SUSTAINABLE DEVELOPMENT IN HONDURAS: ECONOMIC EVALUATION OF SOIL CONSERVATION PRACTICES

by

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ABSTRACT

Costs and benefits associated with erosion reduction and adoption of soil conservation practices for a representative farm in a watershed in Honduras are examined in a linear programming framework. Special attention is paid to income-soil loss tradeoffs, income-risk tradeoffs, and on the effect of different farmers' planning horizons on net farm income.

A representative farm model for the area was constructed to achieve the objectives of the study. Twelve farmers in the region were surveyed, crop budgets were prepared, and soil loss values were calculated to provide the information required to construct this representative farm.

A linear programming model that maximizes net farm income is used to examine the effect of different soil loss levels on farm income. A MOTAD model that minimizes deviation in income (risk) is used to determine risk levels while income and/or soil loss levels restrictions are imposed.

Results indicate that considerable reductions in the amount of soil loss can be achieved in the study area. Erosion is reduced from 328.24

ton./mn./year to 6.56 ton./mn./year[1] when constraints are imposed on the model. The reduced erosion lowers income from L.5929.24/year for high erosion rates to L.2825.81/year for low erosion rates. Low levels of soil erosion are achieved at the expense of higher levels of risk. High levels of income are associated with high levels of risk regardless of whether soil loss constraints exist or not. Small differences in income exist among the four planning horizons analyzed.

The best soil conservation practices for this region turned out to be the cultivation of coffee on the highest slopes, the use of live barriers and terraces, and the use of conventional and minimum tillage.

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[1] A manzana equals 0.7 hectares.

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CHAPTER I

INTRODUCTION

Problem statement

Honduras depends heavily on its natural resource base for development of its agricultural sector. In a country characterized by irregular topography, agriculture is heavily concentrated on steep slopes. Deforestation and the cultivation of highly erodible marginal lands, among other factors, increase the susceptibility of these fragile lands to climatic factors such as water and wind, thereby leading to a loss of topsoil. Soil erosion can reduce agricultural productivity and create downstream siltation and pollution problems that constrain economic development.

Problems of soil erosion have been reported to be critical in the central and southern regions of Honduras (Tracy, 1988:265). In these regions, the majority of farmers still employ traditional and intensive agricultural practices that worsen the impact of cultivation on the soil base. Insecure land tenure characterizes not only these regions but the whole country. Insecure tenure may reduce incentives to invest in soil conservation practices by lowering the expected net returns of such activities to the farmer. Uncertainty about returns is another problem faced by the Honduran farmer. Price and yield risk factors may be important considerations in decisions affecting soil conservation.

There is a need for policies to reduce soil erosion in Honduras. Quantification of the on-farm costs and benefits of alternative soil conservation practices can be useful to the government when formulating soil conservation policies. This study is intended to provide information to help design better soil conservation strategies. Information is provided on the riskiness and costs of different conservation practices and cultivation patterns in a farm-level decision model.

Objectives

The objectives of this thesis are:

(1) To determine the most profitable mix of soil conservation practices and crops that would lead to desired reductions in soil losses for the study area.

(2) To determine the optimal mix of soil conservation practices associated with different levels of risk faced by farmers; and,

(3) To analyze the impacts that different planning horizons might have on the profitability of soil conservation practices. Land tenure is directly related to the length of the planning horizon.

Assumptions

The following assumptions are implicit in the study:

(1) The area chosen for this study is representative of the general conditions of steep slope agriculture in Honduras,

(2) The risk faced by farmers is determined by the price and yield variability of the crops included in the study,

(3) A period of ten years is considered to be the planning horizon of a farmer with secure land tenure. The impacts of insecure land tenure

are assumed to be adequately modeled by shortening this planning horizon.

Procedures and data

A farm-level decision model is developed to fulfill the objectives of this study. A representative farm is constructed in order to model farmer decision making regarding choices of soil conservation practices and cultivation patterns. The area chosen for this study is in Lepaterique, Francisco Morazán, approximately 16 km. from Tegucigalpa, the capital of Honduras. The site is representative of steep slope agriculture in Honduras, the types of soil erosion problems, the availability of extension services, and the current use of soil conservation practices.

Twelve farmers were surveyed to obtain information needed to construct this representative farm model. The survey covered crops planted and their rotations, soil conservation devices and tillage systems used, labor availability, production and input usage, output and input prices, cost of soil conservation devices, knowledge about soil erosion problems, land tenure status, slopes and length of fields, other land characteristics, and other activities.

Because soil loss constitutes the main topic of the study, the management decisions included in the model are those directly linked to soil loss. Crops are limited to those grown in the study area while conservation practices and cultivation patterns include indigenous as well as other practices considered effective in promoting soil conservation.

Following the construction of the representative farm model, soil loss coefficients are calculated for each crop and cultivation pattern. These values are based on soil loss estimates given by the Universal Soil Loss Equation (USLE). The USLE predicts gross soil loss per acre as the product of various erosion-related factors.

A linear programming model is used to assist with the analysis of optimal farm plans and soil conservation practices for different levels of soil loss allowed. Because of the interest of including risk in the study, a MOTAD model is constructed (Hazell, 1971). Five years of data on prices and yields are incorporated in the risk component of the model. These data were obtained from the most recent Honduran agricultural census.

Conservation practices as well as alternative crops and cultivation patterns are considered as activities in the model. The model determines the most profitable mix of crops, practices, and cultivation patterns. Additional crop budget data are obtained by updating the prices and input levels in the budgets for the central region of the country. These updated budgets are modified to reflect the variation in yield levels for different conservation practices. Adjustments also are made to reflect cost differences not related to yield for the alternative conservation practices.

To determine the effect of tenure status of farmers on the profitability of soil conservation practices, returns on investment in soil conservation practices for different planning horizons are considered. For the longer planning horizons, the costs of establishment of devices are spread over a longer period, implying lower average annual costs.

Organization of the study

The remainder of this study is organized as follows. A description of the methodological framework, the model used, and the measure of risk used in the analysis are provided in chapter II. A review of soil erosion studies is also provided in this chapter. The results of the analysis are presented in chapter III. The study is summarized and some policy implications and recommendations for alleviating the soil erosion problem in the area are made in chapter IV.

CHAPTER II.

METHODOLOGY AND MODEL DESCRIPTION.

This chapter presents a description of the methodology used to assess the erosion problem in the study area, including a detailed explanation of the model and the measure of risk used in the analysis. A general background of the area is presented followed by an explanation of the methods employed to achieve the objectives of this study. A review of soil erosion studies is integrated into the presentation as well.

The Study area

The study area is characteristic of the steep slope agriculture in Honduras and is located in the "Guacerique" river watershed, found in the Central Region of the country (Figure 2.1). This watershed provides 60% of the water consumed in the capital city, Tegucigalpa. Soil erosion is a source of concern due to its impacts on water quality and on the effective lives of the major reservoirs of water for Tegucigalpa. The study area is also the most important supplier of horticultural production for the central and southern markets of the country.

Approximately twenty percent of the watershed area (180 square km.) is dedicated to agriculture while seventy percent is forested and ten percent is devoted to animal production and population centers. The area has an average altitude of 1420 meters above sea level. The average precipitation is 1200 mm. The average annual temperature is 18°C and varies according to the altitude.

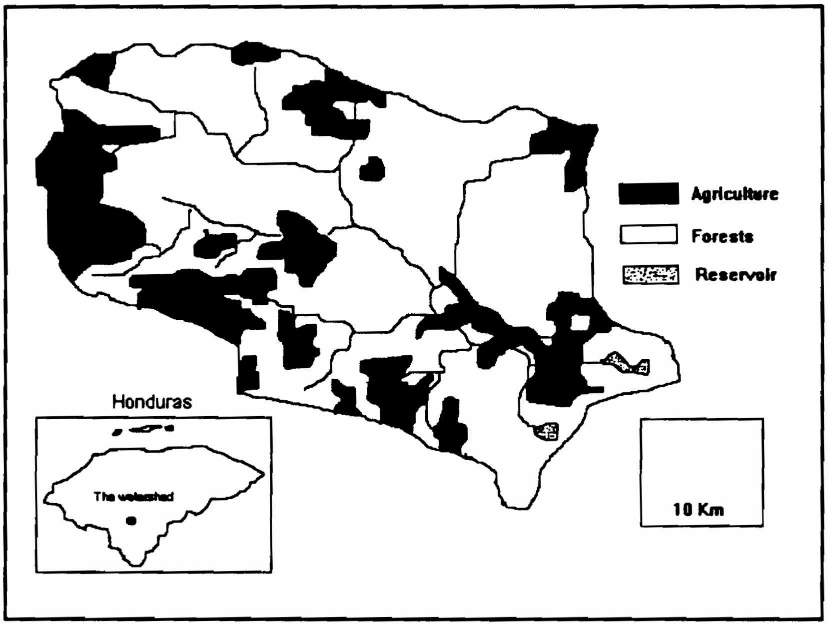

FIGURE 2.1 GUACERIQUE RIVER WATERSHED.

Eighty two percent of the total agricultural area is planted to subsistence crops, especially corn. Beans, the other principal subsistence crop, are planted in a lower proportion. Five percent of the agricultural area is dedicated to vegetable production. This latter area is considered commercial agriculture, although the fields are generally small, from 0.30 to 1.00 manzanas (a manzana equal 0.70 hectares). Sales of vegetables provide the main source of cash income for the farmers in the area. The most important vegetables in terms of value produced are: cabbage, lettuce, carrot, beet, cauliflower, broccoli, parsley and celery.

Where irrigation is available, production is continuous throughout the year and consists mainly of vegetables. The main problems facing agriculture in the area include: improper use of pesticides that contaminate the Guacerique river, deforestation due to migratory (slash and burn) agriculture and gathering of fuelwood, and high rates of soil erosion (Welchez, 1991).

Taking in account the characteristics of agriculture in Honduras and the specific conditions of the study area, a mathematical programming model that deals with the problem of soil erosion and its implications is developed. The methodology used in trying to develop this farm-level model is described in the next section followed by explanations of each subsection.

Methods

The methods employed in this study are presented and described in the order in which they are required to comply with the objectives of the research:

- Description of the linear programming model and the measure of risk to be used.
- Construction of a representative farm model.
- A field survey.
- Determination of soil loss values.
- Crop budgets and investment costs for soil erosion control devices.

The linear programming model

A linear programming model is used to assist with the analysis of the problem (the computer program CPLEX is utilized). Linear programming has been used extensively to study soil loss-related problems. Its use in farm-level as well as in watershed- level studies is widespread. At the farm level, linear programming has been used to examine the effects of uncertain soil loss (Segarra, Kramer, and Taylor, 1985), the effects of depth of topsoil and percentage of organic matter (Burt, 1981), the impact of technological change (Segarra and Taylor, 1987), the influence of risk on farm level soil conservation decisions (Kramer, McSweeny, and Stavros, 1983), the effects of variations in the discount rate, planning period, and cost-sharing level (Ervin and Washburn, 1981), and the influence of public policy (White and Partenheimer, 1980). At the watershed level, linear programming studies have been mainly directed toward analysis of erosion control policies (Seitz, et. al, 1979; Walker and Simmons, 1980; Berglund and Michalson, 1981; McQueen, Shulstad, and Osborn, 1982).

A typical mathematical programming model can be stated as follows:

Optimize $Z = C'X$ (1)

Subject to $AX \leq b$ (2)

and $X \geq 0,$ (3)

where: Z is the objective function to be optimized; C is a vector of costs and returns; X is a vector of the activities; A is a matrix of technical coefficients; and b is a vector of constraint coefficients.

Due to the assumed importance of risk to the conservation decision (Dillon and Scandizzo, 1978; Binswanger, 1980; Kamal and Anderson, 1982), a risk model is utilized. Minimization of the Total Absolute Deviations (MOTAD) is used (Hazell, 1971). MOTAD considers the variability of farm income for a pre-determined number of years. The variance of farm income for a given farm plan can be estimated as an aggregation of the sample variances and covariances of the individual activities:

$$\hat{V} = \sum_{j} \sum_{k} X_j X_k \left[(1/T-1) \sum_{t=1}^{t} (c_{jt} - \bar{c}_j)(c_{kt} - \bar{c}_k) \right] \qquad (4)$$

where V = variance; X_j = the level of the jth farm activity; t = 1 to T denotes the sample observation; c_{jt} is the gross margin of the jth activity in the tth year with sample mean gross margin $\bar{c}_j$. Alternatively, c_{jt} can be obtained by calculating the farm income Y_t corresponding to each sample observation on the activity gross margins and estimating the variance of the single random variable Y:

$$\hat{V} = (1/T-1) \sum_{t} \left[\sum_{j} c_{jt} X_j - \sum_{j} \bar{c}_j X_j \right]^2 \qquad (5)$$

$$= (1/T-1) \sum_{t} \left[Y_t - \bar{Y} \right]^2 . \qquad (6)$$

The deviation of farm income from its mean in year t can be denoted Z_t^+ if it is positive, and Z_t^- if it is negative. Then,

$$Z_t^+ - Z_t^- = \sum_j c_{jt} X_j - \sum \bar{c}_j X_j \, , \quad \forall \text{ all } t. \tag{7}$$

Both Z_t^+ and Z_t^- are non-negative in this formulation, so they measure the absolute size of the deviation in income from its mean. Further, only one of them can be greater than zero each year; the deviation cannot be positive and negative at the same time.

