86
Cuatro Esquinas	0.82	3.75
Agua Agria	0.65	6.08
Los Ranchones	0.53	17.13
El Mombacho	0.68	37.33
Guillermo Roncales	0.89	2.40
Jose B.Escobar	0.87	3.93
El Coyolar	0.84	2.24
San Diego	0.85	3.87
Rolando Espinoza	0.87	3.39
Veracruz	0.72	7.14
Palo Quemado	0.80	2.28
El Portillo	0.75	12.49
Hoja Chigue	0.85	2.38
San. Juan de Oriente	0.70	6.35
Niquinohomo	0.55	6.42
San. Jose de Masatpe.	0.85	2.82

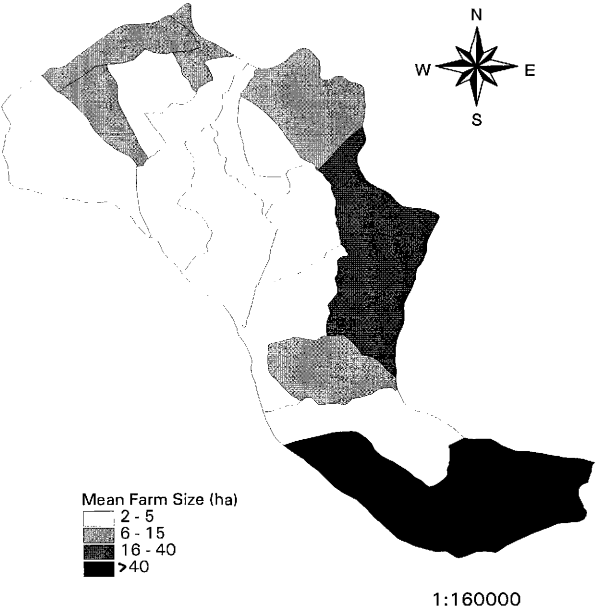


Figure 19. Mean farm size by comarca, as determined by the 1996 farmer survey, El Pital watershed, Nicaragua

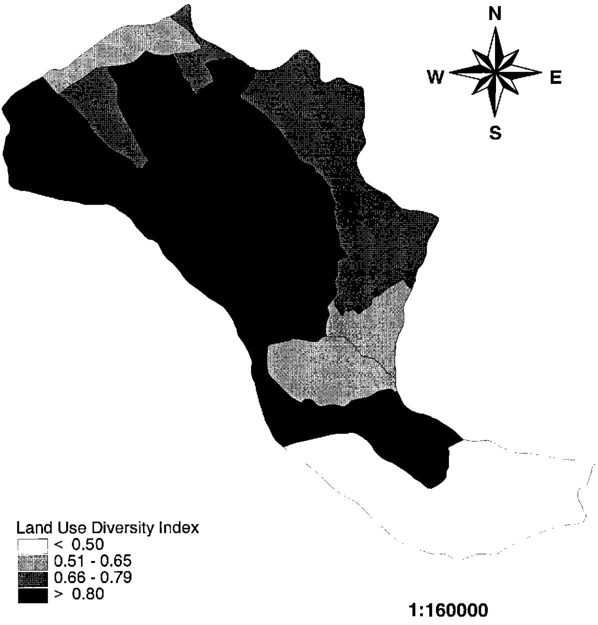


Figure 20. Land use diversity index, mean by comarca, as determined by the 1996 farmer survey, El Pital watershed, Nicaragua

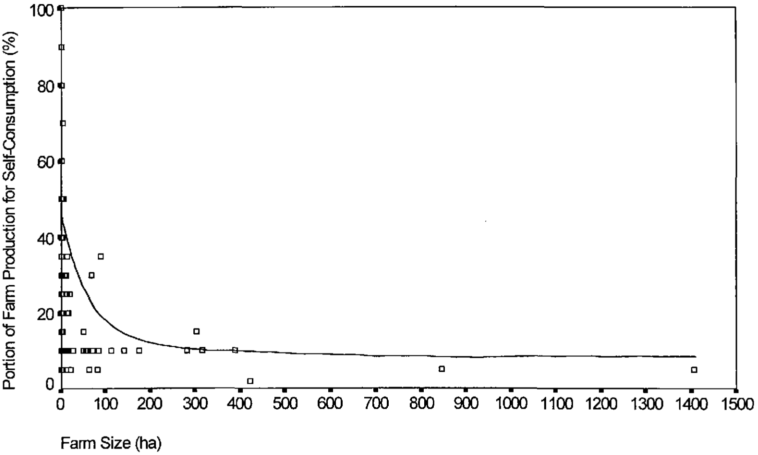


Figure 21. Portion of farm production used for self-consumption and its relationship with farm size, El Pital watershed, Nicaragua

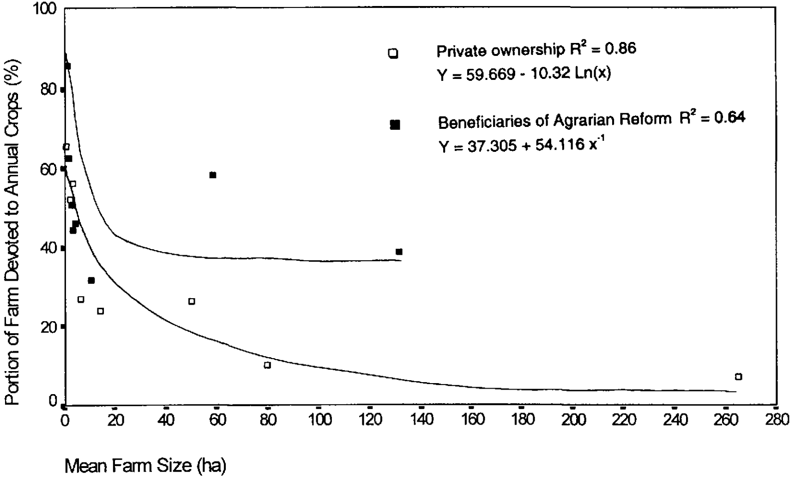


Figure 22. Portion of land devoted to annual crops and its relationship with mean farm size, El Pital watershed, Nicaragua

many farmers working together to cultivate some cash crops (e.g., coffee) also cultivates annual crops to meet their food needs. Therefore, even though some cooperatives represent large land holdings, the resident of the cooperatives actually behave as small farmers. The previous facts sustain the hypothesis that crop selection on small holdings will emphasize annual crop production, which has been established as a condition that poses a greater erosion risk than agronomic perennial crops, ranges, or forests.

The portion of land devoted to coffee increases as farm size increases (Figure 23). This implies that once the basic food needs are provided for, additional land area will be devoted to cash crops such as coffee. This is a beneficial trend from soil erosion perspective because coffee protects soil from erosion much better than does annual crops.

The portion of land devoted to perennial crops has similar behavior than annual crops in the private sector (logarithmic model) dropping when the size of the farm increases, while in the BAR sector the perennial crops portion does not vary according to farm size (Figure 24).

The portion of land devoted to rangeland follows a trend similar to coffee (Figure 25). This makes sense in the context that more rangeland implies more land resources are being devoted to cash generation derived from livestock products. Rangeland also provides good soil cover that helps to reduce erosion risk.

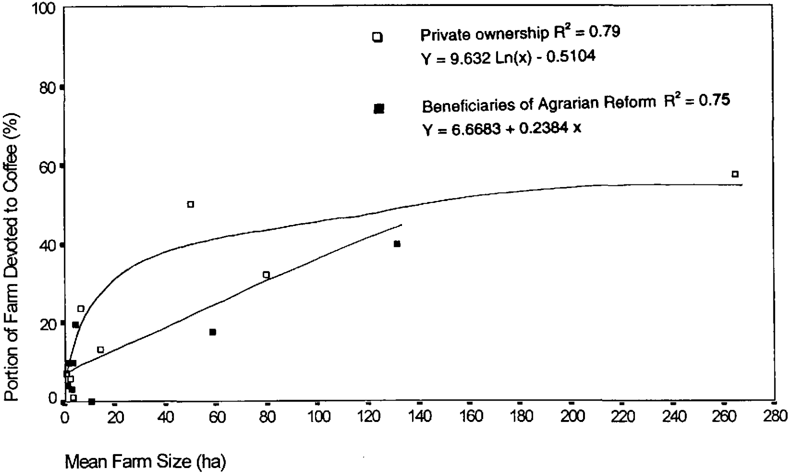


Figure 23. Portion of land devoted to coffee and its relationship with mean farm size, El Pital watershed, Nicaragua.

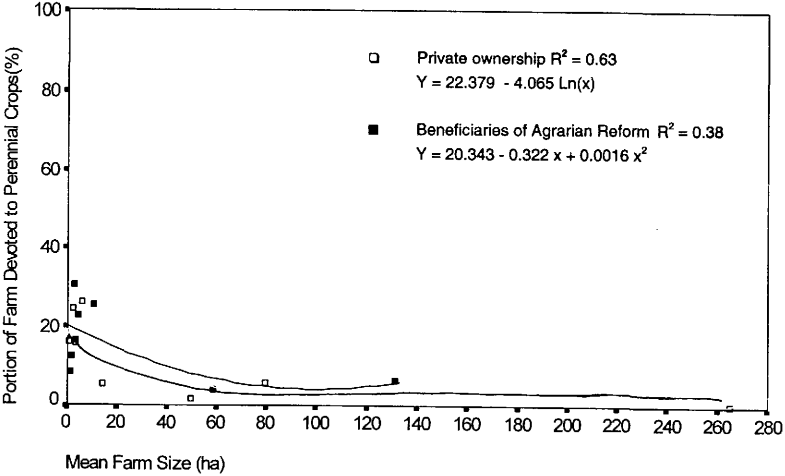


Figure 24. Portion of farm devoted to perennial crops and its relationship with mean farm size, El Pital watershed, Nicaragua

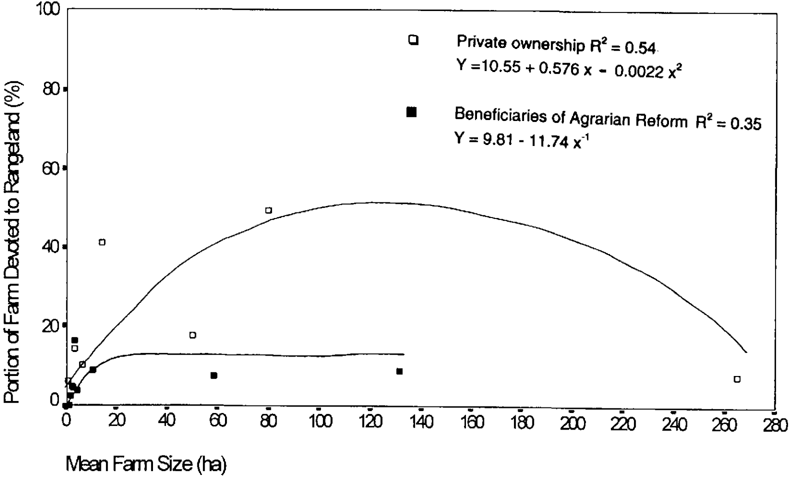


Figure 25. Portion of land devoted to rangeland and its relationship with mean farm size, El Pital watershed, Nicaragua

These data imply that trends toward fragmentation of land ownership encourages behavior that leads to a greater portion of the land holding being devoted to annual or perennial crops (other than coffee). This indicates that if national policy and population pressure are going to lead to increased fragmentation, there will be a greater erosion risk and thus a greater need for the government to facilitate soil conservation initiatives.