$\sum_t (Z_t^+ + Z_t^-)$ measures the sum of the absolute values of the income deviations for a farm plan. Hence, the objective function in the model is the Minimization of the Total Absolute Deviations. Five years of data were included in the calculation of risk for this study.

To develop coefficients, constraints, yields, and prices for the linear programming model, a representative farm model is constructed.

<u>Representative farm model</u>

A farm model is constructed in order to use linear programming to model farm decision-making with respect to soil conservation practices and cultivation patterns. In linear programming, an objective function is maximized by choosing among a number of alternative activities subject to constraints on resource availability. The information required to construct this model includes:

1. Technical coefficients (the A matrix in equation 2). These are the amount of inputs or constraining variables (such as land, labor, money for inputs, etc.) required for each activity.

Yields or outputs are also considered technical coefficients.

2. Constraints (the vector b in equation 2). Refers to the restrictions on the total availability of each of these decision variables. For example, the amount of soil loss produced by each activity can be summed across farm activities and constrained to be less than some total amount.
3. Prices (the vector C in equation 1).
4. Risk elements outlined above.

This information can be obtained from different sources such as a field survey, soil loss calculations, and secondary data.

Field survey

Twelve 12 farmers were surveyed to obtain information to characterize the representative farm. The farmers included in the study were chosen at random from a set identified by personnel of the L.U.P.E. project (Land Use and Production Enhancement) who work in the area. A detailed description of the methodology and questions in the survey is presented in Appendix 1 and the general information from the field survey is presented in Table 2.1.

The results of the survey show that the average farm size is 1.675 manzanas. Measures of average slope and slope length were made as required for the calculation of the USLE equation. Following this measurement, the typical farm is divided into three land types according to slope: a land type A with an average slope of 2%, a land type B with an average slope of 10%, and a land type C with an average slope of 24%.

TABLE 2.1 MAIN CHARACTERISTICS OF THE REPRESENTATIVE MODEL FARM.

SIZE - 1.675 MANZANAS (MN.)[a]
  AREA UNDER LAND A - 0.5945 MN. (35.5%)
    AVERAGE SLOPE - 2%.
  AREA UNDER LAND B - 0.4305 MN. (25.7%)
    AVERAGE SLOPE - 10% ; 68.75 MTS. OR 225.5 FEET IN LENGTH.
  AREA UNDER LAND C - 0.650 MN. (38.8%)
    AVERAGE SLOPE - 24% ; 67.22 MTS. OR 220.48 FEET IN LENGTH.

% OF FARMERS WITH IRRIGATION - 60%
  AREA WITH IRRIGATION - 0.402 MN. (24%)

CROPS PRODUCED - CORN, BEANS, CABBAGE, ONIONS, TOMATOES.

OF PEOPLE IN THE FAMILY - 4, HUSBAND, WIFE, AND TWO CHILDREN.

SOIL CONSERVATION PRACTICES USED - CONTOUR CULTIVATION, LIVE BARRIERS, HILL SIDE DITCHES, AND TERRACES.

TILLAGE SYSTEMS PRACTICED[b] - CONVENTIONAL, MINIMUM, AND NO-TILLAGE.

WAGE RATE - L. 8.00[c].

SOURCE OF CREDIT - COOPERATIVE (24% ANNUAL INTEREST RATE).

ROTATIONS INCLUDED -

FIRST RAINY SEASON	SECOND RAINY SEASON	DRY SEASON
CORN	CORN	CABBAGE, TOMATOES
CORN-BEANS	CORN-BEANS	CABBAGE, TOMATOES
ONIONS	ONIONS	ONIONS
CABBAGE	CABBAGE	IDLE
CABBAGE	CABBAGE	CABBAGE, TOMATOES
BEANS	CABBAGE	IDLE
BEANS	CABBAGE	CABBAGE, TOMATOES
IDLE	BEANS	CABBAGE, TOMATOES

---

[a] A manzana equals 0.7 hectares.

[b] The differences among these systems refer to the amount of labor required for the planting activities needing more for conventional tillage and less for no-tillage. Insects and weeds control is also easier with conventional tillage than with no-tillage. When complemented with the use of fertilizers and pesticides conventional tillage produce crops with higher yields than the other two systems under the same conditions. With respect to soil erosion, no-tillage produces less soil erosion than the other two systems.

[c] A Lempira equals $ 0.18.

Approximately 35% of the area of the farm falls into land A, 26% into land B, and 39% into land C. Slope length is no longer than 225 feet in all the farms visited. None of the farmers in the survey were found to be renting land for any purpose. In some cases, relatives' land is cultivated and the benefits are divided equally among the people participating in the activities.

The most important crops in the area are corn, beans, corn-beans intercropped, cabbage, onions, and tomatoes; these are included in the model. Coffee is also included in the model. Coffee production is not widespread in the region, but considering the potential benefits that coffee brings in terms of erosion reduction on the steepest slopes and the climatic conditions that would make coffee cultivation viable in this region of Honduras, it was included in the model as a convenient way to reduce erosion on the steepest slopes.

Production in the area is continuous from May through December (rainy season), and when irrigation is available, it is extended through the summer months (January through April). Sixty percent of the farmers in the survey have irrigation on 24% of the area (approximately 0.40 mn.)

The main soil conservation devices used in the area include: contour cultivation, live barriers, hill-side ditches, and terraces. The existence of these practices is basically due to efforts of the agricultural extension service that since the early 70s has promoted the use of soil conservation practices in the region. At the present, the extension service role is fulfilled by the LUPE project. All these practices were introduced into the model.

The most common tillage system found in the area is conventional tillage although minimum tillage and no-tillage were observed on a few farms. The three tillage systems were included for corn, beans, and corn-beans intercropped production, whereas for cabbage, tomatoes, and onions production, only conventional tillage was considered. Coffee was assumed to be produced under the conventional production system used by Honduran farmers.

The rotations included in the model represent the most frequent ones practiced. During the dry season, only vegetable production is allowed in the model (on irrigated land). Coffee production occurs throughout the year. Crop planting periods were specified during the interviews and they are illustrated in Figure 2.2.

The average family consists of 4 people: a farmer, his wife, and two children. Agricultural activities are performed in greater degree by men and children, while women take care of household tasks and help with agricultural activities when needed.

People in the area are reluctant to use credit (which may be true for farmers throughout the country). A cooperative in the area provides credit and input purchasing services at an annual interest rate of 24% though few farmers (3 out of the 12 farmers surveyed) used this credit.

Soil loss values

Soil-loss values are required for each farming activity in order to build a constraint that will give the amount of soil loss for a specific farm plan under specific conditions (management practice, weather, type of

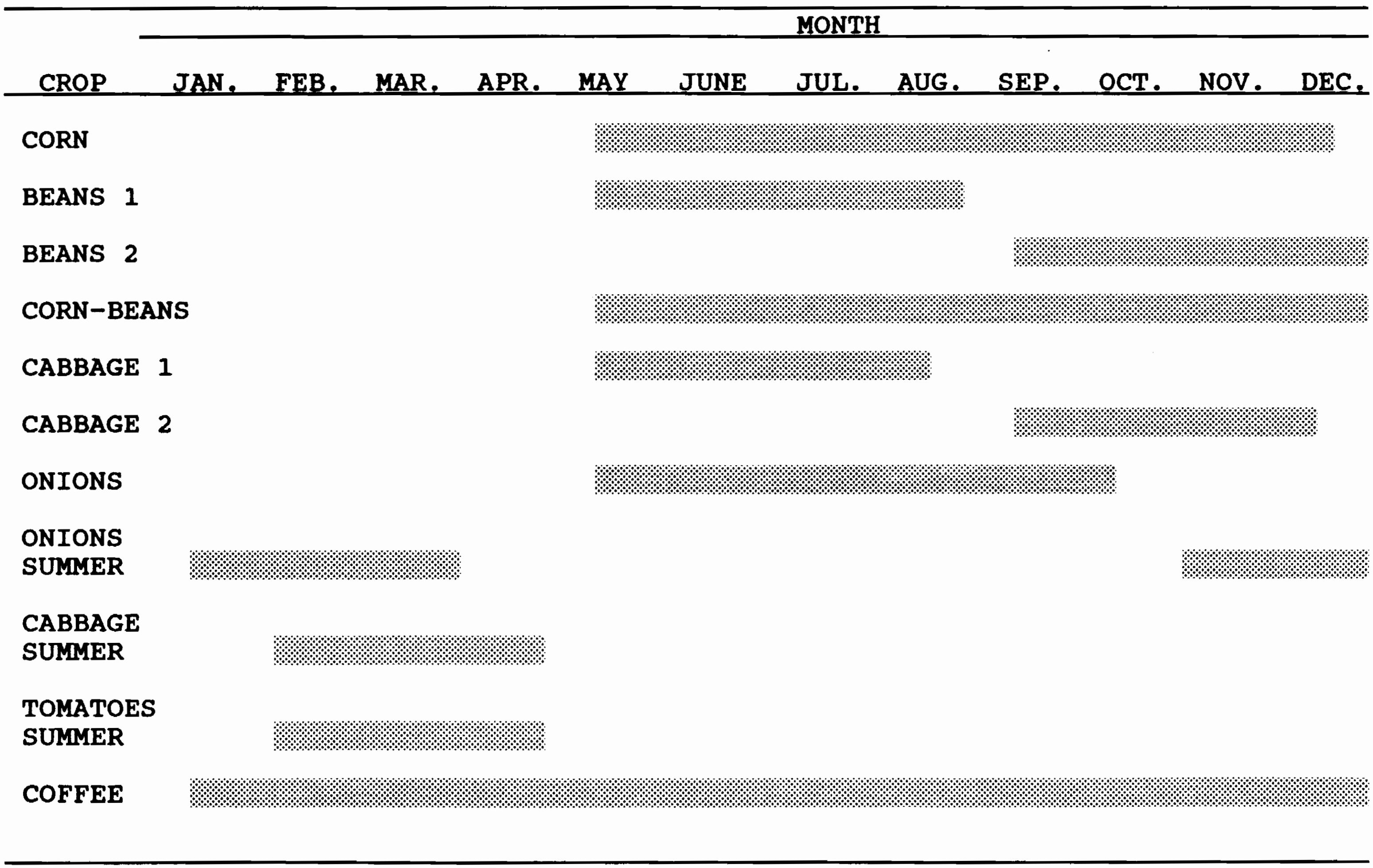

FIGURE 2.2. CROP PLANTING PERIODS.

soil, soil conservation practices used, and slope of the field). Soil-loss coefficients for each crop activity were calculated using the Universal Soil Loss Equation (USLE).

The USLE is designed to compute average soil losses from sheet and rill erosion under specified cropping and management systems. It predicts gross soil loss per acre as the product of six major erosion factors whose most likely values at a particular location can be expressed numerically (Wischmeier and Smith, 1978). Specifically the USLE is:

$$A = R * K * LS * C * P$$

where

A, the computed soil loss per unit area, is expressed in the units selected for K and for the period selected for R. In practice, these are usually selected to compute A in tons per acre per year, but other units can be selected.

R, the rainfall and runoff factor, is the number of erosion index units plus a factor for runoff from snowmelt or applied water where such runoff is significant; it quantifies the raindrop impact effect and also provides relative information on the amount and the rate of runoff likely to be associated with the rain.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6-ft length of uniform 9-percent slope continuously in clean-tilled fallow.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-ft length under identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support device like contouring or terracing to that with straight-row farming up and down the slope.

Numerical values for each of the six factors were derived for the study area. The values for the factors used to calculate the USLE are presented in Table 2.2. The rainfall and runoff factor, R, was found in a study completed near the study area (Wouters, 1980). This value was assumed to approximate the rainfall and runoff characteristics of the area. The soil erodibility factor, K, was calculated using figure 3, page 11 in the USDA publication _Agricultural Handbook No. 537_. It was developed from soil analysis of different sectors in the study area (Recursos Hidricos, 1983). Values for the support practice factor, P, and for the slope-length and slope-steepness factors, L and S, for contouring, hill side ditches, and terracing were found in _Agricultural Handbook No. 537_. Due to the absence of information about the P, L, and S factors for live barriers in the literature, these values had to be constructed from the assumption that live barriers prevent more erosion than contour cultivation but less than hill side ditches. Factor C, which measures the

TABLE 2.2 VALUES USED TO CALCULATE SOIL LOSS WITH THE USLE EQUATION.

FACTOR	PRACTICES	SLOPE 2%	10%	24%	VALUE
P[a]	CONTOURING	0.60	0.60	0.95	
	BARRIERS	0.59	0.58	0.93	
	HILL SIDE DITCHES	--	0.55	0.90	
	TERRACING	--	0.55	0.90	
LS[a]	CONTOURING	0.248	2.0475	8.00	
	BARRIERS	0.201	0.85	3.00	
	HILL SIDE DITCHES	--	0.825	3.00	
	TERRACING	--	0.50	2.00	
R[b]					234.64
K[c]					0.20
C[c]	CORN CONVENTIONAL TILLAGE				0.513
	CORN MINIMUM TILLAGE				0.26428
	CORN NO-TILL				0.15476
	BEANS CONVENTIONAL TILLAGE 1[d]				0.41625
	BEANS MINIMUM TILLAGE 1[d]				0.2211
	BEANS NO-TILL 1[d]				0.1477
	BEANS CONVENTIONAL TILLAGE 2[e]				0.6377
	BEANS MINIMUM TILLAGE 2[e]				0.3627
	BEANS NO-TILL 2[e]				0.15164
	CORN-BEANS CONVENTIONAL TILLAGE				0.4664
	CORN-BEANS MINIMUM TILLAGE				0.2407
	CORN-BEANS NO-TILL				0.1322
	CABBAGE 1[d]				0.5798
	CABBAGE 2[e]				0.7354
	CABBAGE SUMMER				0.3328
	ONIONS				0.6090
	ONIONS SUMMER				0.7266
	TOMATOES SUMMER				0.3328
	COFFEE				0.040

Sources:

[a] Wischmeier, W.H. and D.D. Smith, 1978.

[b] Wouters, 1980;

[c] Calculated by the author.

[d] Refers to beans and cabbage planted from May to August.

[e] Refers to beans and cabbage planted from September to December.

combined effect of all interrelated cover and management variables was calculated for each combination of crop and tillage system. The process employed in Agricultural Handbook No. 537 was followed for its estimation. The calculation of the C factor for all crops is illustrated in Appendix 2.

Values of 10%, 40%, and 60% of initial cover crop were used to represent conventional, minimum, and no-tillage systems respectively. Crops stages were identified through consultations with agronomists working in the study area. Factor C gives an idea of the magnitude of soil erosion among crops. Cabbage, onions and beans are the most soil erosive crops.

Budgets and investment costs

Crop budgets (variable costs of the crops as well as input requirements and yields) were constructed by including current prices and input levels in the budgets published for the central region of the country. These budgets were adjusted to reflect variations in yield levels according to land slope (see Table 2.3).

A 0.5% decrease in yields on the 10% slope lands from those on the 2% slopes and a 3% decrease in yields on the 24% slope land are included (Table 2.3). These values capture the effect of slope on the area of land under production. These values can be considered the lower levels of yield reductions since other factors such as differences in nutrients, sunshine, etc. on the different slopes also affect the yield, but due to lack of information were not included in the model.

TABLE 2.3. YIELD VARIABILITY ACCORDING TO LAND SLOPE BY CROP PRACTICE AND TILLAGE SYSTEM (QQ/MN.[a]).

		SLOPE		
CROP	TILLAGE[b]	2%[c]	10%[d]	24%[e]
CORN	C	32.00	31.87	31.04
	M	25.00	24.87	24.25
	N	15.00	14.92	14.55
BEANS	C	14.00	13.93	13.58
	M	8.00	7.96	7.76
	N	5.00	4.97	4.85
CORN-BEANS				
CORN	C	24.00	23.88	23.28
	M	18.75	18.65	18.18
	N	11.25	11.19	10.91
BEANS	C	8.40	8.35	8.14
	M	4.80	4.77	4.65
	N	3.00	2.98	2.91
CABBAGE	C	250.00	248.75	242.50
ONIONS	C	150.00	149.25	145.50
TOMATOES	C	300.00	298.50	291.00

[a] Quintals per manzana.
[b] C = Conventional tillage; M = Minimum tillage; N = No-tillage.
[c] Directly from Table A.4.2.
[d] Assuming a 0.5% decrease in yields.
[e] Assuming a 3% decrease in yields.

In cases where budgets for different tillage systems (conventional, minimum, and no-tillage) were unavailable, they had to be constructed from information obtained from the field survey and from information given by agronomists working in the area. Prices and yield data were obtained from the latest Honduran Agricultural Census. Budgets for the different crops can be found in Appendix 4.

Budgets for the conservation devices and construction labor requirements were obtained from the literature on soil conservation (Almendariz, 1990; Tracy and Mungia, 1986; Michaelsen, 1980). These budgets include construction and maintenance costs for the three conservation devices included in the model. Since labor is the only input used in the construction of the devices, construction costs reflect the amount of labor (expressed in man-days) needed to construct a determined amount (expressed in meters) of conservation device. Ten percent of these labor requirements was charged as the annual maintenance costs for each device.

These values were compared and updated with the values that personnel of the LUPE project have generated for the area. In most cases, the values used were similar to the LUPE values, although adjustments had to be made in some.

Adjustments were also made to reflect the effects of the different conservation devices on the amount of cultivable land[2]. The amount of

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[2] Barriers take 2.5%, 6% and 7.7% of the cultivable land for 2%, 10%, and 24% slope land respectively. Hill ditches take 12% and 16.3% of the cultivable land for 10% and 24% slope lands respectively. Terraces take 17.6% and 17.9% of the cultivable land for 10% and 24% slope respectively.

cultivable land taken out of production by the presence of these devices is considerable for the steepest slopes. Specifications for the construction of devices and labor investment requirements for the different conservation devices can be found in Appendix 5.

The model in detail

A tableau for the representative farm is presented in Figure 2.3. Each column and row depicts model categories with several activities and constraints within each. The base model (the model without risk) is presented first and the model with risk is described later. A one-year model was assumed for this study. A general description of the model is followed by detailed explanations of each major section. The base model contains 243 columns and 197 rows. The risk model contains 15 additional columns and 11 additional rows.

Objective function

The base model maximizes net returns to land, overhead, and management. The objective function reflects: a) the variable cost for each crop for 1991, b) prices for each crop for 1991, c) a wage rate in the study area of L. 8.00 per day, d) an annual interest rate of 24%, and e) the cost of purchasing inputs associated with each conservation device (specifically the grass that is planted to protect each conservation device).

This base model is a standard linear programming problem. When risk is included, minimization of deviations from average income (risk) becomes the objective function of the model and the model becomes a MOTAD model.

Columns Rows	Land A C1.....C36	Land B C37..C108	Land C C109..C181	Sell Crops SCR..SCF	Credit BOCR1..12	Hire Labor HJA..HDC	Const. BMP's CLA...CTC	Transfer TRCH1...12	Fam. Exp. EXP1..12	RHS
Objective Function (L.)	- C.......................................- C			P.............P	- I.....- I	- W..........- W	- G..........- G			MAXIMIZE
Cash requirements (L.)	D.......................................D			- P........- P	-1			-1	E	≤ B
Crop Transfers (QQ./Mn.)	- Y	- Y	- Y	1						= 0
Land A (Mn.)	1.........1									≤ X1
Land B (Mn.)		1.............1								≤ X2
Land C (Mn.)			1.............1							≤ X3
Labor requirements (Days)	L	L	L			-1				≤ F
Construction BMP's						-1	Z..........Z			≤ 0
Rotational Requirem. (Mn.)										
Land A	- 1 1									≤ 0
Land B		- 1 1								≤ 0
Land C			- 1 1							≤ 0
Soil Loss (Ton./Mn.)	S.......................................S									≤ ¥

C = Variable cost of production. P = Price of crops. I = Interest rate. W = Wage rate. G = Grass Cost. D = Monthly cash requirement. E = Family expenses. B = Initial cash availability. Y = Crop Yield. X1 = Land Type A available. X2 = Land Type B available. X3 = Land Type C available. L = Amount of labor required for each crop. F = Household available labor. Z = Practice construction labor required. S = Soil Loss values for each crop. ¥ = Soil loss constraint.

FIGURE 2.3. PROGRAMMING MODEL TABLEAU FOR A REPRESENTATIVE FARM IN THE GUACERIQUE RIVER WATERSHED AREA IN HONDURAS MODEL WITHOUT RISK.

Activities

The model activities can be grouped into seven categories: 1) crop production on each land type, 2) resource hiring, 3) credit and borrowing, 4) construction of conservation devices, 5) crop sales, 6) cash transfer, 7) family expenses, and 8) soil accounting. A complete list of all activities is found in Appendix 3.

Constraints

The constraints include: 1) cash flows, 2) crop transfers, 3) land constraints, 4) monthly labor requirements, 5) rotations, 6) constraints to the construction of devices, and 7) a soil loss constraint. When risk is included, expected total gross margin and risk constraints for five years become new constraints into the model.

Crops can be grown on land A (2% slope), land B (10% slope), or land C (24% slope). Coffee is allowed to be grown on land C only. There are 181 crop production activities that result from the combination of crops, planting seasons, land types, conservation devices used, and tillage systems (Appendix 3). All the crops are assumed to be sold in the market. Although corn and beans are mainly subsistence crops (only used for family consumption), a return has to be considered for the resources used in their production.

An important feature of this model is that it allows the farm to take land out of production as the desired levels of soil erosion get lower and lower. This is done by relaxing the requirement that the whole land area has to be cultivated at any time.

Construction of live barriers is permitted on the three land types, whereas hill-side ditches and terraces are allowed to be constructed only on land types B and C. Construction of these devices is assumed to occur during summer months (February, March and April). To analyze the impact of construction of devices on farm income, hired labor must be used to construct these practices. Although there is slack family labor during the construction months, it is assumed that the difficulty of construction must be reflected as an income penalty.

Twelve borrowing activities, corresponding to the twelve months of the year are included. The interest rate charged by the farmers' cooperative is used. No other sources of credit were identified during the survey. Hiring labor activities are included for the twelve months of the year; the available family labor is 48 man-days (a man and two children)[3]. When family labor is not enough to cover the crop requirements, extra labor can be hired, at a wage rate of L.8.00/day. Family expenses for the twelve months are also included. A standard value of L.386.16[4] is used as the monthly family-living expenses requirement.

To determine monthly cash flows, monthly cash requirements were calculated for each crop. These requirements included hired labor as well as input requirements. Cash requirements as well as family expenses are to be paid from an initial endowment of L. 494.10, from crop sales, and

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[3] Assuming that a man works 24 days/month and that children work half the time a man does.

[4] Source: Franklin, R., 1990. Assuming expenses of L.70.80/month/person and food expenses of 75% of total expenses.

from the available source of credit. Transfers of cash surpluses are made to subsequent months. At the end of the year, the cash balance has to be sufficient to pay the amount of money borrowed and the initial endowment of money the farmers started with.

One soil-loss constraint was included in this model to analyze the effects of erosion reduction for the whole farm rather than for each type of land. The calculation of soil loss for each activity is shown in Appendix 3.

The no-risk model was used to determine the effect that different soil-loss requirements have on farm income. When risk is included in the model, 15 more columns and 10 more rows were added to the model (Figure 2.4). Minimization of deviations (that is, the sum of the absolute values of the income deviations from the average income for the farm plan) for the five years becomes the new objective function. The first five rows measure the absolute size of the deviation of farm income from its mean for each year. The last five rows are accounting rows that permit calculation of the variance for each year (that is, to account for the total deviation, whether it is positive of negative). The accounting activity - Nt (where t refers to the year) indicates if there has been any positive deviation, and the accounting activity + Pt tells us if there has been any negative deviation in the observation, t.

The measure of risk was based on the variability of yields and prices. Yields and prices for the crops included in the risk model are presented in Appendix 5. Deflated prices were used to account for the effect of inflation, with 1990 used as the base year.

Columns	Land A	Land B	Land C	Sell Crops	Credit	Hire Labor	Const. BMP's	Transfer	Fam. Exp.	Deviations					Accounting activities										
Rows	C1....C36	C37..C108	C109..C181	SCR..SCF	BOCR1..12	HJA..HDC	CLA...CTC	TRCH1...12	EXP1..12	Z1	Z2	Z3	Z4	Z5	N1	N2	N3	N4	N5	P1	P2	P3	P4	P5	RHS
Objective Function										1	1	1	1	1											MINIMIZE
Expected Profit (L.)	- C..- C			P............P	- I.....- I	- W.........- W	- G.........- G																		= £
Cash requirements (L.)	D..D			- P.........- P	-1			-1	E																≤ B
Crop Transfers (QQ./Mn.)	- Y	- Y	- Y	1																					= 0
Land A (Mn.)	1.........1																								≤ X1
Land B (Mn.)		1............1																							≤ X2
Land C (Mn.)			1............1																						≤ X3
Labor requirements (Days)	L	L	L			-1																			≤ F
Construction BMP's						-1	Z..........Z																		≤ 0
Rotational Requirem. (Mn.)																									
Land A	- 1 1																								≤ 0
Land B		- 1 1																							≤ 0
Land C			- 1 1																						≤ 0
Soil Loss (Ton./Mn.)	S..S																								≤ ¥
Risk rows (L.)																									
Year 1	A_1..A_1									1															≥ 0
Year 2	A_2..A_2										1														≥ 0
Year 3	A_3..A_3											1													≥ 0
Year 4	A_4..A_4												1												≥ 0
Year 5	A_5..A_5													1											≥ 0
Year 1	A_1..A_1														- 1					1					= 0
Year 2	A_2..A_2															- 1					1				= 0
Year 3	A_3..A_3																- 1					1			= 0
Year 4	A_4..A_4																	- 1					1		= 0
Year 5	A_5..A_5																		- 1					1	= 0

C = Variable cost of production. P = Price of crops. I = Interest rate. W = Wage rate. G = Grass Cost. £ = Income target. D = Monthly cash requirement. E = Family expenses. B = Initial cash availability. Y = Crop Yield. X1 = Land Type A available. X2 = Land Type B avaiable. X3 = Land Type C available. L = Amount of labor required for each crop. F = Household available labor. Z = Practice construction labor required. S = Soil Loss values for each crop. ¥ = Soil loss constraint. A_i = Income deviations for each activity, year $_i$. These deviations can be positive or negative.