The length of time since a farm was established is directly related to farm size, with the oldest land holdings tending to be the largest (Figure 26). Because large farms tend to have a small portion of the land devoted to annual crops, the 1968 estimated erosion was low in part because the large farms controlled a large portion of the watershed.. The time of permanency among the nine groups of crop emphasis and land tenure show a major mean time of private farm ownership is about 25 years compared to mean of 12 years for the BAR farmers. The livestock-oriented farms had the longest mean time of permanency (about 40 years) and there was a slightly longer mean permanency for holdings oriented to grain production on plains and coffee, in both tenure categories. This suggests that permanency is prolonged more on less risky environments or more protective production systems, like coffee, than in the grains on hillsides, which are the more unstable production areas of the watershed. This suggests that the land was settled following a pattern whereby cultivation on the hillsides is a relatively recent phenomenon, a production pattern not selected by the early settlers.

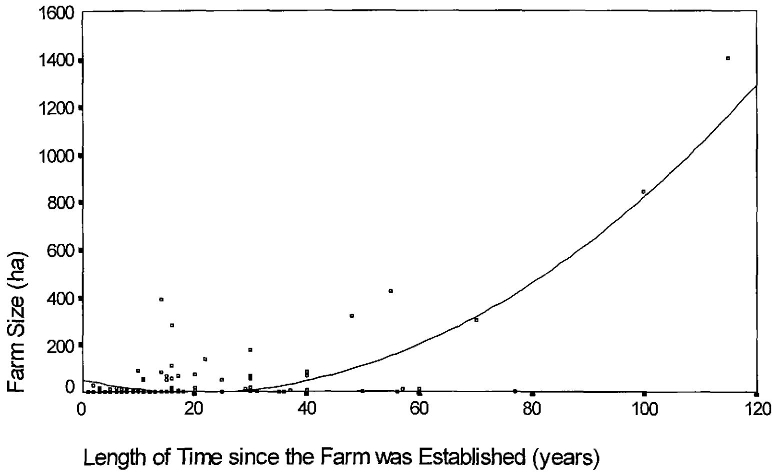
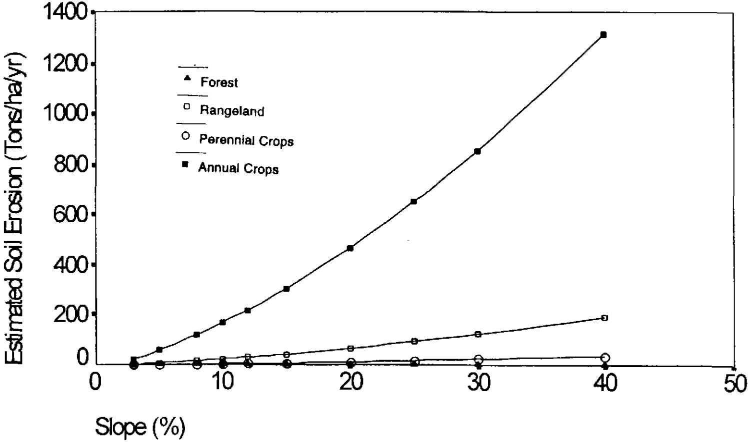


Figure 26. Farm size and its relationship to the length of time since the farm was established, El Pital watershed, Nicaragua

Unfortunately, these hillsides areas tend to be small land holdings which leads the farmer to devote a greater portion of land to annual crop production. This is an especially serious trend because the slope characteristics of these lands put them in the highest erosion risk category in the watershed. Therefore, the lands that have the highest erosion risk are cultivated with crops that pose the greatest erosion risk.

Slope and land use. To illustrate how the slope and type of cover dramatically alter the erosion risk, the soil erosion was calculated for four different types of land use within the watershed, using standard R and K factors, only changing the slope and comparing with the type of cover and management factor. It is clear that the tendency of soil erosion under annual crops was to have an exponential increment, whereas under perennial and range cover, there is a slight increment, and under forest cover, soil erosion is dramatically low, almost 0 (Figure 27).



27. Estimated soil erosion for four land use types under equal R and K factors at different slopes, El Pital watershed, Nicaragua

Predominant crop relationship with erosion. It is clear that the soil erosion risk is greater in the grains on hillsides category (140 Tons/ha/yr) than in any other category (Figure 28). This is indicative of the two main factors influencing soil erosion: slope and land use. The coffee category has the lowest erosion hazard (39 Tons/ha/yr) compared with other categories that have similar slope conditions. The livestock and grain production on the plains have the overall lowest erosion rates (25 and 23 Tons/ha/yr, respectively) because the prevalent slope for those groups tends to be < 10%. If a comparison is done between land tenure categories, it is notable that the diverse crops and coffee categories in the BAR farms have higher erosion hazard (73 Tons/ha/yr and 55 Tons/ha/yr, respectively) than their homologues in the private category (39 Tons/ha/yr and 24 Tons/ha/yr, respectively) (Figure 29). These differences are because the portion of land the BAR coffee category devoted to annual crops is 38% compared to only 5% on the private sector (Table 7). Also, the BAR group of the diverse category only devote 29% of their land to perennial crops as compared with 42% of the private land holders.

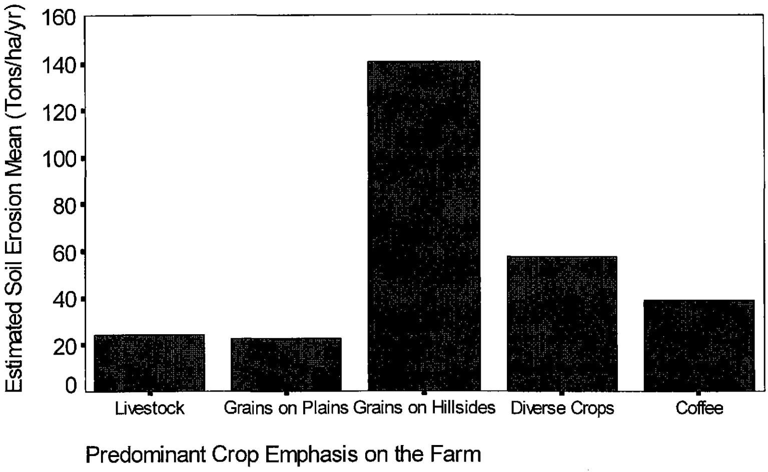
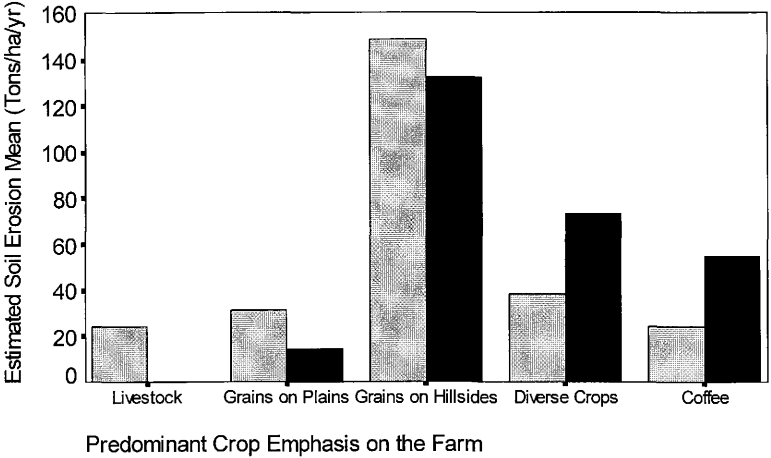


Figure 28. Estimated soil erosion among predominant crop emphasis on the farm, El Pital watershed, Nicaragua



29. Estimated soil erosion among predominant crop emphasis on the farm and land tenure, El Pital watershed, Nicaragua

Table 7. Characterization of the nine predominant crop emphasis and land tenure categories by land use distribution in the El Pital watershed, Nicaragua

	Percent of land use distribution											
Predominant crop emphasis	Predominant crop emphasis											
	BAR farms						Private farms					
	Ac	Pc	C	Rn	Ft	Fw	Ac	Pc	C	R	Ft	Fw
Grains on plains	76	6	0	10	1	7	77	4	0	16	1	2
Grains on hillsides	54	3	0	23	12	8	32	11	3	20	16	18
Diverse crops	44	29	0	7	3	17	41	42	3	6	6	2
Coffee	38	4	46	3	3	6	5	1	66	8	14	6
Livestock							4	1	1	73	17	4
Weighted average	48	6	28	8	3	7	8	2	21	50	13	6

Ac : Annual crops Pc: Perennial crops C : Coffee
Rn : Rangeland Ft : Forest Fw: Fallow

Adoption of soil and water conservation practices

Nine types of soil and water conservation practices were identified in the watershed: compost, green manure, cover practices, live fences, reforestation, conservation tillage, live barriers, terraces, and gully control. Compost is made by collection and preparation of organic matter to obtain a partially decomposed mixture that is applied to the crops. Green manure refers to the use of cover plants, particularly legumes, that are grown and then plowed into the soil to increase soil fertility. Cover practices includes techniques to keep crop residues on the surface, the use of crop association, and also includes the shadow coffee system that offers surface cover protection by virtue of extensive canopy coverage. Live fences are composed of different species of trees which are pruned seasonally and branches used as fuelwood or as saplings to replant other areas. Reforestation refers to tree plantations grown for the purpose of producing fuelwood or timber. Conservation tillage includes minimum tillage, non-tillage, the traditional *espeque* sowing, contour tillage and contour sowing. Live barriers refers to the use of grass, shrubs, or tree barriers grown along the contour, either alone or in association with terraces. Terraces includes ridge terraces, bench terraces, and individual basins. Gully control is the application of any type of dam or dike to reduce runoff velocity and encourage siltation that will fill the gullies.

The hypothesis asserting that the decision to adopt soil conservation practices is correlated with land erosion risk, land tenure, and farm size, is supported by the analysis of conservation practices used in the watershed. In general, BAR farmers apply more practices than private (Figure 30). The percent of farmers applying 4 or more practices is greater in BAR farms; on the other hand the percent of farmers applying 3 or fewer practices is greater in the private farms.

The predominant crop emphasis of the farm and the land tenure system influence the number of conservation practices used by farmers. If the means are considered only by the predominant crop emphasis on the farm, it is clear that coffee and diverse crops are the farm types with the highest number of conservation practices (Figure 31). In fact, the mean number of practices in these two farm types is significantly different from the number of practices used in the other three categories (Table 8). This may be due to two circumstances. Technical assistance is greater in these two categories (Table 9), particularly in the BAR farmers sector. Also, these categories in the watershed still use the traditional cropping systems that have characteristics that encourage soil and water conservation, such as use of mulch, minimum tillage, contour tillage, individual basins, and/or use of compost. With respect to land tenure, more conservation practices applied tend to be applied in the BAR sector than in the private sector (Figure 32). It is notable that all groups averaged at least one conservation practice. This is an indicative of the concern that farmers have about the need to conserve their soils.