FIGURE 2.4. PROGRAMMING MODEL TABLEAU FOR A REPRESENTATIVE FARM IN THE GUACERIQUE RIVER WATERSHED AREA IN HONDURAS. MODEL WITH RISK.

The risk model allowed for risk minimization while accounting for differences in the levels of soil loss as well as in the amount of income.

In summary for the construction of the representative farm model farmers were surveyed, crop budgets were prepared, and soil loss values were calculated. A one-year linear programming model that maximizes net farm income is used to examine the effect of different soil loss levels on farm income. A MOTAD model that minimizes deviations in income from an average income is used to determine risk levels while income and/or soil loss levels restrictions are imposed. Model results are presented in the following chapter.

CHAPTER III

RESULTS AND ANALYSIS

The results obtained from running the linear programming model are discussed in this chapter. Three types of analysis corresponding to the study objectives are described. Income-soil loss tradeoffs are presented first, followed by risk-income tradeoffs, and the impact of different planning horizons on model outcomes. Shadow prices are interpreted for selected constraints and comparisons are made among the several runs performed. Sensitivity analysis is also described and interpreted.

Different model solutions result from changes in the amount of soil loss allowed, the amount of income targeted, or a combination of both. Income-soil loss tradeoffs and risk-income tradeoffs assume a 10 year planning horizon[5].

Base run

The base model is run without including risk so that the objective is the maximization of farm income. The objective is to determine the amount of soil erosion resulting from the maximization of income without constraining soil loss. The base farm has 1.67 manzanas of land, 48 man-days/month available, and an initial cash availability of L.494.10.

The base solution results in soil loss of 328.24 ton./mn./year with

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[5] The cost of and the maintenance of the conservation practices structures were spread over the ten years.

an income level of L.5924.24/year[6]. Soil erosion is then constrained to be reduced by 20%, 40%, 60%, 80%, 85%, 90%, 95%, 96%, 97%, and 98% of this initial value. Different levels of farm income correspond to these different erosion reductions. Basis changes reveal the optimal on-farm adjustments to different levels of erosion reduction.

Income-soil loss tradeoffs

Income - soil loss tradeoffs are presented for two cases. In the first, the effects of different soil-loss limits on net farm income, crops produced, and conservation practices used are analyzed. In the second, constraints on the amount of income are imposed. That is, the level of income targeted is changed without constraining soil loss. In this second case, risk is minimized subject to income levels corresponding to the soil loss levels from the first case. Because the focus of this section is on the income - soil loss relationships, the effect of these changes on risk is analyzed later. The analysis of the first case follows.

The effects of different soil-loss limits on net farm income and crop produced are presented in Table 3.1. The effects of soil-loss limits on conservation devices employed and tillage systems used are presented in Table 3.2. Income (returns to land, family labor, and management) falls from L.5924.24 with no limit on soil loss (328.24 tn./mn./year) to L. 2825.81 when soil loss is reduced to 2% of this initial value (6.56 tn./mn./year).

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[6] This income refers to returns to land, family labor, and management. Average per capita annual income in Honduras in 1989 was $ 900.00 (approximately L.4950.00).

TABLE 3.1. EFFECTS OF SOIL LOSS REDUCTIONS ON INCOME AND CROPS PRODUCED.

S.L.	SOIL LOSS	INCOME	LAND	CROP ACTIVITIES[a] (MN.)					
LEVEL	(TON/MN.)	(LEMP.)	TYPE	CR	BN	CR-BN	CB	ON	CF
100%	328.24	5929.24	A	-	0.45	-	0.45	0.28	-
			B	-	0.33	-	0.33	0.21	-
			C	-	0.49	-	0.49	0.31	-
80%	262.59	5876.92	A	-	0.45	-	0.45	0.28	-
			B	-	0.33	-	0.33	0.21	-
			C	-	0.48	-	0.48	0.31	-
60%	196.95	5824.61	A	-	0.45	-	0.45	0.28	-
			B	-	0.33	-	0.33	0.21	-
			C	-	0.46	-	0.46	0.31	-
40%	131.29	5748.80	A	-	0.45	-	0.45	0.28	-
			B	-	0.32	-	0.32	0.21	-
			C	-	0.46	-	0.46	0.29	-
20%	65.65	5152.02	A	-	0.45	-	0.45	0.28	-
			B	-	0.31	-	0.31	0.19	-
			C	-	0.42	-	0.42	0.06	0.12
15%	49.23	4838.75	A	-	0.45	-	0.45	0.28	-
			B	-	0.31	-	0.31	0.19	-
			C	-	0.22	0.22	0.22	-	0.16
10%	32.82	4482.37	A	-	0.45	-	0.45	0.28	-
			B	-	0.31	-	0.31	0.19	-
			C	-	-	0.45	-	-	0.16
5%	16.41	3869.75	A	-	0.45	-	0.45	0.28	-
			B	-	0.29	-	0.29	0.19	-
			C	-	-	-	-	-	0.16
4%	13.13	3728.10	A	-	0.44	-	0.44	0.28	-
			B	-	0.28	-	0.28	0.18	-
			C	-	-	-	-	-	0.16
3%	9.84	3364.91	A	-	0.44	-	0.44	0.28	-
			B	0.09	0.19	0.09	0.28	-	-
			C	-	-	-	-	-	0.10
2%	6.56	2825.81	A	-	0.44	-	0.44	0.28	-
			B	0.06	0.11	0.19	0.17	-	-
			C	-	-	-	-	-	-

[a] CR=Corn; BN=Beans; CR-BN=Corn intercropped with beans; CB=Cabbage; ON=Onions; CF=Coffee; A=2% slope; B=10% slope; C=24% slope.

TABLE 3.2. EFFECTS OF SOIL LOSS REDUCTIONS ON CONSERVATION DEVICES AND TILLAGE SYSTEMS USED (MN.)

PERCENT	LAND	DEVICE AND TILLAGE SYSTEM[a]								
REDUCT.	TYPE	CC	CM	CN	LC	LM	LN	TC	TM	TN
100%	A	1.19	-	-	-	-	-	-	-	-
	B	0.86	-	-	-	-	-	-	-	-
	C	1.30	-	-	-	-	-	-	-	-
80%	A	1.19	-	-	-	-	-	-	-	-
	B	0.86	-	-	-	-	-	-	-	-
	C	0.84	-	-	0.42	-	-	-	-	-
60%	A	1.19	-	-	-	-	-	-	-	-
	B	0.86	-	-	-	-	-	-	-	-
	C	0.38	-	-	0.85	-	-	-	-	-
40%	A	1.19	-	-	-	-	-	-	-	-
	B	0.64	-	-	0.20	-	-	-	-	-
	C	-	-	-	1.21	-	-	-	-	-
20%	A	1.19	-	-	-	-	-	-	-	-
	B	-	-	-	0.81	-	-	-	-	-
	C	-	-	-	-	-	-	0.9	-	-
15%	A	1.19	-	-	-	-	-	-	-	-
	B	-	-	-	0.81	-	-	-	-	-
	C	0.16	-	-	-	0.22	-	0.44	-	-
10%	A	1.19	-	-	-	-	-	-	-	-
	B	-	-	-	0.81	-	-	-	-	-
	C	0.16	-	-	-	0.35	-	0.10	-	-
5%	A	1.19	-	-	-	-	-	-	-	-
	B	-	-	-	0.39	-	-	0.38	-	-
	C	0.16	-	-	-	-	-	-	-	-
4%	A	0.28	-	-	0.88	-	-	-	-	-
	B	-	-	-	0.07	-	-	0.67	-	-
	C	0.16	-	-	-	-	-	-	-	-
3%	A	1.16	-	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	0.56	0.09	-
	C	0.10	-	-	-	-	-	-	-	-
2%	A	-	-	-	1.16	-	-	-	-	-
	B	-	-	-	-	-	-	0.23	0.25	0.06
	C	-	-	-	-	-	-	-	-	-

[a] CC, CM, CN = Contour cultivation with Conventional, Minimum, and No-tillage respectively.
LC, LM, LN = Live barriers with Conventional, Minimum, and No-tillage respectively.
TC, TM, TN = Terraces with Conventional, Minimum, and No-tillage respectively.

Production of beans, cabbage and onions on the three types of land under conventional tillage and contour cultivation lead to the highest level of income as well as the most soil erosion (Table 3.1). Due to the different planting periods and to the possibility of growing more than one crop within a year, the sum of the areas planted under each type of land does not correspond to the total available land in Table 3.1. L.859.60 are borrowed in May because cash is needed to finance agricultural activities which commence during this month. No more credit is required thereafter. There is no need to hire labor to complete farm activities.

More than a 50% reduction in soil erosion can be achieved at very little loss of income. However, as soil loss is reduced to between 40% and 20% of the initial unconstrained level, income begins to fall dramatically. Until erosion is constrained to below 20% of initial soil loss levels, virtually no adjustments to crop rotations are made. Beans, cabbage, and onions continue to be grown, coffee is only added to the solution on the 24% slope lands when a 80% reduction in soil erosion is required. The adjustments made on the farm to comply with erosion restrictions are the construction of conservation devices used. Construction of live barriers, first on the most erosive lands (the C land) and then on the middle erosive lands (B) and construction of terraces on C land, can reduce erosion up to 20% of the unconstrained level. Reductions below 20% lead to drastic income declines (of 13% from unconstrained base income and higher). Some of the reasons for these income reductions are: 1) the high prices associated with the most soil-erodible crops (cabbage and onions), 2) the fact that some land is taken out of production when only low levels of soil loss are permitted. Land type C (24% slope) is first taken out of production followed by land type B (12% slope) and finally by land type A (2% slope), and 3) the increased cost of investment in soil-conservation structures at low levels of soil loss. Below this level of erosion (20% of base levels), coffee continues to be grown on the steepest slopes and, eventually, it becomes the only crop grown on these slopes. Corn and corn-beans intercropped also appear when erosion constraints are severe. A more marked shift is observed in conservation devices and tillage systems. Live barriers and terraces continue to be present at low levels of soil loss. Shifts to minimum tillage and no-tillage are also observed at low levels of allowed soil erosion.

Finally, the lowest level of income and soil loss is achieved when beans, cabbage, and onions are grown on land A, corn, beans, corn-beans intercropped, and cabbage grown on land B. Live barriers (with conventional tillage) and terraces (conventional, minimum, and no-tillage) are constructed at these low levels. The amount of money borrowed in May falls to L.77.27 and labor is hired to construct live barriers and terraces. The relationship between soil loss and income for these model runs is illustrated in Figure 3.1.

In summary, beans, cabbage, and onions are consistently produced regardless of the level of income (and therefore, of soil loss). Coffee (which is only allowed to be planted on 24% slope lands) enters the model when considerable reductions in the permissible amount of soil loss are imposed, since it is less erosive than the other crops. It is also less

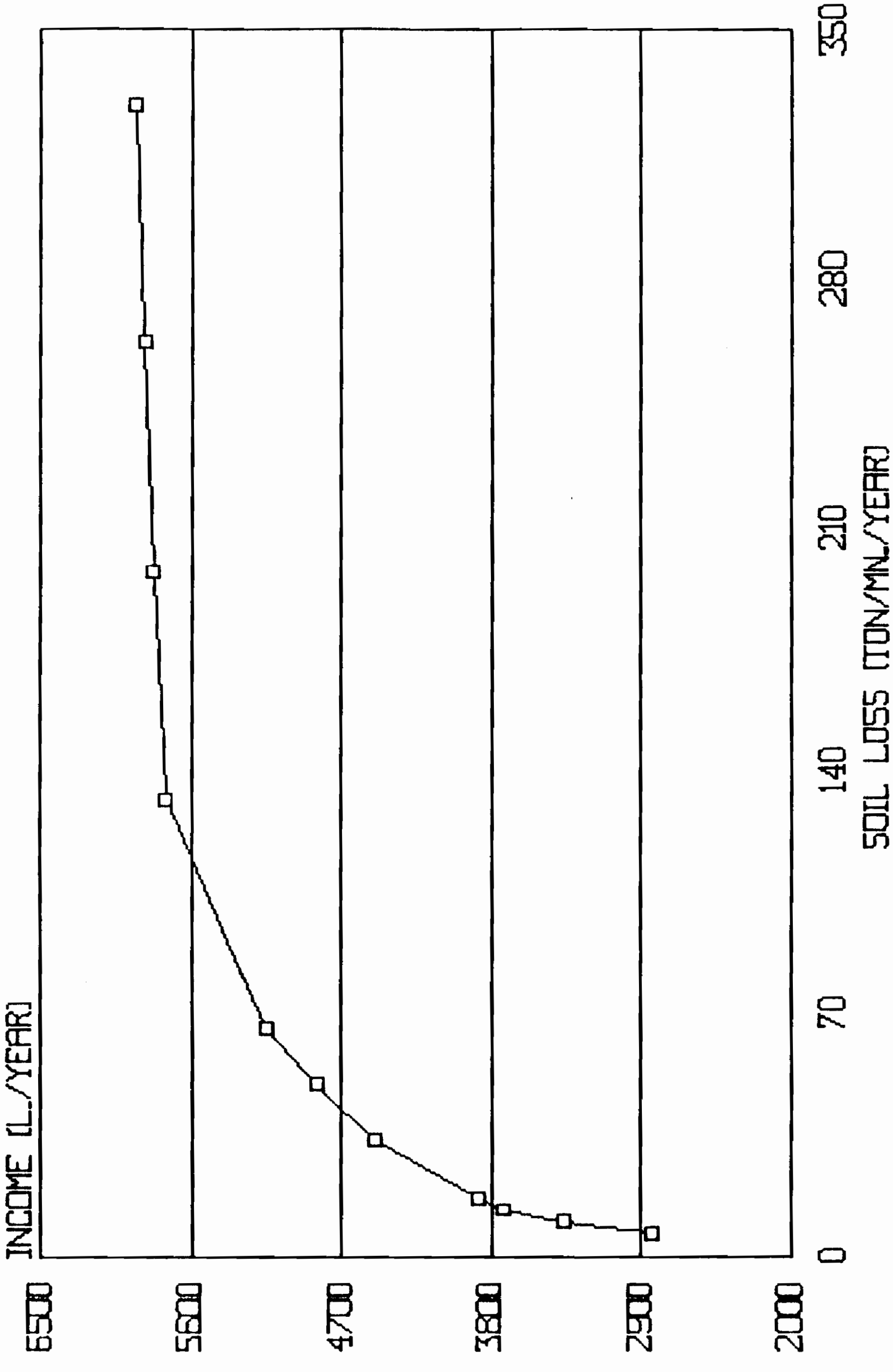

FIGURE 3.1. SOIL LOSS - INCOME RELATION WHEN LIMITS ON SOIL LOSS ARE IMPOSED

profitable than the vegetable crops. Corn and corn-beans intercropped also begin to appear when soil erosion is constrained to low levels. Cultivation of high return crops is made profitable under extreme reductions in permissible erosion only by altering the tillage system and/or by introducing conservation devices.

Regarding the four conservation devices included in the model, only hill-side ditches never enter the solution. The values for soil loss from the USLE equation did not differ much between hill-side ditches and live barriers (Table 2.2). Since live barriers are much cheaper to construct than hill-side ditches, the model always chooses barriers instead. Due to the low levels of soil loss for crops grown on the 2% slope land, contour cultivation appears to be the best management practice on the low-slope lands, whereas for 10% and 24% slope lands, a gradual conversion from live barriers to terraces take place as soil-loss tolerances get lower and lower. Changes in tillage systems from the conventional to the alternative minimum and no-tillage systems are less evident until low levels of soil loss are imposed on the model.

The second case analyzed has income constrained while imposing no constraint on soil loss levels and minimizing risk. The effect on soil loss and crops produced is analyzed. The results are shown in Table 3.3. The levels of income used are those obtained from the first case. This is done in order to draw conclusions about the effect of a set of income levels on soil loss levels and crops produced when soil loss is constrained and when it is not, but rather risk is minimized. Since no constraints on soil loss are imposed, the levels of soil loss are compared

TABLE 3.3. MODEL RESULTS FOR VARIOUS REDUCTIONS IN INCOME FROM BASE MODEL.

INCOME (LEMP.)	SOIL LOSS (TON/MN.)	LAND TYPE	CROP ACTIVITIES (MN.)				
			CR	BN	CR-BN	CB	ON
5929.24	328.24	A	-	0.45	-	0.45	0.28
		B	-	0.33	-	0.33	0.21
		C	-	0.49	-	0.49	0.31
5876.92	325.44	A	-	0.45	-	0.45	0.28
		B	-	0.33	-	0.33	0.21
		C	-	0.54	-	0.54	0.21
5824.61	322.64	A	-	0.45	-	0.45	0.28
		B	-	0.33	-	0.33	0.21
		C	-	0.59	-	0.59	0.11
5748.80	319.43	A	-	0.45	-	0.45	0.28
		B	-	0.34	-	0.34	0.17
		C	-	0.65	-	0.65	-
5152.02	250.60	A	0.10	0.38	0.10	0.48	0.02
		B	0.10	0.22	0.10	0.32	-
		C	0.16	0.34	0.16	0.49	-
4838.75	225.00	A	0.17	0.28	0.14	0.43	-
		B	0.12	0.21	0.10	0.31	-
		C	0.27	0.25	0.13	0.38	-
4482.37	184.11	A	0.17	0.28	0.14	0.43	-
		B	0.12	0.21	0.10	0.31	-
		C	0.48	0.11	0.06	0.17	-
3869.75	144.24	A	0.17	0.28	0.14	0.43	-
		B	0.27	0.10	0.05	0.14	-
		C	0.65	-	-	-	-
3728.10	141.80	A	0.17	0.28	0.14	0.43	-
		B	0.36	0.04	0.02	0.07	-
		C	0.65	-	-	-	-
3364.91	139.10	A	0.28	0.21	0.10	0.31	-
		B	0.43	-	-	-	-
		C	0.65	-	-	-	-
2825.81	138.07	A	0.53	0.03	0.04	0.04	-
		B	0.43	-	-	-	-
		C	0.65	-	-	-	-

to the levels obtained in the first case. Soil loss falls from 328.24 ton./mn./year, with the highest level of income to 138.07 ton./mn./year, with the lowest level of income analyzed (Table 3.3).

With respect to crops produced, beans, cabbage, and onions are produced at all levels of income (except onions, which are only produced at high levels of income). At low income levels, beans and cabbage are only produced in the low slope lands where the amount of soil loss they cause is relatively low. Corn and corn-beans intercropped are also produced at medium-high levels of income and their production continues until low levels of income. It is interesting to note that coffee production does not enter the solution at any of these levels. Without constraints on soil loss, coffee cannot compete in terms of income and risk reduction. In terms of crop riskiness, onions is the riskiest crop followed by cabbage and beans; corn and coffee are the least risky crops. Under this framework no conservation devices are constructed and the only tillage system practiced is conventional. The income - soil loss relationship for this case is illustrated in Figure 3.2.

Looking at the income - soil loss tradeoffs just described for these two cases, it can be seen how two completely different sets of soil-loss levels can be achieved with the same level of income, depending on the assumed objectives of the farmer. The difference in soil-loss values is considerable, especially at low and medium levels of income. Reduced soil-loss values are achieved, in the first case, by building soil conservation devices and by growing the most profitable crops under different tillage systems. In the second case, though, minimization of

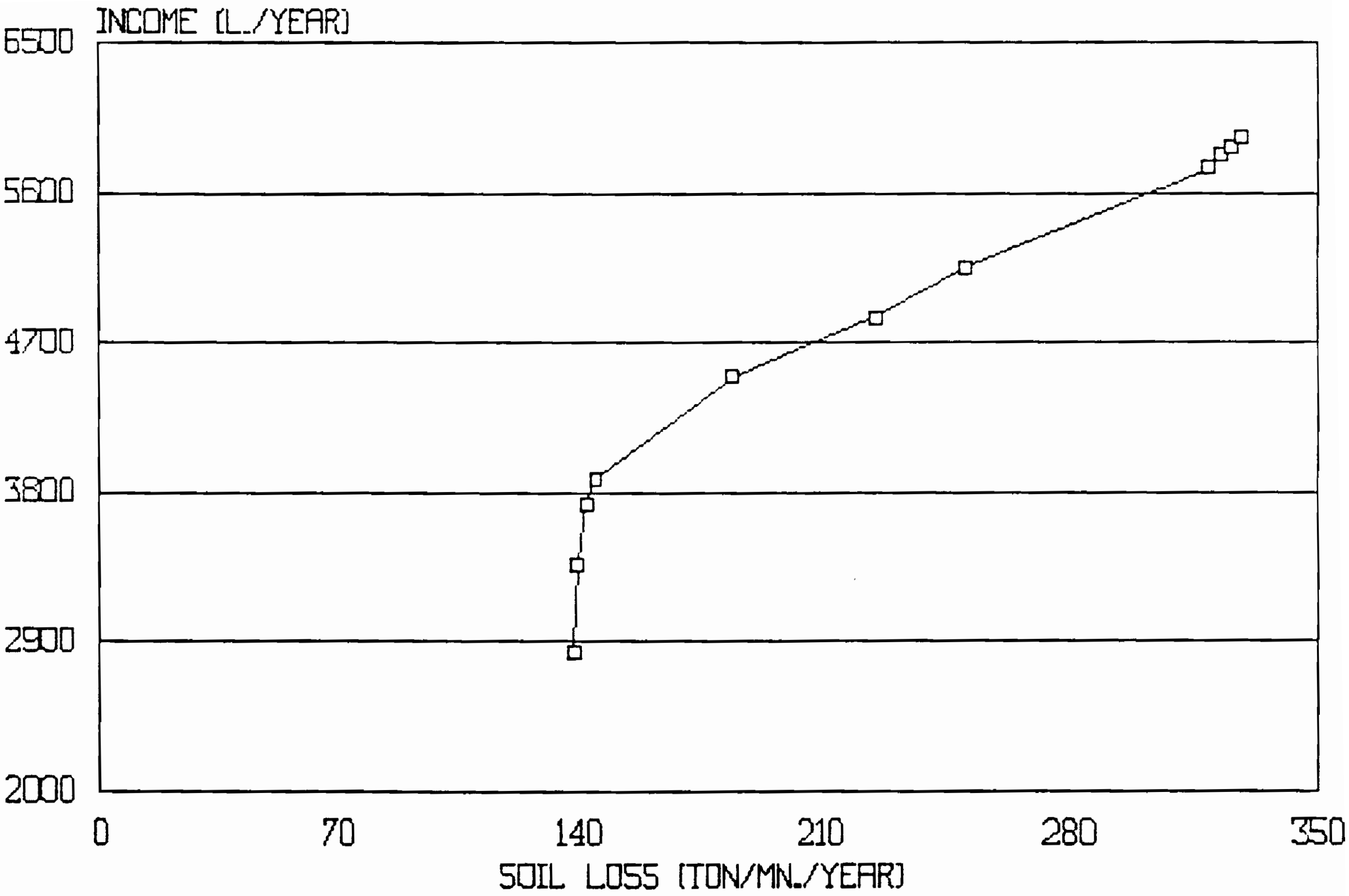

FIGURE 3.2 SOIL LOSS - INCOME RELATION WHEN LIMITS ON INCOME ARE IMPOSED

risk is achieved when no conservation devices are built and when the crops are grown using only the conventional tillage system. This is explained by the lack of soil erosion constraints that do not force the model to include any conservation practice to reduce soil erosion.

The whole situation would suggest that using certain conservation devices and tillage systems, farmers would not only achieve the same levels of income (compared to farmers who do not employ any of these technologies), but they would also realize significant reductions in the amount of soil loss that in the long run would bring higher income through increased crop yields. Risk has also to be considered when promoting soil conservation. This suggestion is analyzed in the risk - income tradeoffs section when we study the effect of risk on the farmers' conservation behavior.

Sensitivity analysis

Sensitivity analyses for wages and crop prices are described in this section. Shadow prices are also presented for the different levels of soil loss allowed. The model used in these analyses is the one in which income is maximized (the no-risk model) subject to restrictions on soil loss. Sensitivity analysis is performed to identify the relatively sensitive parameters (those that cannot be changed much without changing the optimal). This analysis can be performed for specific objective function variables or for the right-hand side of a constraint. Objective function sensitivity information is useful for determining how sensitive the optimal solution is to the "cost" or "profit" (crop prices, etc.)

associated with each activity. Right-hand side sensitivity information is useful to determine how sensitive the optimal solution and resource values are to the "availability" of those resources.

Labor costs have a low impact on the optimal solution value. When wages increase by 25% (increasing labor cost from L.8.00 per man/day to L.10.00 per man/day), the differences in model results were small (Table 3.4). The largest difference found between the model with a labor cost of L.8.00 and the model with a labor cost of L.10.00 was L.46.00. The existence of such small differences is explained by the fact that hired labor is only used for construction of erosion control devices (which represents a small percentage of total costs) since no labor is hired for agricultural activities.