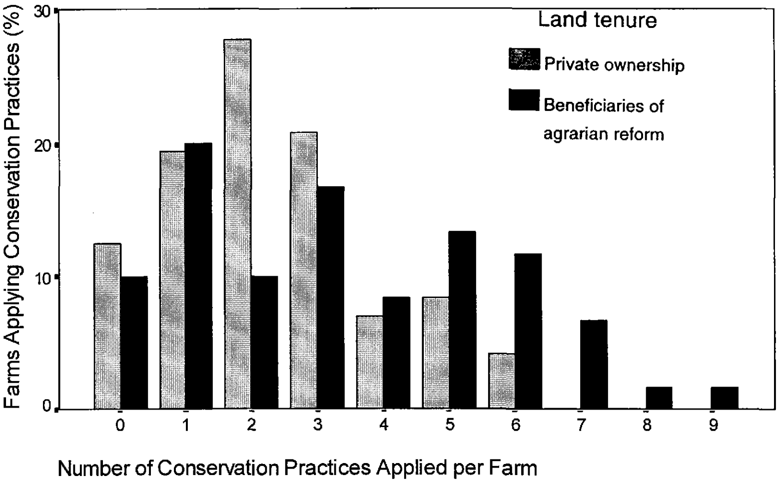


Figure 30. Distribution of the number of soil and water conservation practices applied per farm within the El Pital watershed, Nicaragua

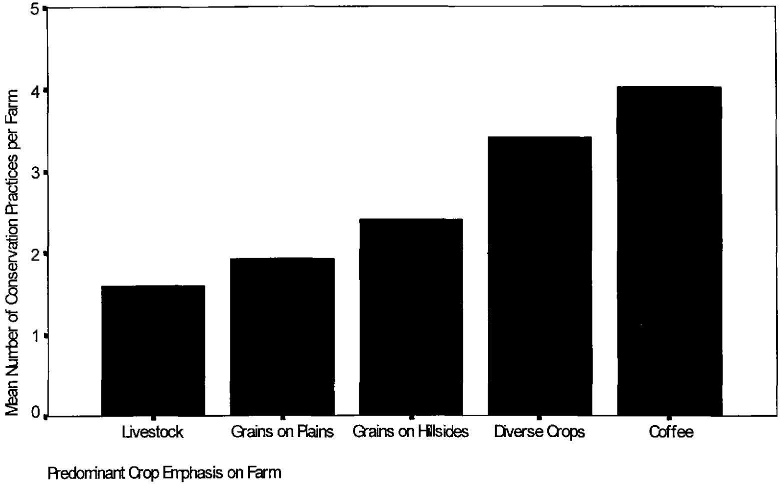


Figure 31. Mean number of soil and water conservation practices applied per farm as related to the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

Table 8. Mean number of soil and water conservation practices applied by farmers as related to land tenure and predominant crop emphasis of farm, El Pital watershed, Nicaragua, *1996 farmer survey*. Lower case values *within* a column and upper case values within a row with the same letter are not significantly different

Predominant crop emphasis on the farm	Mean number of conservation practices	
	Land tenure	
	BAR farms	Private farms
Basic Grains on Plains	1.87 b A	2.00 b A
Basic Grains on Hillsides	2.80 b A	2.00 b A
Diverse Crops	4.19 a A	2.46 b B
Coffee	4.57 a A	3.53 a B
Livestock		1.60 b

Table 9. Mean of assessment of quality of technical assistance by farmers in soil and water conservation topics, El Pital watershed, Nicaragua, 1996 farmer survey. Lower case values within a column and upper case values within a row with the same letter are not significantly different

Predominant crop emphasis on the farm	Mean of assessment of quality of technical assistance	
	Land tenure	
	BAR farms	Private farms
Basic Grains on Plains	2.27 b A	1.27 a B
Basic Grains on Hillsides	2.27 b A	0.57 a B
Diverse Crops	3.62 a A	2.31 b B
Coffee	2.79 ab A	1.33 a B
Livestock		1.33 a

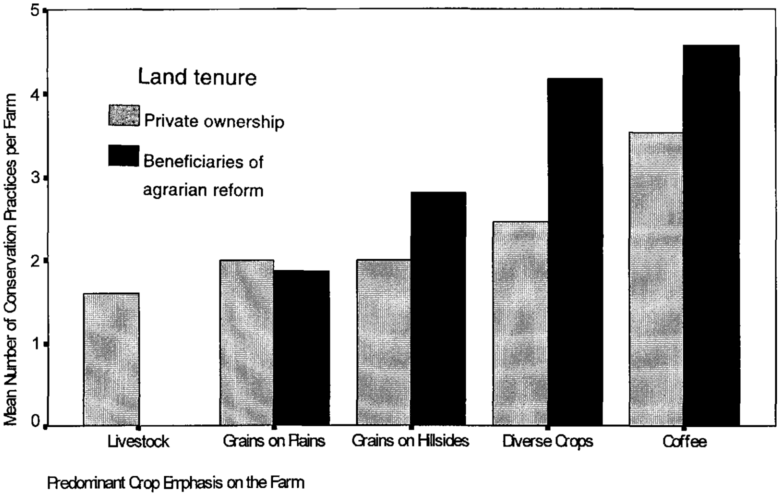


Figure 32. Mean number of soil and water conservation practices applied per farm as related to the predominant crop emphasis on the farm and the land tenure type, El Pital watershed, Nicaragua

Technical assistance and soil conservation practices. The hypothesis that technical assistance is related to farmers' decisions regarding implementation of erosion control practices is confirmed by the fact that the quality of technical assistance is directly related to the mean number of conservation practices applied per farm (Figure 33). The portion of farmers who receive excellent technical assistance have a mean number of practices of 4.2 on private farms and 4.9 on BAR farms while the mean for those receiving none or poor quality technical assistance is 1.8 and 2.0 respectively.

The assessment of quality of technical assistance by farmers indicates there is a large segment of the private farmers, 40%, that not receive technical assistance in soil conservation, compared to only 12% in the BAR sector (Figure 34). Farmers who feel the quality of technical assistance they receive is poor represent 19% of private farmers whereas only 7% of BAR farmers feel the technical assistance they receive is poor. On the other hand, excellent technical assistance is acknowledge by only 7% of the private farmers in contrast with 38% of the BAR farmers. This helps to explain why the BAR farmers have a higher mean number of practices also apply up to 9 kind of conservation practices compared to only 6 on private sector (Figure 30). Another rationale to explain why the number of practices on BAR have a tendency to be higher than the private farms is that the size of the BAR farm tends to be smaller and the intensity of land use is greater than on private farms.

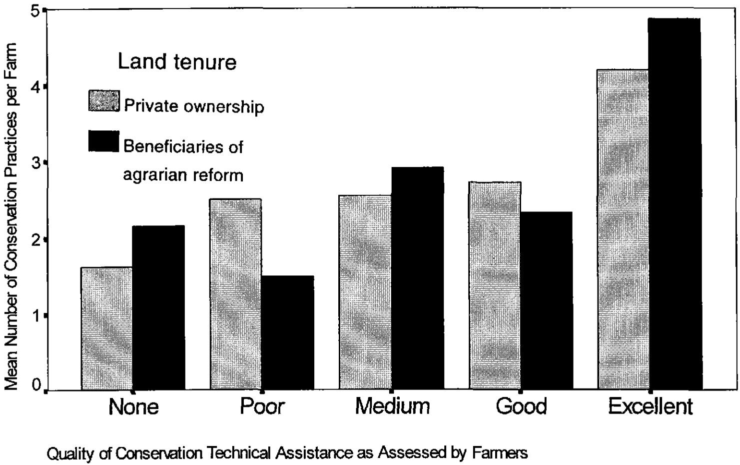


Figure 33. Mean number of soil and water conservation practices applied per farm as related to the quality of soil and water conservation technical assistance, as assessed by farmers within the El Pital watershed, Nicaragua

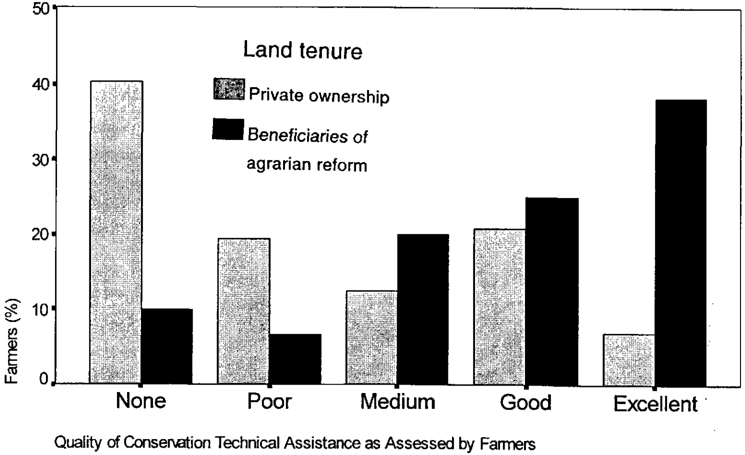


Figure 34. Distribution of the quality of soil and water conservation technical assistance as assessed by farmers within the El Pital watershed, Nicaragua

Soil and water conservation practices applied within the El Pital watershed. The analysis of the various conservation practices shows that some practices are applied more by BAR farmers than by private farmers. For example conservation tillage is practiced on 60% of the BAR farms and only 33% of the private (Figure 35). Green manure, live barriers, and gully control are practiced by BAR farmers 18%, 37%, and 23% respectively in contrast with only 7%, 15, and 7% on the private farms. Given that other practices such as compost, live fences and terraces are equally applied by both groups it is evident there are different factors which are influencing adoption of some practices.

Terraces and live fences are traditional practices. Some terraces have been established more than 20 years ago on some of the large farms dedicated to annual crops and pasture. Also, in coffee plantations is very common traditional practice to use individual basins on steeplands. In contrast conservation practices that have been introduced by institutions working in the watershed, such as live barriers, gully control, reforestation, and use of green manure are practiced more by BAR farmers. This is because the BAR farmers are the target of technical assistance programs in soil and water conservation topics.

The analysis of individual practices among the land tenure and crop emphasis on the farm categories reflects that use of compost is practiced by all the land tenure and predominant crop emphasis categories, livestock category only 13% and grains on plains close to 30%, the category with the highest percent is BAR grains on hillsides

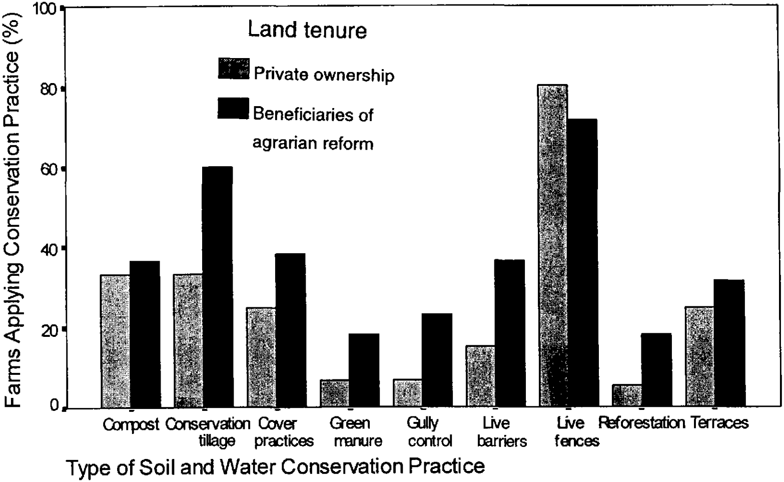


Figure 35. Percent of farms applying the various soil and water conservation practices used in the El Pital watershed, Nicaragua

53% (Figure 36). This practice is traditionally used in the coffee category because of the available residues of coffee production, and knowledge of the farmers about the benefits of this practice to coffee productivity. On the lands where grains are the predominant crops this practices has been widespread by the institutions providing technical assistance in soil conservation matters, especially in the hillsides areas. In addition farmers on the hillsides are understandably more concerned about erosion risk than farmers on the plains. Consequently, the grain producers on hillside are the category that has the highest portion of farmers using compost. Compost is one of the practices equally applied in small farms as well as in big farms (Table 10).