The sensitivity analysis for crop prices illustrates the effect of crop price changes on farm income, on optimal rotations, and on the cost of soil conservation. The results of the sensitivity analysis are found in Table 3.4. Three types of analysis were performed. The first one involved a 10% change (increase and decrease) in vegetable prices, the second a 15% change in corn and beans prices, and the third one a 10% change in coffee price.

The largest differences in farm income are caused by changes in vegetables prices. For this particular region of the country and set of constraints, farm income is more sensitive to changes in vegetables prices than to changes in corn and beans prices. In terms of soil conservation, it is easier to conserve soil when vegetables prices fall (an income reduction of 51% between the highest and the lowest level of soil loss is

TABLE 3.4. EFFECT OF CROP PRICE AND LABOR COST CHANGES ON FARM INCOME.

	INCOME (LEMPIRAS)				
SOIL LOSS (TON./MN.)	BASE INCOME LEVEL	10 % CHANGE IN VEGETABLES PRICES		15% CHANGE IN CORN AND BEANS PRICES	
		INCREASE	DECREASE	INCREASE	DECREASE
328.24	5929.24	6974.15	4884.33	6325.05	5533.43
262.59	5876.92	6913.09	4839.94	6267.74	5486.10
196.95	5824.61	6853.66	4795.55	6210.43	5438.78
131.29	5748.80	6762.25	4735.35	6131.95	5365.65
65.65	5152.01	6027.20	4311.54	5519.05	4784.98
49.23	4838.75	5612.11	4168.00	5243.32	4487.31
32.82	4482.37	5113.50	3851.24	4854.24	4119.19
16.41	3869.75	4490.59	3253.36	4125.20	3637.23
13.13	3728.10	4331.85	3125.33	3957.67	3502.09
9.84	3364.91	3945.04	2865.88	3626.62	3139.30
6.56	2825.81	3284.66	2413.78	3091.89	2608.08

	INCOME (LEMPIRAS)			
SOIL LOSS (TON./MN.)	BASE INCOME LEVEL	10 % CHANGE IN COFFEE PRICES		25% INCREASE IN LABOR COST
		INCREASE	DECREASE	
328.24	5929.24	5929.24	5929.24	5929.24
262.59	5876.92	5876.92	5876.92	5876.64
196.95	5824.61	5824.61	5824.61	5824.05
131.29	5748.80	5748.80	5748.80	5747.89
65.65	5152.01	5196.94	5109.15	5106.59
49.23	4838.75	4894.89	4782.60	4815.87
32.82	4482.37	4538.52	4426.22	4479.90
16.41	3869.75	3925.89	3813.60	3859.08
13.13	3728.10	3784.25	3671.95	3703.35
9.84	3364.91	3409.76	3352.05	3337.96
6.56	2825.81	2825.81	2825.81	2798.86

obtained when vegetable prices fall as compared to a 53% income reduction when vegetable prices increase). This situation is explained by the high levels of soil erosion caused by the vegetable crops and by their high prices, which causes a switch from less profitable crops. Changes in coffee price have little impact on farm income; this is explained by the low levels of coffee produced.

Shadow prices and sensitivity analysis for levels of soil erosion are illustrated in Table 3.5. A shadow price for a specific resource measures the marginal value of this resource, that is, the rate at which the value of the objective function could be increased by increasing the amount of this resource by one unit. The shadow prices shown in Table 3.5 confirm the tendency shown in Figure 3.1. At high levels of soil loss, the effect of small changes in the amount of permitted soil loss on the objective function value is very small (when soil loss is unconstrained, that is, 100% of soil loss, the marginal value of soil loss is zero). As we move towards medium levels of soil loss, the marginal value of soil loss increases and consequently the effect of soil loss reductions on the objective function. The lowest levels of soil loss are associated with the highest shadow prices. These shadow prices represent the cost of erosion reductions; this cost varies according to the amount of reduction desired. The value of 0.47 associated with high levels of erosion means that the marginal value of an extra ton of erosion is L.0.47. The value of 20.98 associated with a 90% reduction of soil loss, implies that the marginal cost of controlling erosion is L.20.98.

The sensitivity analysis shows a similar behavior. At high levels

TABLE 3.5. SOIL LOSS SHADOW PRICES AND SENSITIVITY ANALYSIS FOR DIFFERENT LEVELS OF SOIL EROSION.

SOIL LOSS LEVEL	SHADOW PRICE (LEMPIRAS/TON)	SENSITIVITY ANALYSIS DOWN[a]	CURRENT[b]	UP[c]
100%	----	328.24	328.24	INFINITY
80%	0.47	186.41	262.59	328.24
60%	0.47	186.41	196.95	328.24
40%	2.60	121.60	131.29	135.92
20%	7.92	62.55	65.65	70.97
15%	12.20	34.25	49.23	62.55
10%	20.98	28.12	32.82	34.25
5%	25.07	15.00	16.41	19.34
4%	26.42	12.60	13.13	14.15
3%	82.35	8.89	9.84	10.60
2%	130.71	5.41	6.56	7.29

[a] Refers to the lowest value of soil erosion that will not cause any change in the basis.

[b] Refers to the current value of soil erosion expressed in ton./mn./year.

[c] Refers to the highest value of soil erosion that will not cause any change in the basis.

of soil loss, big reductions or increases in permissible soil loss levels have no impact on the shadow price value, whereas for low levels of soil loss, only small changes in soil loss are allowed before the shadow price value changes.

Risk-income tradeoffs

The approach used to calculate risk and the data used in this study were explained in Chapter II. In this section, the effect of risk (as measured by variability in income) on soil conservation behavior is analyzed. Two scenarios are presented. In the first, risk is minimized subject to different levels of income while placing no constraint on the amount of soil loss allowed. This is called the unconstrained model. In the second scenario, minimization of risk is subject to income and erosion levels obtained from Table 3.1. This is called the constrained model. The results for both of these scenarios in terms of the amount of soil loss and the variance (risk) levels associated with different levels of income are presented in Table 3.6. These results are consistent with expectations. The direct relation between income and variance implies that high levels of income are associated with high levels of risk. The differences in these two sets of variances for both models illustrate that reductions in soil loss at given levels of income are attained only at the cost of higher risk. At high levels of income, the variance for both models is relatively comparable but as we move towards medium and low levels of income, differences in variance for both models become considerable.

TABLE 3.6. RESULTS FOR THE CONSTRAINED AND THE UNCONSTRAINED MODEL[a].

	Constrained model			Unconstrained model	
Income level	Soil loss level	S.L. (Ton./Mn.)	Variance[b] (Millions)	S.L. (Ton./Mn.)	Variance[b] (Millions)
5929.24	100%	328.24	2.15	328.24	2.15
5876.92	80%	262.59	2.12	325.44	2.00
5824.61	60%	196.95	2.10	322.64	1.80
5748.80	40%	131.29	2.02	319.43	1.60
5152.02	20%	65.65	1.40	250.60	0.62
4838.75	15%	49.23	1.03	225.00	0.44
4482.37	10%	32.82	0.81	184.11	0.29
3869.75	5%	16.41	0.75	144.24	0.12
3728.10	4%	13.13	0.70	141.80	0.09
3364.91	3%	9.84	0.45	139.10	0.04
2825.81	2%	6.56	0.37	138.07	0.003

[a] Constrained model minimizes deviations (risk) and soil loss. Unconstrained model minimizes only risk.

[b] These variances are computed by using the deviations deviations from an average income through the use of accounting activities. Then, each term (deviation) is squared; the squared terms are then summed and divided by the number of observations (years) minus 1.

The EV frontiers in Figure 3.3 illustrate the relationship between income and variance (risk). An EV frontier shows the set of feasible farm plans that have the property that variance V is minimized for associated expected income levels E. Such plans are called efficient EV pairs and they define an efficient boundary over the set of all feasible farm plans. The upper curve shows the normal EV curve, minimizing risk subject to certain levels of income without regard to soil loss. There is a smooth concave relationship between income and risk. The lower curve corresponds to the constrained model. Although a farmer can reach a determined income level with small amounts of soil loss, there is significantly more risk associated with this reduced soil loss. Farmers practicing soil conservation at the lower and medium levels of income can achieve considerable reductions in soil loss at the cost of exposing themselves to higher risk; the horizontal gaps between the curves appear significant. This analysis confirms that when designing packages to promote reduced erosion, not only income (the suggestion made in the previous section), but increased risk must be considered.

The EV frontier shows the efficient plans, and the farmer should choose among them based on his/her preferences for risk (his/her utility function). When this function can be measured, a unique farm plan which provides the farmer with the highest utility can be identified. Here the parameters of the expected utility function are not known and the set of efficient farm plans is presented; the farmer has to make the final choice. From an extension agent's point of view, the best approach would be to present farmers the results for the two situations (Figure 3.3) and

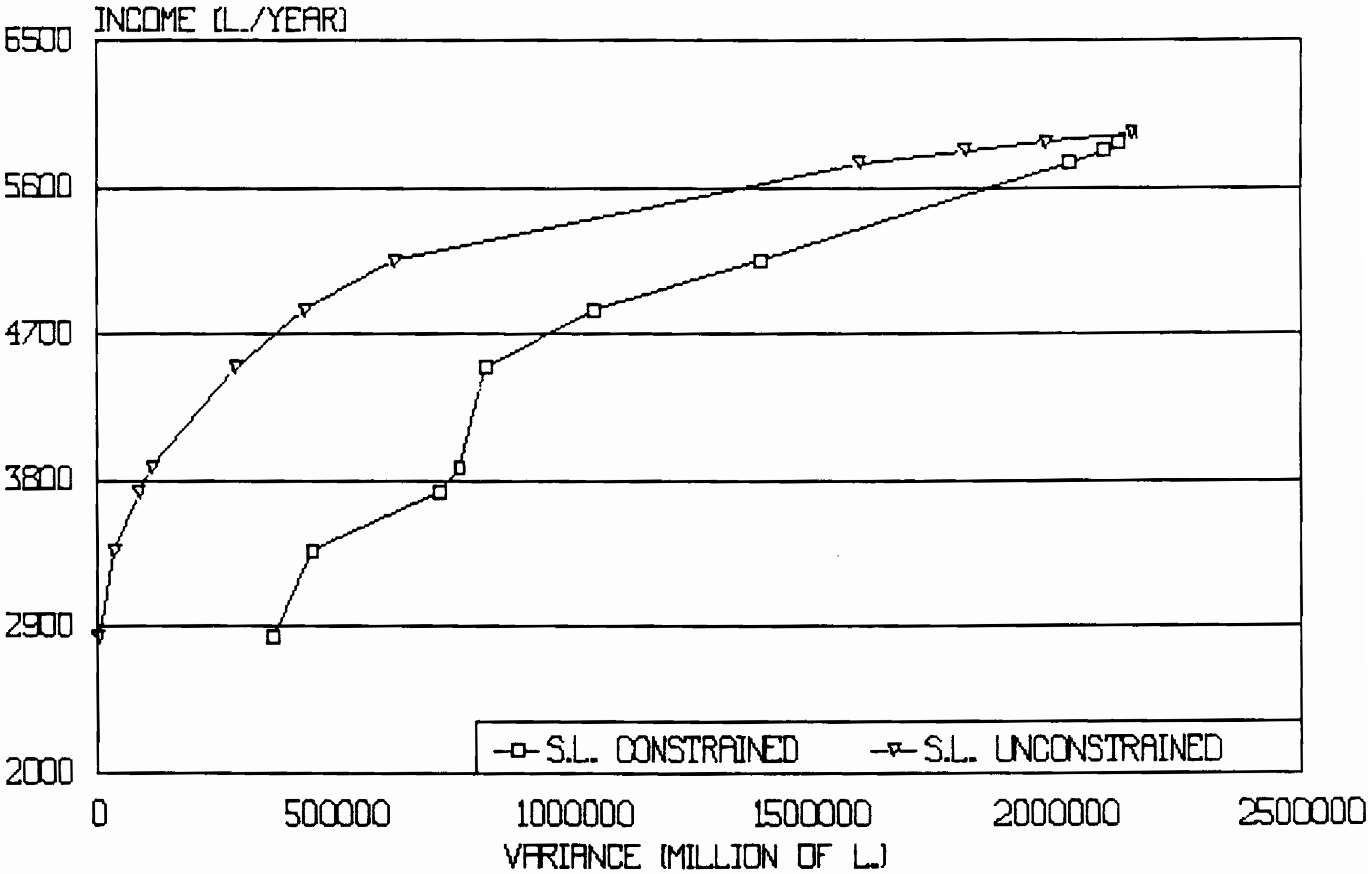

FIGURE 3.3. INCOME - VARIANCE RELATION (EV FRONTIER)

indicate to them that high income levels are associated with high risk levels and also that soil conservation implies higher risk than no conservation. Variance values are a measure of magnitude and should be only used to draw comparisons among different scenarios. This approach is also more flexible in avoiding too rigid a specification of the utility function and perhaps compensates to some extent for situations where income variance is not the best measure of uncertainty. Further, if other socioeconomic factors enter the utility function in addition to E and V, the farmer is free to choose the plan he/she most prefers in relation to a multiplicity of goals.