Cover practices are more likely to be applied in farms growing coffee as predominant crop whether they are BAR (71%) or private (73%) farmers (Figure 37). For coffee producers, the use of a traditional cover practices such as keeping residues of shadow trees and shrubs between the rows of coffee, and using some cover crops between the rows, is a common custom. Whereas for the grain producers the use of cover practices is not habitually used. This is because the farmers traditionally would either use cover residue for fodder or else would burn it to control insect infestation. Diverse crops and grains on plains categories in the BAR sector also applies a fair amount of this kind of practices, 31% for the first and 40% for the second. The difference of farmers in the BAR category using these techniques relative to the private farmers is a result of the advisors tending to target the BAR farmers. Cover practices tend to be used most on the large farms (Table 10), which is evidently because the

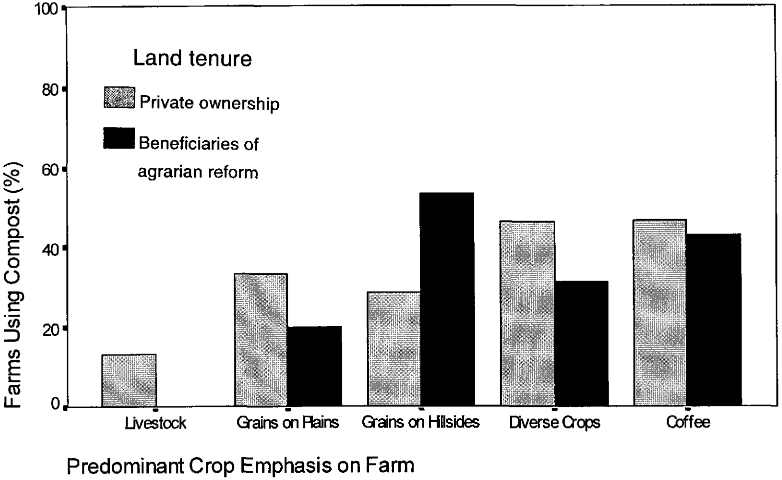


Figure 36. Use of compost as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

Table 10. Distribution of soil and water conservation practices applied by farm size, El Pital watershed, Nicaragua

Soil and water conservation practice	Portion of the conservation practices applied by farm size group (%)	
	Farms < 4 ha	Farms ≥ 4 ha
Compost	52	48
Cover practices	44	56
Green manure	69	31
Live fences	49	51
Reforestation	68	32
Conservation tillage	58	42
Live barriers	58	42
Terraces	46	54
Gully control	53	47

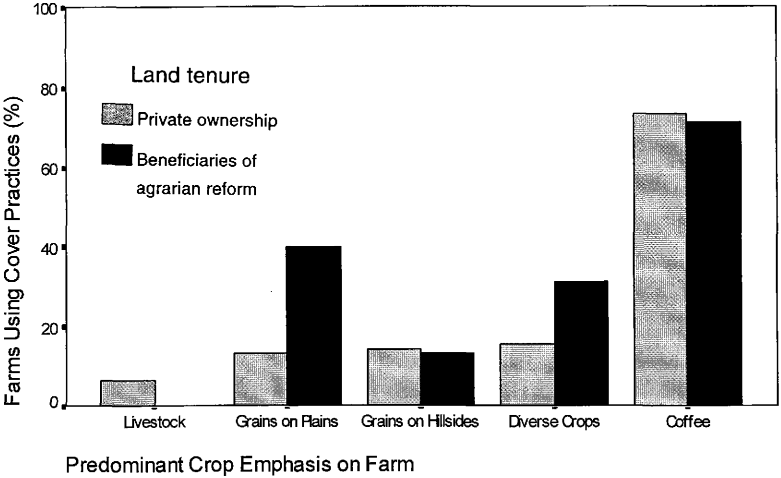


Figure 37. Use of cover practices as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

coffee farms are the main land use on large farms and cover practices are implemented with this crop.

Use of green manure is infrequently applied, on livestock and grain production systems. The categories that are more likely to implement this practice are diverse crops and coffee producers in the BAR category (Figure 38). Green manuring is a practices that is advocated by many of the soil conservation institutions working in the watershed. Since these institutions target the BAR farmers it makes sense that this group is more likely to practice it. Green manuring is one of the practices most used by small farmers with 67% of the farmers using green manure on farms of less than 4 hectares (Table 10). This is because on small farms the need for production is high, cash availability for fertilizer is low and labor is available to intensively cultivate the small land-holding.

Live fences is a widespread practice in the country and this watershed is not the exception. This practice is least likely to be used in both land tenure categories of grains on hillsides and the BAR category of grains on plains (Figure 39). This is probably because many of these farms are small and they do not want the trees which compose the fences to be competing with their crops. The live fences not only occupy the space but also shade a portion of the field, which is not good for crops such as corn, and sorghum.

Reforestation is poorly implemented in general (Figure 40). Grains on hillsides do not practice this at all, probably because of lack of land to devote to a crop that can not be harvested for many years. The private coffee producers do not feel a need for

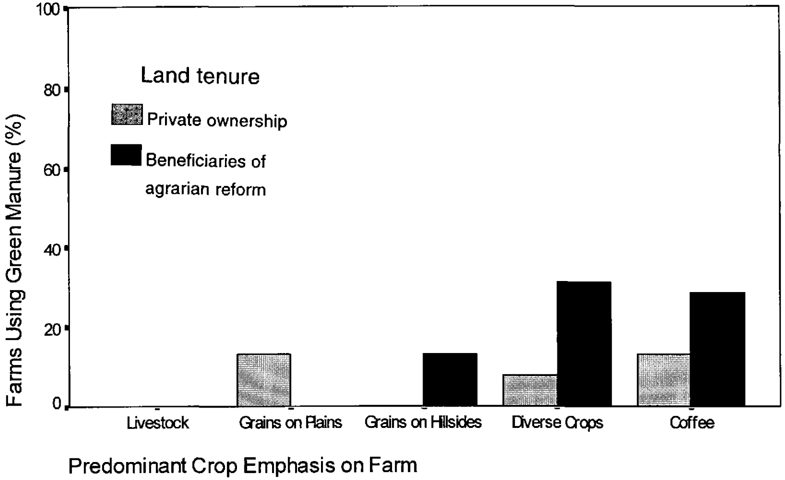


Figure 38. Use of green manure as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

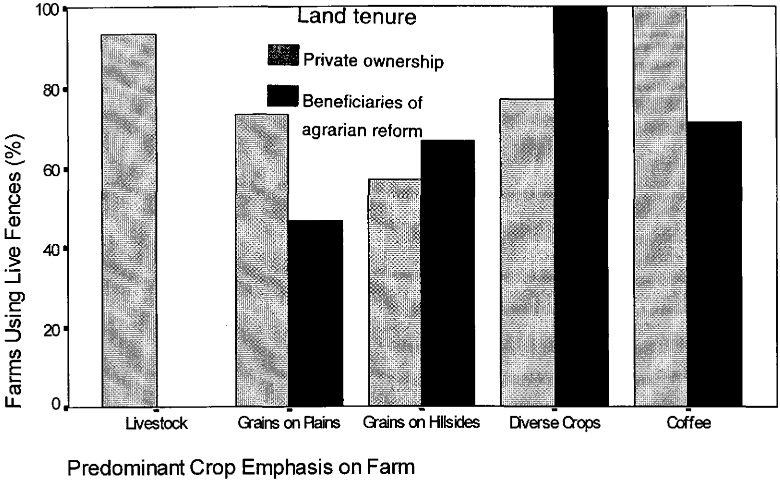


Figure 39. Use of live fences as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

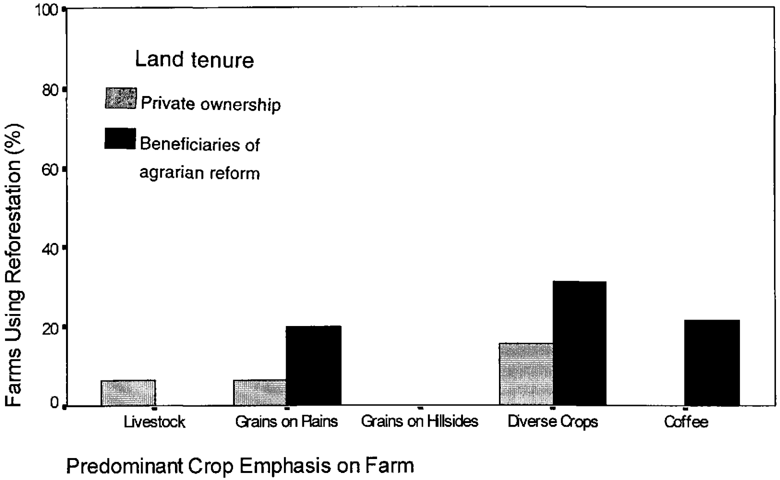


Figure 40. Use of reforestation as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

reforestation since they usually have big pieces of land where they can leave some portion of the land with forest. Also, when they establish coffee plantations they leave shadow trees on the land, under which they plant coffee. The percent of forest in this land category is five times higher than it is for coffee producers in the BAR category, probably because the private coffee producers ten do have much larger farms than the BAR farmers. Thus the private farmers can spare some of the marginal, highly erosive land for leaving the forest (Table 7). Reforestation is practiced more by small farmers (73%) than by large farms with greater than 4 ha (27%). This reflects the need for fuelwood production.

Conservation tillage in general is practiced more by all the BAR categories than by the private sector (Figure 41). Conservation tillage is not applicable to the livestock category since they do not till the land. The reason for the BAR group applying this practice more extensively is that BAR are targeted by many institutions giving technical assistance in the watershed. For example, the coffee BAR category has the highest portion of farmers applying this practice (93%)compared with 47% of the private group. The use of conservation tillage is greatest on lands with greater erosion risk. For example in both land tenure categories, percentage of the producers of grains on the plains applying conservation tillage is almost half (27% and 33%) of the farmers applying this practice for grain production on hillsides (50% and 60%), private and BAR respectively. This is evidence that farmers tend to apply more soil conservation practices when their land is at greater risk.

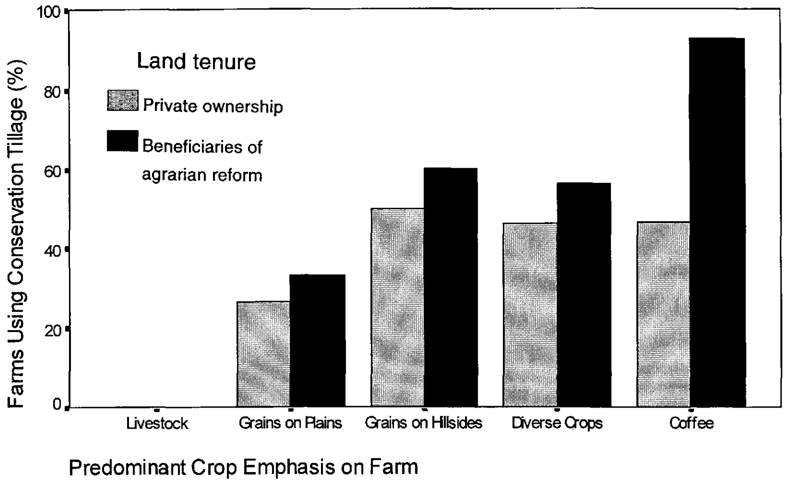


Figure 41. *Use of conservation tillage as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua*

Live barriers is another practice predominately used by BAR farmers, particularly in the diverse crops and coffee categories, where 56% and 57% of the farmers, respectively, use live barriers (Figure 42). Evidently this is another illustration of the effect of technical assistance, particularly since this practice is being disseminated by some institutions promoting soil conservation and targeting the BAR farmers. Again, the pattern of greater use of conservation practices on lands with greater erosion risk is repeated. In the grains on plains both land tenure, only 7 % of the farmers use live barriers whereas in the grains on hillsides 29% and 27% of the farmers, private and BAR respectively, apply the practice.

Use of terraces is dominated in all the groups by the BAR category except the grains on plains (Figure 43). The portion of farmers applying terraces in the diverse crops and grains on hillsides BAR category is greater than the portion of private farmers in their analogous groups. This is connected with the institutions promotion soil conservation targeting the BAR groups. However the coffee category in both land tenure types is the one that most use terraces, this could be attribute to the typical use of individual basins for coffee producers.

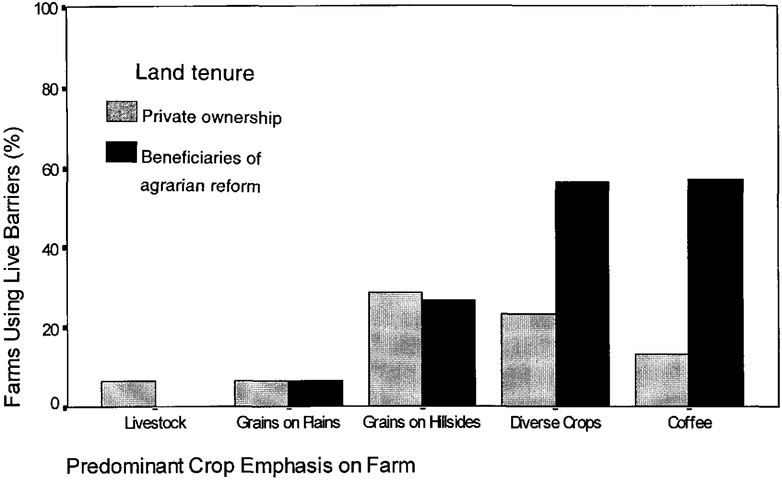


Figure 42. Use of live barriers as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

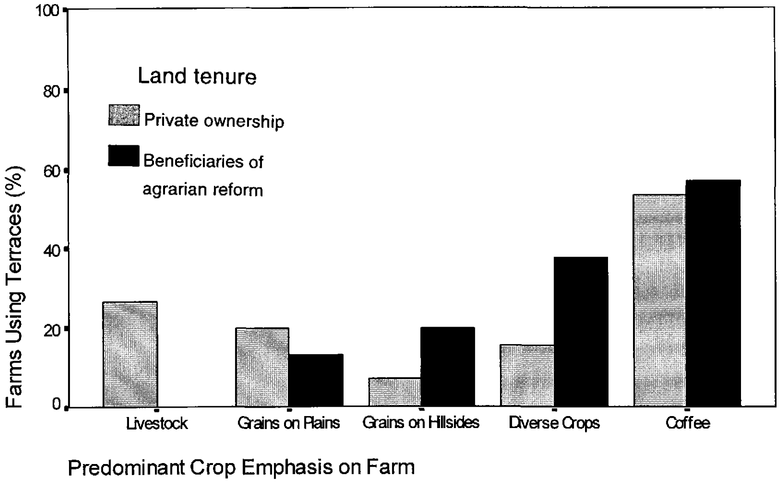


Figure 43. Use of terraces as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

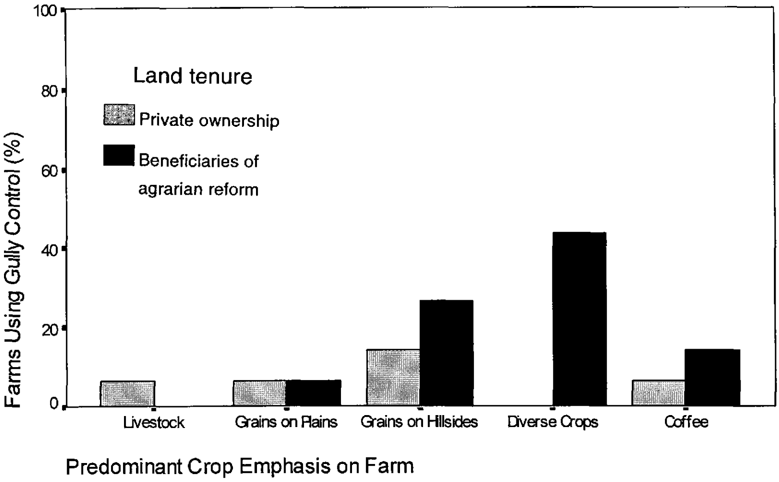


Figure 44. Use of gully control as related to the land tenure and the predominant crop emphasis on the farm, El Pital watershed, Nicaragua

Gully control is rarely applied in the watershed (Figure 44). This is because the factors that cause the gully (e.g. runoff from uplands) is not able to be influenced by the downslope landowners where the gullys are a problem. Gully control requires a planned and collective work of many neighboring land owners in order to accomplish an effective control. In general the BAR tenure is the one that applies more this practice. This is aided by the past communal characteristics of the BAR farms. Also, institutions providing technical assistance target the BAR farmers, thereby encouraging them to adopt this practice.

The *comarcas* that have the greatest erosion risk are also the one that have more conservation practices per farm (Figure 45). This is indicative that when the farmers recognize soil erosion is a problem on their land they will be more likely to adopt soil and water conservation measures.

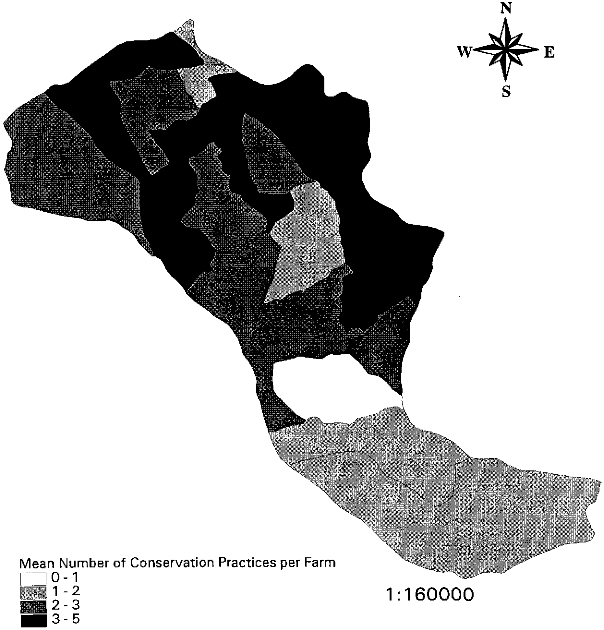


Figure 45. Mean number of conservation practices applied per farm by comarca, as determined by the 1996 farmer survey, El Pital watershed, Nicaragua

Limiting factors, long-term concerns and long-term hopes expressed by the farmers

The factors limiting crop productivity most mentioned by farmers are those related to credit access. This is a problem because many farmers do not have collateral to secure the loan or they do not have access to the credit system (Table 11). The high interest rate is mostly mentioned by the coffee category and the private grains on plains and livestock producers, which reflects they may not have problems with collateral or credit access, rather, they think bank interest rates (generally about 20%) are too high.

Another socioeconomic factor that is frequently mentioned is production cost and market fluctuations. When the crops are harvested, the price of the grains is so low that it almost does not pay for production costs. When they plant the new crop, they have to buy the grain at a high market price. This "sell low, buy high" activity limits their ability to make a profit and is caused by their inability to store grain for sale when the price is high.

The technological aspects of farm management were not expressed as a problem limiting crop productivity. Only the 1) grains on hillsides group in both land tenure categories, and 2) the private coffee producers expressed worry about technical shortage in pest control techniques. Many farmers perceive the need to add fertilizer, but are inhibited by the cost of the fertilizer. An environmental factor affecting the farmers is a sense that droughts are increasing. Long-term rainfall records do not support this assertion; therefore reduction of soil water-holding capacity due to soil erosion is the likely factor that results in an increased perception of water shortage. Soil erosion was rarely named as a concern for grains on plains and on hillsides and was not mentioned at all by coffee and livestock categories. Education stressing the linkage between drought, fertility and soil conservation would help farmers to appreciate this relationship.

Long-term concerns continue to reflect the major factors limiting productivity, such as credit access decline, and a negative impact of the government policies on crop prices (Table 12). The current agricultural policies and market fluctuations are not favoring basic grain production because of the inadequate transportation and commerce support structure in agricultural regions.

A desire for improved technical assistance was a concern for some BAR farmers producing grains on hillsides, private farmers producing diverse crops, and BAR coffee producers. This is indicative that in general farmers do not feel a need for technical assistance as much as a need for agricultural policies and government support for moderating seasonal price fluctuation of commodities.

Fear of land redistribution was commonly mentioned by all categories, even the private ones, with the exception of coffee and livestock categories. This indicates an insecurity about land tenure within the watershed which may pose a barrier to adoption of some of the long-term investments associated with soil conservation.

A social concern frequently mentioned for some categories such as grains on plains, livestock, and BAR grains on hillsides is the need for crime prevention. This concern imports a social consequence of the general economic situation of the country, and has added to the stress existent in the heavily populated agricultural sectors such as the El Pital watershed.

Long-term hopes most mentioned are the investment on cultivation of specialty fruit crops such as pithaya, calala, granadilla, and others; and the establishment of fruit tree plantations, reforestation with woody trees, and expansion or initiation of coffee and cattle production (Table 13). Also mentioned was a desire to establish an irrigation system and increase use of soil and water conservation practices.

Table 11. Limiting factors listed by farmers by predominant crop emphasis on the farm and land tenure categories, El Pital watershed, Nicaragua, 1996. Data are represented as percent of farmers that expressed concern about the respective limiting factors

	Predominant crop emphasis on the farm and land tenure categories								
Limiting Factors	Grains on plains		Grains on hillsides		Diverse crops		Coffee		Livestock
	Private	BAR	Private	BAR	Private	BAR	Private	BAR	Private
No collateral	0	12	0	15	0	24	0	6	0
No access to credit	31	18	25	13	24	19	21	47	13
High interest	14	3	0	3	10	5	32	18	20
Delayed	10	0	0	3	0	0	5	0	7
Production costs (high)	10	26	13	16	14	0	0	6	7
Market fluctuation	0	29	8	13	10	10	0	0	7
Land tenure	5	0	0	0	22	14	0	0	0
Robbery	5	0	13	3	0	0	0	0	13
Pest control									
Expensive	5	0	8	3	0	0	0	0	7
Technical	0	0	29	27	7	0	20	7	13
Herbicide									
Technical *	5	0	0	0	0	0	0	0	0
Fertilizer									
Expensive**	5	3	8	6	0	0	0	6	0
Drought/ Rainy season	10	6	4	9	5	23	26	12	13
Soil erosion	0	3	4	3	10	5	0	0	0

* None of the respondents said that herbicides are expensive.

** None of the respondents said they need technical advise to apply fertilizers.

Table 12 . Long-term concerns listed by farmers by predominant crop emphasis on the farm and land tenure categories, EL Pital watershed, Nicaragua, 1996. Data are represented as percent of farmers that expressed the respective long-term concern

	Predominant crop emphasis on the farm and land tenure categories								
Long-term concerns	Grains on plains		Grains on hillsides		Diverse crops		Coffee		Livestock
	Private	BAR	Private	BAR	Private	BAR	Private	BAR	Private
Lack of land	0	0	18	0	18	18	0	0	0
No title of the land	0	0	10	25	0	36	0	50	0
Fear of land redistribution	17	12	18	0	9	18	0	0	0
Credit access decline	33	41	0	25	18	9	25	25	25
Negative impact on price decision	33	41	18	25	36	9	62	0	50
Limited Technical assistance	0	0	0	17	18	0	0	25	0
Deforestation	0	0	18	8	0	9	12	0	0
Crime prevention	17	6	18	0	0	0	0	0	25

Table 13. Long-term hopes listed by farmers by predominant crop emphasis on the farm and land tenure categories, El Pital watershed, Nicaragua, 1996. Data are represented as percent of farmers that expressed the respective long-term hopes

	Predominant crop emphasis on the farm and land tenure categories								
Long-term hopes	Grains on plains		Grains on hillsides		Diverse crops		Coffee		Livestock
	Private	BAR	Private	BAR	Private	BAR	Private	BAR	Private
Irrigation	0	25	0	0	6	0	0	9	0
Soil and water conservation	0	0	0	9	19	20	9	15	0
Increase area for crops	0	0	0	9	0	5	0	0	9
Invest on:									
Specialty fruit crops	0	0	17	0	19	10	0	9	0
Fruit trees	17	25	0	55	25	20	18	0	9
Wood trees	0	12	0	9	19	25	0	0	0
Vegetables	0	13	0	0	6	0	0	0	0
Rice	0	0	0	0	0	0	0	0	9
Cattle	17	0	33	18	0	15	0	15	55
Coffee	0	0	17	0	0	5	46	46	0
Keep on farm cultivating	66	25	33	0	6	0	27	16	9

CONCLUSIONS

Agriculture has been and continues to be the primary economic activity within the El Pital watershed. There has been increasing erosion within the watershed over the past several decades. This trends threatens sustainable agriculture production on the upland and negatively impacts downstream areas in terms of increased siltation and flooding.