Some implications can be derived from this section. First, To reduce price risk farmers could be better organized (i.e. coops could help stabilize returns) to be able to obtain better prices for their products and to reduce price fluctuations. Especially in the case for vegetable crops, where governmental stabilization schemes are difficult to implement, coops might be used to stabilize revenues. Second, to reduce yield risk the ministry of Agriculture should promote research with the purpose of increasing and stabilizing crop yields. Such research might examine increased drought and pest resistance.

Planning horizons.

The impact of land ownership on soil conservation behavior has been widely studied (Feder and Onchan, 1987; Lee, 1980; Ervin and Ervin, 1982; Reinhardt, 1987; ASA, 1982). The literature gives secure tenure an extremely important role in ensuring the adoption of soil conservation schemes.

The effect of tenure is analyzed in this study by comparing four possible planning horizons that correspond to different levels of tenure security faced by farmers. The first horizon corresponds to a ten-year period and reflects farmers with secure tenure. This assumption is used in the previously presented model runs. The other planning horizons are five years, three years, and one year. Shorter planning horizons are associated with progressively more insecure tenure.

The differentiation between planning horizons is possible by altering the total cost of the soil conservation devices. One-tenth of the total installation and maintenance cost of conservation devices was charged to the conservation device budget for the ten-year period case. One-fifth, one-third, and full cost were charged for each year in the subsequent simulations, respectively.

The results for the four horizons analyzed are presented in Table 3.7. The same soil loss levels used in Table 3.1 are used for this analysis, so the results for the different horizons represent income levels associated with same levels of soil loss. The results for the extreme two cases - a ten-year period and a one-year period - are illustrated in Figure 3.4. Curves for the other two horizons lie between the two curves presented.

In general, the outcomes between the horizons analyzed differ only slightly. At high levels of permitted soil loss, few conservation devices are constructed and therefore differences in income between the two horizons are small. Medium levels of soil loss lead to more significant

TABLE 3.7. EFFECT OF DIFFERENT PLANNING HORIZONS AND SOIL LOSS LEVELS ON FARMERS' INCOME.

Soil loss levels	Income (L./Year) Planning Horizon[a] A	B	C	D
100%	5929.24	5929.24	5929.24	5929.24
80%	5876.93	5874.98	5872.36	5859.30
60%	5824.61	5820.71	5815.48	5789.36
40%	5748.80	5742.57	5734.22	5692.49
20%	5152.02	5025.74	5015.51	4966.46
15%	4838.75	4797.36	4787.90	4740.81
10%	4482.37	4474.24	4465.38	4421.11
5%	3869.75	3827.16	3801.38	3772.10
4%	3728.10	3626.73	3538.51	3507.55
3%	3364.91	3251.87	3193.28	3111.15
2%	2825.81	2731.59	2712.52	2675.35

[a] A = 10 year period; B = 5 year period; C = 3 year period; D = 1 year period.

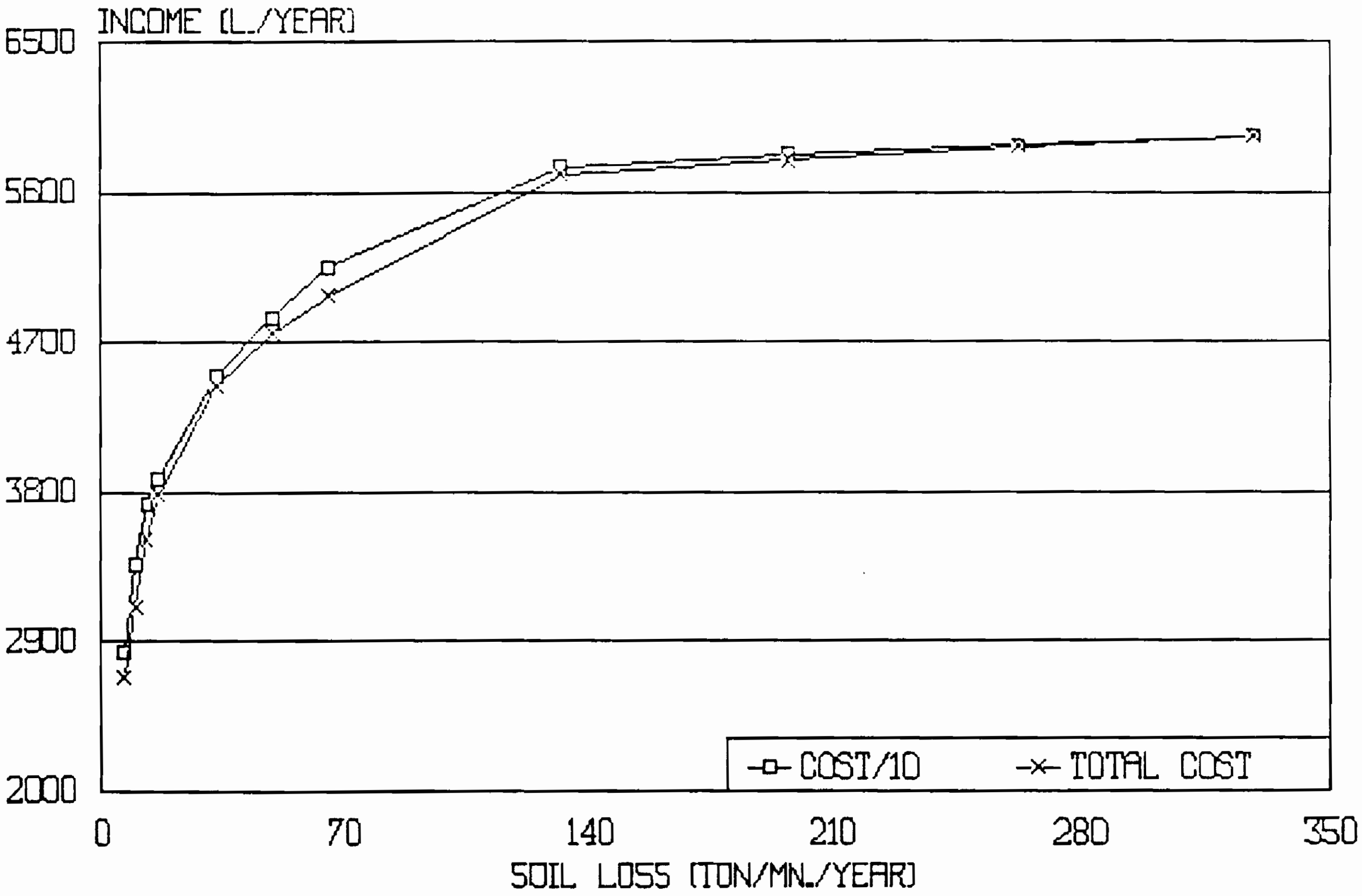

FIGURE 3.4 INCOME - SOIL LOSS RELATION FOR TWO PLANNING HORIZONS

income differences. When soil loss is reduced to very low levels, fallow land enters the solution so that the differences in the cost ofconservation devices caused by the planning horizons are once again minimal.

These results illustrate that different lengths of planning horizons may have little impact on the income loss costs associated with erosion reduction. This result is caused by a couple of factors. First, the opportunity cost of labor, the main input into the construction of erosion control devices, is low. Hired labor is abundant and cheap and the amount of labor required for construction of devices is small relative to total farm labor needs[7]. Second, much erosion reduction comes in the form of adjustment in cropping patterns, such as moving the most erosive products off the 24% slopes. The costs of these adjustments do not depend greatly on the length of the planning horizon.

This research has dealt with one aspect of tenure security, that is, the different costs of conservation practices associated with different planning horizons. For this area, the costs are related to the construction of the conservation devices. It has been shown that under these conditions tenure status does not affect the cost of implementing soil conservation. The other aspect of the tenure security refers to the on-farm benefits of soil conservation. Such benefits (i.e. enhanced soil

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[7] For an income level of L.4838.21 and a soil loss level of 49.23 ton./mn./year, the labor cost for construction of erosion control devices represents approximately 5% of total farm labor cost (L.91.47 out of L.1971.47). The total labor cost represents approximately 37% of total production costs (L.1971.47 out of L.5354.21).

fertility) will vary according to tenure security; this variation might be strong enough to prevent those farmers with insecure tenure from adopting soil conservation measures.

Summary

The main findings of this chapter are summarized below followed by some implications of these results.

Considerable reductions in the amount of soil loss can be achieved in the study area. Erosion is reduced from 328.24 ton./mn./year to 6.56 ton./mn./year when soil loss constraints are imposed on the model. Farm income goes from L.5929.24/year for high erosion rates to L.2825.81/year for low erosion rates. The same levels of income are achieved when soil loss constraints are not imposed but risk is minimized. For this case erosion is only reduced from 328.24 ton./mn./year to 138.07 ton./mn./year. The large differences between these two situations reflect the benefits of practicing soil conservation. However, reduced erosion is accompanied by greater risk.

The low rates of soil erosion and the resulting reduced farm income are the product of some adjustments on the farm:

a) A shift to production of less profitable crops. This is due to the positive relation between crop prices and crop erosivity (a relation that does not hold in the case of beans). Coffee, for example, is the least erosive, yet also the least profitable crop. The model brings coffee production in automatically as a means of controlling erosion.

b) Implementation of soil conservation practices. Vegetable crops are attractive because of their profitability, but since they are highly erosive crops their permanency on farm plans as erosion reductions are imposed depends on the adoption of different soil conservation devices and tillage systems. Live barriers and terraces are constructed, and tillage moves slowly from conventional to minimum and no-tillage systems.

c) Reduction in the amount of cultivated land. In order to achieve low levels of soil erosion some land ultimately has to be taken out of production.

Low levels of soil erosion are achieved at the expense of higher levels of risk. High levels of income are associated with high levels of risk regardless of whether soil-loss constraints exist of not. These results highlight the importance of considering risk when promoting soil conservation schemes.

Small differences in income exist among the four planning horizons analyzed. What this suggests is that tenure status does not greatly affect the costs of employing these practices.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary

This research was motivated by the increasing concern about soil erosion in developing countries as well as by the lack of empirical examination of alternative means of reducing erosion in these countries. With this concern in mind, a watershed in the central region of Honduras, for which severe soil-erosion rates have been reported, was selected to be the subject of this study.

Specifically, this study was aimed at identifying the costs associated with erosion reduction for a representative farm in the Guacerique river watershed in Honduras. The objectives of this study included:

* To determine the most profitable mix of soil conservation practices and crops that would lead to a desired reduction in soil losses for the study area.
* To determine the optional mix of soil conservation practices associated with different levels of risk faced by farmers; and,
* To analyze the impacts that different planning horizons might have on the profitability of soil conservation practices. Land tenure is directly related to the length of the planning horizon.

The methodology used to assess the erosion problem in the study area was described in chapter II. This chapter also included a detailed explanation of the model and the measure of risk used in the analysis. To comply with the objectives, a representative farm for the area was constructed. Activities and constraints were identified. A field survey, crop budgets, and calculated soil loss values were used to construct this representative farm. Information was also collected from published literature and personal interviews. A Motad model was used to assist with the analysis of the study. This model farm had 1.67 mn. of land with corn, beans, cabbage, onions, and tomatoes being grown. Coffee was also included and was found to be important for reducing erosion on the steepest slopes. The soil conservation practices used by the farmers in the area are contour cultivation, live barriers, hill-side ditches, and terraces. Some important characteristics of these farmers are their reluctance to use credit, the absence of land rental by farmers, and the fact that the type of ownership of the land they have does not guarantee their permanency on the land over the long run (government action to deprive them of their land is always a possibility).

Results for the different runs performed were presented in chapter III. Three types of relationships were analyzed: income-soil loss tradeoffs, risk-income tradeoffs, and the impact of variable-length planning horizons. The main conclusions and implications of these results are presented in the next section.

Conclusions

The results show that considerable reductions in the amount of soil loss can be achieved in the study area, from 328.24 ton./mn./year to 6.56 ton./mn./year. The erosion reductions lower income from L.5929.24/year for high erosion rates to L.2825.81/year for low erosion rates. More than a 50% reduction in soil loss can be achieved at relatively little loss of income. Cabbage and onions, the highest-return crops, were also the most erosive and were always present in the farm plans regardless of the levels of soil loss required. The lowest levels of soil erosion were achieved when some land was taken out of production, terraces were constructed, and when minimum and no-tillage cultivation were practiced. Cultivation of coffee was also found to be a feasible alternative to reducing soil erosion on the steepest slopes.

From the conservation practices included in the model, only hill-side ditches never entered the solution. This is caused by the comparable soil-loss values between hill-side ditches and live barriers and by the fact that hill-side ditches are much more expensive to construct than barriers.