The trend toward increased erosion in the El Pital watershed is linked to the fact that cultivation of annual crops has increased. A model of factors leading to incresed erosion risk establishes the relationships between land use, land tenure and agricultural policies and how these interrelated factors influence soil erosion risk (Figure 46). Annual crop production is the land use that poses the greates erosion risk within the watershed. This is because annual crop cultivation exposes the soil to erosive raindrop impact and there is little vegetative obstruction to runoff. Annual crop cultivation is strongly correlated with farm size. This is because small farms tend to emphasize annual crop production to meet their subsistence needs. The agrarian reform activities during the 1980's substantially increased the number of small farms within the watershed. The greatest increase in small farm density has been on the steep lands, where erosion hazard is naturally high. The rapid pace of small farms being established on steeplands is a function of political and economic considerations which make these lands most available for settlement.

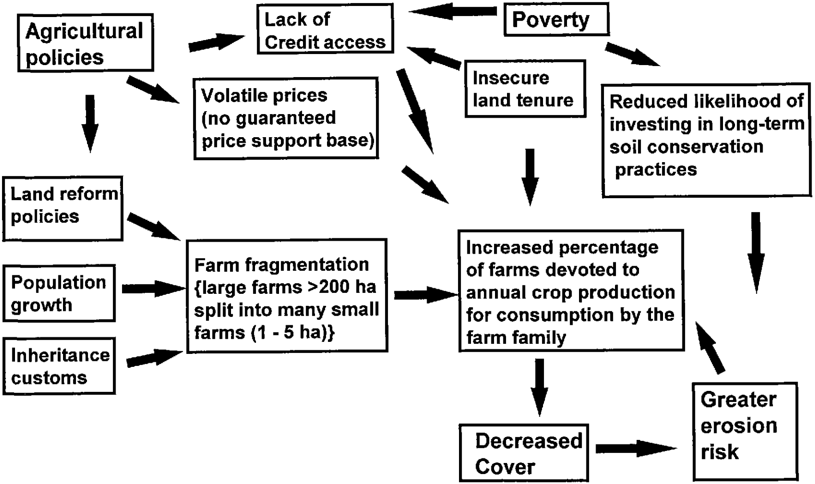


Figure 46. Conceptual model of factors contributing to an increased erosion risk in the El Pital watershed, Nicaragua

Programs are needed that will enhance adoption of soil and water conservation technologies by small farmers. Most of the institutions working in the watershed to encourage soil conservation have targeted beneficiaries of agrarian reform. The result has been that adoption of soil conservation practices has tended to be greater on these farms than on lands that were traditionally privately owned. This illustrates that extension activities do make a significant difference in adoption of soil conservation. However, it is currently difficult for the government or donor agencies to place a firm monetary value on their extension investment. To do this, it is necessary to understand how much soil is saved when conservation technology is installed and what this savings means in terms of crop production potential and in terms of reducing the costs of downstream siltation and flooding. Currently, there is not an understanding of erosion processes on tropical steep land to accomplish this. Therefore, research to improve erosion estimation techniques and quantify on-site and downstream benefits of soil conservation should be a high priority.

Technical institutions providing assistance in soil and water conservation should be aware that farmers do indeed understand the need to conserve soil. What they need are technologies that they are able to apply within the context of the economic constraints they face. Strong fluctuations in commodity prices work against the interest of most small farmers. They sell into very low markets at harvest time because they do not have the means to store their crop or transport it beyond the depressed local market. They buy seed and chemicals at very high prices at the beginning of the planting season because the local markets essentially have a captive consumer since they cannot realistically purchase their supplies at a fair price. Consequently, there is a chronic cash shortage among small farmers which makes it very difficult for them to invest in soil conservation technologies that provide benefits that will be primarily realized over the long term. Investment in soil conservation is further exacerbated by the barriers to small farmers associated with obtaining access to credit at a reasonable interest.

In addition to economic barriers to investment in soil conservation, there is a lingering insecurity of land tenure in the minds of many farmers (even if they hold legal title of the land). This works against long-term investments such as soil conservation, as there is a fear that they will not be able to reap fully the benefits of their investment.

To overcome these barriers to adoption, the institutions encouraging soil conservation need to structure program that will address these issues in the minds of the farmers. Education regarding the general benefits of soil conservation does not seem to be necessary because most farmers already acknowledge this. Rather, a more refined education program may be more useful that will illustrate how perceived problems regarding drought and soil fertility are linked to difficult to perceive interrill erosion.

RECOMMENDATIONS

Many of the small farmers do not have the resources to bare the full cost of investing in conservation technologies, therefore they will need help in procuring advice and financial support to install the technologies. The results of this thesis show that extension support makes a significant difference in aiding adoption of soil and water conservation technologies. Therefore, expanded support of extension programs should be considered.

While this thesis shows that extension aids adoption of soil and water conservation technologies, further analysis of the values of extension activities is limited by lack of data on how effective the conservation technologies at preventing erosion. Research should be encouraged that measures the on-field benefits of the conservation technologies to sustainable crop production and measures the off-field benefits to other portions of the watershed, such as the downstream cost of flooding and erosion that would occur if the conservation technologies were not installed.

The thesis shows that there is a difference in adoption of different soil and water conservation technologies depending on the characteristics of the farming system and the socioeconomic characteristics of the farm family. Therefore it is very important that technologies should be designed to meet the needs of the farmers. There appears to be opportunities for enhanced soil conservation activities it they would be better targeted to compliment the expressed goals of the farmers.

REFERENCES CITED

Alfsen, K. H., M. A. De Franco, S. Glomsrod, and J. Torgeir. 1996. Analysis the cost of soil erosion in Nicaragua. Ecological Economics 16: 129-145.

Brown, S., H. Schreier, W.A. Thompson, and I. Vertinsky. 1994. Linking multiple accounts with GIS as decision support system to resolve forestry/wildlife conflicts. Journal of Environmental Management 42: 349-364.

Dangermond, 1989. Starting GIS technology: Three important processes to remember. Public Works 120: 42- 44.

Espinoza, J.Z. 1994. Diagnostico socioeconomico de las comunidades de las micro-cuencas de Diriomo y Mombacho. CARE Internacional en Nicaragua Proyecto Agroforestal El Pital. Masaya, Nicaragua, 86p.

Food and Agriculture Organization (FAO) of the United Nations. 1993. Guidelines for land-use planning. Development Series 1. Rome, Italy, 96p.

Hudson, N. 1995. Soil conservation. Iowa State University Press, Ames, IA, 391p.

Instituto de Recursos Naturales y del Ambiente (IRENA). Estudio de Ordenamiento Territorial y Plan de Acción Ambiental de Nicaragua (ECOT-PAF). 1994. Plan de Acción Ambiental de Nicaragua. Ministerio de Economia y Desarrollo (MEDE) e IRENA-ECOT-PAF, Editorial El Amanecer. Managua, Nicaragua, 136p.

Jimenez, J. and B. Gonzalez. 1991. Inventario de sistemas agroforestales tradicionales en fincas pequenas de Masaya y Carazo. Facultad de Recursos Naturales y del Ambiente, Universidad Nacional Agraria. Managua, Nicaragua, 88p.

López, M. and B. Gonzalez. 1994. Inventario de sistemas agroforestales tradicionales en fincas pequenas de Granada y Rivas. Facultad de Recursos Naturales y del Ambiente, Universidad Nacional Agraria. Managua, Nicaragua, 94p.

Mendoza, B. and D. Rivas. 1996. Informe anual parcelas de escurrimiento con el Proyecto Agroforestal El Pital. Facultad de Recursos Naturales y del Ambiente. Universidad Nacional Agraria, Managua, Nicaragua, 34p.

Ministerio del Ambiente y Recursos Naturales (MARENA). 1993. Estudio de ordenamiento para el desarrollo agroforestal de las microcuencas de Diriomo y Mombacho de la cuenca El Pital. CARE Internacional en Nicaragua. Proyecto Agroforestal El Pital, Nicaragua, 193p.

Mitchell, J.K., and G.D. Bubenezer. 1980. Soil loss estimation; chapter 2. In: M.J. Kirby and R.P.C. Morgan (eds.) Soil erosion. John Wiley and Sons, Ltd., Chichester, England, pp. 17-62.

Napier, T. L. 1991. Factors affecting acceptance and continued use of soil conservation practices in developing societies: A diffusion perspective. Agriculture, Ecosystems and Environment 36: 127-140.

Nill, D., U. Schwertmann, U. Sabe-Koschella, M. Bernhard, and J. Brener. 1996. Soil erosion by water in Africa. Principles, prediction and protection. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Eschborn, Germany, 292p.

Obando, M. and D. Montalvan 1993. Technical and economic analysis of a soil conservation project in Nicaragua. In: E. Lutx, S. Pagiola and C. Reiche (eds.) Economic and institutional analyses of soil conservation projects in Central America and the Caribbean. World Bank Environment Paper No. 8, Washington, DC, pp. 74-80.

Pimentel, D., C. Harvey, P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Shpritz, L. Fitton, R. Saffouri, and R. Blair. 1995. Erosion and conservation benefits. Science 267: 1117-1122.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1996. Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). US Department of Agriculture, Agricultural Research Service, Agriculture Handbook No. 703, Washington, DC, 370p.

Scott, H. D. and J. M. McKimmey. 1992. GIS characterization of Beaver Watershed. Technical completion report research No 159. Arkansas Water Resources Center, University of Arkansas, Fayetteville, AK, 54p.

Selman P., D. Davidson, A. Watson, and S. Winterbottom. 1991. GIS in rural environmental planning. Town Planning Review 62: 215-223.

Sheng, T.C. 1989. Soil conservation for small farmers in the humid tropics. FAO Soils Bulletin 60. Rome, Italy, 104p.

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

Smith, J. E. Jr. 1997. Assessment of soil and water conservation methods applied to the cultivated steeplands of southern Honduras. M.S. Thesis, Soil and Crops Science Department, Texas A&M University, College Station, TX, 160p.

Spoor, M. 1995. The state and domestic agricultural markets in Nicaragua. Institute of Social Studies, St. Martin's Press, New York, NY, 298p.

Stonehouse, D. P. and R. Protz. 1993. Socioeconomic perspectives on making conservation practices acceptable. Topics in Applied Resource Management 3: 29-58.

Thurow, T. L. and A.S.R. Juo 1995. The rationale for using a watershed as the basis for planning and development. In: J.M.Bartels (ed.) Agriculture and environment: bridging food production and environmental protection in developing countries. Published by ASA, CSSA, and SSSA, Madison, WI, pp. 91-114.

Wischmeier, W. H. 1976. Use and misuse of the Universal Soil Loss Equation. Journal of Soil and Water Conservation 26(5): 189-193.

Wischmeier, W. H. and D.D. Smith. 1978. Predicting rainfall erosion losses - a guide to conservation planning. USDA, Science and Education Administration, Agricultural Handbook 537, Washington, DC, 85p.

Sources Consulted

Castillo, R. 1990. The agricultural systems and soil loss in the Corridor river basin, Costa Rica. M.S. Thesis, Geography Department, Texas A&M University, College Station, TX. 189p.

Chen, H-W. 1995. Sensitivity of soil loss equation to slope classifications. M.S. Thesis, Texas A&M University, College Station, TX. 105p.

Dueker, K. J. and P. Barton. 1990. GIS in the Land development planning process. Journal of the American Planning Association 56, 3: 483-491.

El-Swaify, S.A. 1993. Soil erosion and conservation in the humid tropics. In: D. Pimentel (ed.) World soil erosion and conservation. Cambridge University Press, Grain Britain, pp. 111-140.

Mugabe, P. 1994. Analysis of factor Productivity in Agricultural Systems in Zimbabwe and Application of GIS in Soil Erosion Prediction. M.S. Thesis, Rangeland Ecology and Management Department, Texas A&M University, College Station, TX. 160p.

Sheng, T.C., R. E. Barrett, and T.R. Mitchell. 1997. Using Geographic Information Systems for watershed classification and rating in developing countries. Journal of Soil and Water Conservation 52 (2): 84-89.

Turner, B. and S. Brush 1987. Comparative farming systems. The Guilford Press, New York, NY, 228 p.

Ventura, S.J., B.J. Nieman, Jr., and D. Dmoyer. 1988. A land information system for rural resource planning. Journal of Soil and Water Conservation 43: 226-229.

UNA/PASOLAC 1995. Memorias del segundo seminario nacional de conservación de suelos y agua. Facultad de Recursos Naturales y del Ambiente. Universidad Nacional Agraria, Managua, Nicaragua, 38p.

APPENDIX A

SURVEY FOR EL PITAL WATERSHED

I. Location:

A. Department: **1. Granada** ____ **2. Masaya** _____

B. Municipality: 1.Catarina ____ 2. Diria ____ 3. Diriomo ___

4. Nandaime ____ 5. Niquinohomo _____ 6. San Juan de Oriente ____

7. San Jose de Masatepe ____

C. Comarca: ______________________________

II. General questions:

A. Family' head response: Yes ________ **No** ________

B. Land Tenure:

1. Cooperative land ______ 2. Own in process _____ 3. Own with title _____

4. Rent ____ 5. Occupy "vacant" land with no current effort to obtain title _____

C. Farm Size: ________ Mz.

D.1. Farm slope: ________________ **D.2 Soil type:** ____________________

E. Plan for land use this year:

1. Annual crops	Land area devoted	2. Permanent crops	Land area devoted
__________	____________	____________	____________
__________	____________	____________	____________
__________	____________	____________	____________
__________	____________	____________	____________

3. Pasture land Land area devoted 4. Forest Land area devoted

__________ __________ __________ __________

__________ __________ __________ __________

5. Other Land area devoted

__________ __________

F. How has this land use pattern changed from what you did 5 years ago? Why ?

____

____

G. How would you anticipate this land use pattern changing 5 years from now?

____

____

III. Socioeconomic Aspects

A. Labor Force and Educational level:

Members of the family	**Age**	**Sex**	**Educ. Level**	**Hours work on farm per week**	**Hours work away from farm/week**
spouse					
son					
daughter					
etc.					

C. Time of permanency in the farm: ____ years.

D. When was this land **first** cleared for cultivation ? ____________________________

____

E. Estimation of crops yield over an average of 10 years period:

1. Annual crops — Yield (qq/Mz or other unit specified)

____________ ____________

____________ ____________

____________ ____________

____________ ____________

2. Permanent Crops

____________ ____________

____________ ____________

____________ ____________

____________ ____________

3. Livestock or small animals products

____________ ____________

____________ ____________

4. Forest products

____________ ____________

____________ ____________

5. Other(specify)

____________ ____________

____________ ____________

F. What are the primary factors limiting your current ability to increase production? ____

____

____

____

G. What are your long-term concerns regarding your ability to make a living on this farm? ____

____

____

H. Production purpose:

Self-Consumption (%)	*Local market (%)*	*Exportation (%)*	*Do you obtain credit for produc.?*	*Is this credit neccessary to produce this crop?*	*Do you use: Fertilizer*	*Herb.*	*Insect.*
					How much of each?		
1. Annual crops			yes/no	yes/no			
2. Permanent Crops							
3. Forest							

4. Other (specify)

______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______

I. Domestic animals:

	Self-Consumption (%)	*Local market (%)*	*Exportation (%)*	*Do you obtain credit for produc.?* yes/no	*Is this credit neccessary to raise this animals?* yes/no
Cattle	______	______	______	______	______
Pigs	______	______	______	______	______
Chickens	______	______	______	______	______
Goats	______	______	______	______	______
Bees	______	______	______	______	______
Others	______	______	______	______	______

IV. Technological Aspects

A. Machinery and tools used and owned:

	Used	*Owned*	*How many*
Tractor	______	______	______
Plough with ox	______	______	______
Back-pack pump	______	______	______
Machetes, axes	______	______	______
Mattock	______	______	______

B. Technical Assistance on what subject over the last 3 years:

Subject	How delivered? (workshop, visit,etc.)	How much time/week?
____________	__________________	____________
____________	__________________	____________
____________	__________________	____________
____________	__________________	____________
____________	__________________	____________

C. Institution providing it: ______________________________

D. Institution you prefer to provide it: ______________________________

E. If they are different, why? ______________________________

V. Soil Conservation Condition

A. Knowledge about Soil Erosion and Conservation:

1. Do not know ____ 2. Know but it is not his problem _____

3. Know but does not feel anything can be done ______

4. Know and is willing to do if is provided training for ______

5. Know and is willing to do if is provided equipment and/or funding ______

6. Know and is doing an effort by him or herself ______

7. Know and is doing with the associated level of support ___________________

provided by ____

B. Soil Conservation Practices:

Practices	Know about yes or no	What type are you Using now?	How long have you done this?	What has been your experience? (pros-cons)	Not Use	Why? Why not?	What will be the minimum input neccessary to do it?	Who do you want to give you technical assistance
Agroforestry/ live fences								
Green manure								
Cover practices /mulch								
Compost								

Practices	**Know about yes or no**	**What type are you Using now?**	**How long have you done this?**	**What has been your experience? (pros-cons)**	**Not Use**	**Why? Why not?**	**What will be the minimum input neccessary to do it?**	**Who do you want to give you technical assistance**
Conservation tillage								
Live barriers								
Terraces/ stone or live barriers								
Gully control								
Others								

APPENDIX B

CHARACTERIZATION OF THE SAMPLED FARMS

Table 1. Farm size distribution and area covered by the sampled beneficiaries of agrarian reform farms

Farm size class (ha)	Number of farms	Percent	Area covered by the sample (ha)	Percent
< 4 ha	42	70	103	11
4 - 20 ha	9	15	43	5
21 - 210 ha	8	13	500	54
> 210 ha	1	2	282	30
Total	60	100	928	100

Table 2. Farm size distribution and area covered by the sampled private farms

Farm size class (ha)	Number of farms	Percent	Area covered by the sample (ha)	Percent
< 4 ha	30	42	61	1
4 - 20 ha	23	32	252	5
21 - 210 ha	13	18	1,044	21
> 210 ha	6	8	3,684	73
Total	72	100	5,040	100

APPENDIX C

TABLE C 1. ESTIMATED SOIL EROSION RISK BY FARM AND COMARCA - 1996 SURVEY DATA

Farms by Comarca	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
1		0.016	0.165	17	0	0	0	0	12.7	0	0	0	2.18	12.71
2		0.032	0.303	1.16	0.32	0	0	0.32	13.8	0.40	0	0	2.37	9.41
3		0.016	0.881	0	0	70.4	0	0	37	0	5.29	0	6.34	5.29
4		0.032	0.881	16.9	0	625	152	50.7	74	0	10.6	0.04	12.7	10.07
5		0.032	0.542	70.4	0	1056	211	70.4	45.5	0	6.50	0.03	7.80	7.55
6		0.016	0.303	0	0	82.4	0	0	12.7	0	1.82	0	2.19	1.82
7		0.032	0.303	0	0	10	0	0	25.4	0	3.63	0	4.36	3.63
Dolores	7500			106	0.32	1844	363	121						8.20
8		0.016	0.303	2.98	0.35	0	0	0.17	15.1	0.43	0	0	2.59	13.02
9		0.016	0.165	1.4	0	0	0	0	8.21	0	0	0	1.41	8.20
10		0.016	0.303	38.5	1	0	0	10.5	15.1	0	2.16	0	2.59	12.16
11		0.016	0.881	53.6	2.26	0	0	0.56	43.9	1.26	0	0	7.53	41.84
12		0.016	0.303	3.5	2.1	0	0	1.4	15.1	0	2.16	0	2.59	8.06
13		0.016	0.303	1.8	0.7	0.7	0	0	15.1	0	2.16	0	2.59	8.96
14		0.032	0.165	1.41	0	0	0	0	8.21	0	0	0	1.41	8.21
15		0.032	0.303	1.38	1.38	16.2	0	0.79	30.2	0.86	4.31	0	5.17	5.92
16		0.016	0.303	1.4	1.02	9.9	0	0.38	30.2	0.86	4.31	0	5.17	6.91
17		0.016	0.881	15.9	0	34.9	0	0.52	43.9	0	6.27	0	7.53	17.95
Cuatro esquinas	8900			121	8.81	61.7	0	14.3						20.55

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
18		0.032	1.783	1.8	0	0	0	0	178	0	0	0	30.5	177.8
19		0.032	1.783	1.85	0	0.88	0	0.77	178	0	0	0	0	93.92
20		0.032	0.165	2.78	1.1	10.5	0	1.08		5.08	25.4	0	30.5	22.69
21		0.016	0.165	1.4	0	1.75	0	0.35		0	12.7	0	15.2	11.16
Aguagria	8900			7.83	1.1	13.2	0	2.2						42.77
22		0.016	0.165	1.4	0	0	0	0.7	8.2	0	0	0	1.4	5.95
23		0.032	0.303	58.1	7.15	21.5	2.68	0	30.2	0.86	4.3	.017	5.2	20.72
24		0.032	0.303	0.7	0.14	1.96	0.7	0	30.2	0.86	4.3	.017	5.2	8.49
25		0.032	0.165	2.2	0	0	0	0.28	16.4	0	0	0	2.8	14.90
26		0.032	0.165	2.1	0	0	0	0	16.4	0	0	0	2.8	16.43
27		0.032	2.4914	1.8	0.32	1.38	4.98	2.12	248	7.1	35.5	0.14	42.6	55.59
28		0.032	0.881	10.6	1.41	0.7	0	1.41	87.8	2.5	12.5	0	15.1	68.27
29		0.016	0.165	0	0.35	1.05	0	0	8.2	0..2	1.2	0	1.2	0.93
30		0.032	2.4914	0	8.45	342	71.8	0	248	7.1	35.5	0.14	42.6	28.90
Los Ranchones	8900			76.9	17.8	369	80.2							28.70
31		0.032	0.303	0.54	0	0.36	0	0.9	35.9	0	5.1	0	6.16	14.90
32		0.032	0.165	0.4	0	0	0	0	19.6	0	0	0	3.35	19.56
33		0.032	0.165	1.33	0	0	0	0.08	19.6	0	0	0	3.35	18.64
34		0.032	0.881	0.88	1.05	0.17	1.4	0	105	2.99	14.9	.059	17.9	27.94
35		0.016	0.881	0.7	0.7	0.7	0	1.4	52.3	1.5	7.5	0	8.96	15.84
36	10600	0.016	0.303	2.31	0.71	0.5	0.34	0.34	17.9	0.5	0	.010	3.1	10.22

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
37		0.032	2.4914	1.16	0.52	0	0	0.42	296	8.4	0	0	50.7	175.6
La Granadilla	10600			7.32	2.98	1.73	1.74	3.14						37.01
38		0.032	0.881	2.1	0	0	0	0	116	0	0	0	19.9	116.4
39		0.016	0.881	1.41	0	0	0	0	58.2	0	0	0	9.98	58.2
40		0.016	2.4914	3.92	5	0	2.16	2.42	164	4.7	0	.09	28.2	54.6
41		0.016	0.303	0.55	0.36	0	0.19	0	20.0	0	0	.01	3.43	10.2
42		0.016	0.303	0.7	0	0	0	0	20.0	0	0	0	3.43	20.0
43		0.016	2.4914	1.19	0.17	0	0.04	0	329	9.4	0	.188	56.4	281.0
44		0.032	0.303	2.06	0.35	0.88	0	0.2	20.0	0.57	2.85	0	3.4	12.74
Rolando Espinoza	11800			11.9	5.88	0.88	2.39	2.62						64.41
45		0.032	0.303	0.7	0	0	0	0	40.4	0	0	0	6.86	40.04
46		0.032	0.881	0.7	0	0	0	0	116	0	0	0	19.9	116.4
47		0.032	1.7827	1.62	0.18	0	0	0	235	6.7	0	0	40.4	212.7
48		0.016	1.7827	1.68	0	3.47	0	0.45	118	0	16.8	0	20.2	47.39
49		0.032	0.303	1.19	0.7	0	0	0.04	40.0	1.14	0	0	6.86	34.14
50		0.032	0.881	2.18	1.06	0	0	0.32	116	3.33	0	0	19.9	82.05
El Coyolar	11800			8.07	7.9	3.47	80.2	0.81						79.68
51		0.016	3.275	33.8	1.4	21.1	6.2	6.2	216	6.2	30.9	0.1	37.1	118.9
52		0.032	0.542	1.5	1.0	0	0	0	71.6	2.1	0	0	12.3	42.4
53		0.016	3.275	4.3	0	11.6	0	0	216	0	30.9	0	37.1	83.7

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
54		0.032	0.881	3.4	0.4	0	1.4	1.8	116	3.3	0	.07	19.9	61.9
55		0.032	0.881	2.1	2.1	0	0	0.4	116	3.3	0	.07	19.9	55.7
56		0.032	3.275	1.6	1.8	0.4	0.2	0	433	12.4	61.8	0.25	74.2	188.6
Palo quemado	11800			46.7	6.8	33.1	7.8	8.4	52.3	1.5	0	0	8.96	107.8
57		0.016	0.303	1.4	1.6	0	0	0.2	17.9	0.5	0	0	3.0	8.5
58		0.016	2.4914	2.1	3.2	0.7	0	1.0	148	4.2	21.1	0	25.4	52.2
59		0.032	0.881	9.7	1.5	1.5	0.6	7.8	105	2.9	14.9	.06	17.9	56.0
60		0.032	7.047	7.0	50.7	4.9	2.1	5.6	837	23.9	120	0.5	143	120.7
61		0.016	0.303	1.4	1.6	0.2	0	.06	17.9	0.5	2.6	0	3.1	8.2
62		0.016	1.7827	3.5	14.1	0	0	0	106	3.0	0	0	18.1	23.6
63		0.016	3.275	0	66.9	0	0	3.5	194	5.6	0	0	33.3	6.9
64		0.016	4.577	3.6	21.3	40.5	5.7	0	272	7.8	38.8	0.2	46.6	38.1
Veracruz	10600			28.8	161	47.8	8.4	18.2						51.93
65		0.032	1.7827	1.4	0.7	0	0	0.7	212	6.05	0	0	36.3	116.4
66		0.032	4.577	0.4	0	0	0	0	543	0	0	0	93.2	543.4
67		0.032	4.577	1.1	0	0	0	0	543	0	0	0	93.2	543.4
68		0.032	1.7827	2.1	0	0	0	0	212	0	0	0	36.3	211.6
69		0.016	0.881	1.77	2.11	0	0	0.34	52.3	1.5	0	0	8.96	23.40
70		0.032	1.7827	0.93	1.05	0	0	0.13	212	6.04	0	0	36.3	98.53
71		0.016	0.881	0.48	1.41	0	0	0.21	52.3	1.5	0	0	8.96	13.79
72		0.016	2.4914	1.18	0.53	0	0.1	0.36	148	4.22	0	.08	25.4	88.09

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
73		0.032	0.881	1.11	3.5	0.69	0	0	105	2.99	14.9	0	17.9	25.82
74		0.016	0.881	1.42	1.08	0	0	0	52.3	1.5	0	0	8.96	30.35
75		0.016	0.881	0.92	0.49	0	0	0	52.3	1.5	0	0	8.96	34.64
Hoja Chigue	10600			12.8	10.9	0.69	0.1	1.74						90.55
76		0.016	2.4914	14.2	44.8	0	0	0	148	4.22	0	0	25.4	38.80
77		0.016	3.275	141	0	0	0	0	194	5.6	0	0	33.3	194.4
77		0.016	4.577	0	90.2	11.3	11.3	28.2	272	7.8	38.8	0.16	46.6	17.40
78		0.016	0.165	0	0.7	0	0	0	9.8	0.28	0	0	1.7	10.07
79		0.016	2.4914	36.4	0	0	0	0	148	4.22	0	0	25.4	147.9
79		0.016	4.577	0	155	27.3	18.2	66.7	272	7.8	38.8	0.16	46.6	20.10
80		0.016	3.275	0	63	0	0	0	194	5.6	0	0	33.3	5.55
81		0.016	2.4914	0	113	0	0	0	148	4.22	0	0	25.4	4.22
82		0.032	3.275	21.1	120	0	21.1	14.1	389	11.1	0	0	66.6	50.6
83		0.016	2.4914	0	106	0	33.8	1.4	148	4.2	0	.08	25.4	25.6
84		0.016	4.577	0	143	69.8	105	0	272	7.8	38.8	0.16	46.6	3.5
85		0.016	4.577	0	19.4	175	140	54.3	272	7.8	38.8	0.16	46.6	24.4
86		0.016	1.7827	1.4	0	0	0	0	106	3.0	0	0	18.1	105.8
87		0.016	2.4914	0.7	0	0	0	0	148	0	0	0	25.4	147.9
El Mombacho	10600			214	854	283	329	165						37.21

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
88		0.016	0.881	0.4	1.8	0	0	0	52.3	1.5	0	0	8.9	10.16
89		0.016	0.3027	0.8	0.7	0	0	0.6	17.9	0.5	0	0	3.1	8.16
90		0.032	0.881	40.1	2.8	27.5	0	0	105	2.9	14.9	0	17.9	65.56
91		0.016	0.881	0.5	5.7	0	0.2	0	52.3	1.5	0	.03	8.9	5.49
92		0.032	0.3027	0.2	0.4	0	0	0	35.9	1.0	0	0	6.2	14.40
93		0.032	0.1648	1.4	1.5	0.5	0.1	0	19.6	0.6	2.8	.01	3.3	8.65
94		0.032	0.881	0.9	0.7	0.4	0.2	0	105	2.9	14.9	.06	17.9	46.32
95		0.032	0.881	0.8	1.4	9.9	0	0.6	105	2.9	14.9	0	17.9	19.14
El Portillo	10600			45.1	14.9	38.2	0.5	1.2						50.73
96		0.016	2.4914	1.3	0	0.2	0	0	165	0	23.5	0	28.2	150.62
97		0.032	3.275	3.5	0.2	0.3	0.2	0	433	12.4	61.8	0.25	74.2	368.72
98		0.032	1.7826	2.9	1.4	1.0	0	3.2	236	6.7	33.7	0	40.4	100.24
99		0.016	0.881	1.6	0.2	1.1	0	0	58.2	1.7	8.3	0	10.0	36.50
100		0.032	0.881	2.8	2.6	0	0	0.2	116	3.3	0	0	20.0	60.38
101		0.016	0.3027	0.7	0	0	0	0	20.0	0	0	0	3.4	20.00
San Diego	11800			12.8	4.4	2.6	0.2	3.3						132.47
102		0.016	1.7827	1.1	0.5	0.4	0.2	0	106	3.0	15.1	.06	18.1	58.44
103		0.016	0.3027	2.1	0.4	0	0	1.1	17.9	0.5	0	0	3.1	11.76
104		0.032	1.7827	29.6	54.9	0	0	0	212	6.1	0	0	36.3	78.02
105		0.032	1.7827	0.8	2.5	0	.08	0.5	212	6.1	0	0.13	36.3	50.92
106		0.032	0.3027	1.1	1.1	0	0	0	35.9	1,1	0	0	6.2	18.39

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
107		0.016	4.577	0	17.2	5.6	4.2	1.1	272	7.8	38.8	0.16	46.6	14.40
108		0.016	0.3027	0	15.8	0	0	1.8	17.9	0.5	0	0	3.1	0.77
109		0.032	1.7827	0	5.0	0	0	0	212	6.1	0	0	36.3	6.05
110		0.016	0.881	0	7.0	0	0	0	52.3	1.5	0	0	9.0	1.49
111		0.016	1.7827	0	51.4	0	0	0	106	3.0	0	0	18.1	3.02
112		0.016	2.4914	1.5	1.1	0.25	0.7	0	148	4.2	21.1	.08	25.4	66.17
113		0.032	1.7827	1.6	1.4	0.1	0.1	0	212	6.1	30.2	0.12	36.3	109.4
Niquinhomo	10600			37.7	158	6.4	5.3	4.4						38.64
114		0.016	4.577	0.9	0	1.4	6.9	0	272	0	38.8	0.16	46.6	33.11
115		0.032	4.577	0.7	1.0	5.7	4.9	0	543	15.5	77.6	0.31	93.2	69.77
116		0.016	1.7827	1.1	2.4	0	0	0	106	3.0	0	0	18.2	33.86
117		0.032	1.7827	0	0.4	0	0	0	212	6.0	0	0	36.3	6.05
San Juan de Oriente	10600			2.7	3.8	7.1	11.8	0						50.54

Table C 1. (continued)

Farms by *Comarca*	R factor (Mj·mm/ ha·hr)	K factor (Tons/ha/ Mj·mm/ ha·hr/yr)	LS factor	Area covered in each farm (ha)					Partial soil loss (Tons/ha/yr)					Soil loss weighted average Tons/ha
				Ac	Pc	Rn	Ft	Fw	Ac	Pc	Rn	Ft	Fw	
118		0.032	1.7827	2.0	0	0	0	0.8	236	0	0	0	40.4	181.2
119		0.016	0.3027	1.3	0.4	0	0	0.4	20.0	0.6	0	0	3.4	13.15
120		0.032	0.1648	0.9	.08	0.4	0	0.7	21.8	0.6	3.1	0	3.7	11.89
121		0.032	0.3027	1.1	0.7	0	0	0.7	40.0	1.1	0	0	6.9	19.53
122		0.032	1.7827	3.5	0	0	0	0	236	6.7	33.6	0	40.4	235.6
123		0.032	1.7827	1.4	2.5	0.3	0	0	17.9	0.5	0	0	3.1	86.80
124		0.032	0.881	1.6	0.7	0	0	0.2	116	3.3	0	0	20.0	76.91
Jose Benito Escobar	11800			11.9	4.4	0.7	0	2.7						**100.9**
125		0.016	0.881	2.1	0	0	0	0	52.3	0	0	0	8.9	52.30
126		0.032	1.7827	1.1	0	0.3	0	0	212	0	30.2	0	36.3	166.6
127		0.032	0.352	2.1	0	3.5	0	4.9	41.8	0	5.9	0	7.2	13.69
128		0.032	0.881	0	1.1	0	0	0	105	3.0	0	0	17.9	2.99
129		0.016	1.7827	0	2.5	0	0	0	106	3.0	0	0	18.1	3.02
130		0.032	1.7827	0.4	0.8	0	0	1.0	212	6.0	0	0	36.3	55.02
131		0.016	2.4924	0.4	0.7	0	0	1.1	148	4.2	0	0	25.4	39.23
132		0.032	1.7827	1.8	2.4	0	0	0	212	6.0	0	0	36.3	92.20
San Jose de Masatepe	11800			7.7	7.5	3.9	0	7.0						**41.60**