When risk was minimized subject to the same levels of income as were used in the income maximization models, and no constraints on the amount of soil erosion were imposed, soil loss went from 328.24 ton./mn./year with an income of L.5929.24/year to 138.07 ton./mn./year with and income of L.2825.81. The big differences between the two situations reflect the benefits of practicing soil conservation. Low levels of soil erosion are achieved at the expense of higher levels of risk. High levels of income are associated with high levels of risk regardless of whether soil-loss constraints exist or not. Risk may be a significant barrier to the widespread use of erosion control techniques in the area.

Small differences in income were found among the four planning horizons analyzed. This suggests that tenure may not greatly affect the annualized costs of employing these practices. Insecure tenure affects the decision to conserve soil in two ways: it raises the costs associated with these practices and reduces the expected on-farm benefits (i.e. enhanced soil fertility). The evidence here is that the costs do not vary much according to tenure. The reason for this finding is that the costs of constructing these practices are relatively low. These results suggest that incentive packages designed to promote the construction of different practices can be effective regardless of tenure status.

Policy Implications

The types of changes that should be promoted in the area include:

- On the production side, promotion of less erosive crops. Coffee production, though not predominant in the region, represents a least-cost alternative for reducing erosion on the steepest slopes. What the government might do to promote coffee production is to provide the inputs required for the stabilization of a plantation (trees, fertilizers, etc.), as well as the technical assistance needed to ensure good results. Fields with slopes higher than 20%-25% could be the target of this type of program.
- Production of vegetables on flat (no more than 10% slope) lands while leaving corn and beans production for the medium-slope lands (no more than 20%), and corn-beans intercropped and possibly coffee for the steepest slopes. Such restrictions would require a promotion effort by the ministry of agriculture.
- Taking into account the low cost of live barriers, their acceptable impact on soil conservation, and their alternative use as cattle feed, their use should be promoted in this region.

- Generalized use of minimum tillage should be promoted. This can be important in seasons where labor scarcity might be a problem since minimum tillage needs less labor than conventional tillage. Its contribution to soil erosion reduction is also considerable.

Some policies that would help reduce erosion in the area are:

- Farmers Co-op. The ministry of Agriculture should facilitate the work of the type of co-op like the one that works in this region. Farmers co-ops for small farmers can play an important role in providing them with the inputs needed for production, the technical knowledge required for crop production and soil conservation, and more importantly, the markets for their products in such a way that the crop prices variations be reduced.
- To promote the use of soil conservation practices a package of policies might be implemented. This package could include the use of payments (subsidies) to construct erosion control devices. These payments might equal a portion of the total construction cost. At the same time, the extension service might provide the assistance required to inform farmers about benefits and costs (increasing amount or risk, for example) of soil erosion as well as the technical knowledge about construction of erosion control devices.
- Risk reducing policies. A way in which the government can help reduce risk (specifically yield risk) faced by farmers is through investment in the type of infraestructure (i.e. irrigation, roads, etc.) that would increase crop productivity and at the same time provide new opportunities for market growth. Increased research to develop varieties adapted to

specific regions and conditions would also ensure reduce yield risk.

- Establishment of a more secure land tenure system. Even though land tenure does not have a strong effect on the costs of different soil conservation practices, on-farm benefits may still vary significantly, especially if erosion has a large impact on soil productivity. A complete definition of the land ownership system in the area would promote the adequate adoption of soil conservation schemes and their permanency over the long run in the presence of such differences in benefits. Secure land tenure is likely to increase land values which in turn will make farmers better off and promote investment in conservation practices.

A call for future research

This research presents a modest attempt to clarify the importance of some factors related to soil conservation in a developing country context. It also suggests a need for more information to fully understand the linkages among all factors associated with soil conservation behavior. One way in which this research can help decide the usefulness of soil conservation is through its contribution to the use of benefit/cost analysis. The benefits of soil conservation are: increased crop production, increased family welfare, extended reservoirs life, and reduced pesticide pollution, and others. These benefits can be obtained as a result of future research and weighed against the costs of soil conservation: construction cost, etc. which can be modeled using the present mode. The required information for a successful analysis might be the product of research in the following areas:

- A study of long term impacts of depth of top soil and/or percentage of organic matter on soil erosion control and crop productivity.
- A study of effects of land slope on crop yields.
- Development of USLE values for specific locations in the tropics.
- Feasibility studies for coffee production in the area.
- Studies of other crops that, like coffee, might contribute to reducing soil erosion while providing additional income to the farm.
- Examination into the effects of pesticides pollution and the relationship between soil erosion and pollution.
- A study of the effects that mulch and organic fertilizers might have on soil erosion and soil productivity.
- A study of the effects that different types of tenure systems have on soil conservation benefits.

The present study could also be extended by including:

- Long-term time considerations. Once the impacts of soil erosion on crop productivity are fully understood it will be necessary to model the whole farmer's planning horizon. These considerations will provide valuable information about the effect of different tenure schemes on the long-term profitability of different soil conservation practices.
- Different sources of risk. Income variance does not represent the only source of uncertainty faced by farmers. In fact, farmers' risk aversion behavior is the result of several related factors that create the uncertain environment in which farmers operate.
- Derivation of indifference curves for farmers in a specific region. An

indifference curve shows an individual's risk aversion behavior. When combined with EV frontier curves like the ones developed in this study they give an idea of the levels of income that a farmer can achieve.

Although the model employed in this study analyzes a specific area with particular conditions, it could be applied to other regions for which the required information is available. This would facilitate comparison between regions and therefore enable policy makers to make more accurate decisions with respect to soil conservation incentives.

APPENDIX 1

SURVEY METHODOLOGY

The methodology used in the preparation of the field survey is presented, followed by the questions used in the survey.

The survey is divided into 7 main sections that provide information needed for the construction of the representative farm. These sections are:

- **General Information**. This section provides general information about the farm and the family. It is concerned with the farm endowment of family labor, farm area, etc. as well as with the activities (besides agriculture) performed by household members.

- **Land Tenure**. This sections deals with the ownership status of the farm that may have some influence on soil conservation behavior. It also deals with land rental and the activities realized on rented land.

- **Crops and Rotations**. This section determines the technical aspects of the farm. These aspects include crops grown, area planted with each crop, yields obtained, planting and harvesting periods, and the main rotation practiced. Presence of irrigation in the farm is also determined. A general idea of the costs of production and the prices received for the products sold is obtained.

- **Soil Conservation Practices and Tillage Systems**. This section inquires about the soil conservation practices and tillage systems used on the farm. The use of practices on specific types of land slopes and cultivated with specific crops is also explored. Practices construction costs are obtained.

- **Labor**. This section deals entirely with labor, both family and hired, available to perform agricultural activities when needed. Use of hired labor, its cost, and the periods in which it is needed are determined. Labor scarcity problems are also examined.

- **Credit**. This section determines credit use and sources for the farmers in the area and its availability. The existence of special credit arrangements is also explored.

- **Slopes**. In this section, farm slopes, length of slopes, and the area of farm land that falls into each type of slope are measured. These measures are critical to the calculation of the soil loss values.

Prior to the field visits, the survey's questions were validated through consultation with an agronomist with experience in the area who gave his opinion and advice about the questions that should and should not be included into the survey and the best way to approach the farmers.

Twelve farmers were surveyed between the 20th and the 30th of July of 1991. Each survey took an average time of 45-50 minutes. The surveying was facilitated by personnel from the LUPE project. These personnel identified the farms to be surveyed and accompanied the author during the visits. This was important since there was a close relation between farmers and extension agents so that the farmers felt free to comment about specific issues and problems. With regard to soil conservation problems it was seen that farmers in this region were well informed about the consequences of soil erosion for crop yields as well as the benefits of soil conservation. They were also familiar with the technical aspects involved in the construction and maintenance of soil conservation structures.

Field Survey Questions.

1. GENERAL INFORMATION.
   a. Name
   b. Age.
   c. Number of people that work in the family.
   d. Total area of the farm.
   e. Other activities.

2. LAND TENURE.
   a. Land titled? Dominio Pleno?
   b. If not. Tenure status.
   c. Land rental.
   d. For which crops? How much is paid for rented land?

3. CROPS AND ROTATIONS.
   a. Crops grown, area, yields and main rotations.
   b. If vegetables are grown, What are the main vegetables grown and the main rotations.
   c. Planting dates for each crop.
   d. Irrigation on the farm.
   e. Production costs and prices received.

4. SOIL CONSERVATION PRACTICES.
   a. Soil conservation practices used.
   b. Group of slope in which soil conservation practices are used.
   c. Tillage systems used.
   d. Conservation practices' construction costs.

5. LABOR.
   a. Labor hiring.
   b. Crops for which hired, price of labor.
   c. Months and # of people for each crop?
   d. Existence of labor scarcity.

6. CREDIT.
   a. Borrowing behavior.
   b. Source of borrowed money.
   c. Interest rate.

7. SLOPES.
   a. Measurement of slopes (Percentage slope and length)
   b. Number of manzanas that fall into each group of slopes.
   c. Crops grown on each type of slope.

APPENDIX 2

CALCULATION OF THE C FACTOR

This Appendix describes the procedure employed to calculate the C value of the USLE. A general description of what the C factor means and does is presented, followed by the steps used in its calculation. Calculation of the C factor is then presented for all the crops included in the study. Factor C in the USLE is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables.

The loss that would occur on a particular field if it were continuously in fallow conditions is computed as the product R*K*L*S in the soil-loss equation. Actual soil loss from the cropped field is usually less than this amount. Just how much less depends on the particular combination of cover, crop sequence, and management practices. It also depends on the particular stage of growth and development of the vegetative cover at the time of the rain. C adjusts the soil-loss estimate for these conditions.

The correspondence of periods of expected highly-erosive rainfall with periods of poor or good plant cover differs between regions or locations. Therefore, the value of C for a particular cropping system will not be the same in all parts of the country.

To calculate the C value for specific situations, the following information needs to be gathered and placed on a "C" factor worksheet similar to those presented in this appendix (Tables A.2.1 .... A.2.7):

1. Crop to be planted and percent of initial ground cover. 10%, 40%, and 60% of initial ground cover were used to represent conventional, minimum, and no-tillage systems respectively. These percentages were identified during the field survey.

2. A chronological sequence of all the land cover changes that begin new crop-stage periods.

3. Dates for each crop stage. Crop- stage dates were identified through consultations with agronomists working in the study area.

4. Record of the cumulative percentage of E.I. (Erosion Index) for the corresponding dates under "RD FACTOR" (column 4, all tables). The E.I. refers to how the year's erosive rainfall is distributed among the crop-stage periods of each crop included in the system. Since there is a linear relation between precipitation and erosion in the area (Wouters, 1980), the erosion index was developed from the values of precipitation for the area.

5. Determination of the E.I values (column 5). Erosion Index values are determined by subtracting the given reading at the beginning of a crop stage from the reading at the end of the same crop-stage. In other words, it is calculated by subtracting line # 1 in the RD FACTOR column from line # 2 in the same column. Then, subtracting line # 2 from line # 3 and so on. These differences are recorded in column 5 (E.I.).

6. Record the Soil-Loss Ratio values (column 6). These ratios reflect the effects of crops and management in successive segments of a rotation cycle. These ratios were obtained from the Soil Conservation Servuce in Puerto Rico.

7. Calculation of the Crop-Stage "C" value and the average "C" value (column 7). The Crop Stage value is the result of multiplying the E.I. value (column 5) times the Soil-Loss Ratio (column 6). The sum of these products is the value of "C" for the entire rotation. To obtain the average annual "C" value, the total sum in column 7 is divided by the number of years in rotation, determined by adding all E.I. values in column 5. The obtained average "C" value is used in the equation. For example, 0.513 is entered as the C value for corn under conventional tillage.

Table A.2.1. Calculation of the C factor for corn with three types of tillage systems.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
CORN	1	PL-SB	5/1-5/15	0.08	0.07	0.90	0.063	
10%	2	SB-P-10%	5/15-6/15	0.15	0.18	0.75	0.135	
INITIAL GROUND	3	10%-50%	6/15-8/15	0.33	0.25	0.52	0.130	
COVER	4	50%-75%	8/15-9/15	0.58	0.17	0.42	0.07	
CONVENTIONAL	5	75%-95%	9/15-10/15	0.75	0.15	0.30	0.045	
TILLAGE	6	HARVEST	10/15-12/15	0.90	0.09	0.25	0.0225	0.4669
	7		12/15-	0.99				
		ROTATION TOTALS			0.91			0.513
CORN	1	PL-SB	5/1-5/15	0.08	0.07	0.65	0.0455	
40%	2	SB-P-10%	5/15-6/15	0.15	0.18	0.35	0.063	
INITIAL GROUND	3	10%-50%	6/15-8/15	0.33	0.25	0.26	0.065	
COVER	4	50%-75%	8/15-9/15	0.58	0.17	0.21	0.0357	
MINIMUM	5	75%-95%	9/15-10/15	0.75	0.15	0.15	0.025	
TILLAGE	6	HARVEST	10/15-12/15	0.90	0.09	0.07	0.063	0.2405
	7		12/15	0.99				
		ROTATION TOTALS			0.91			0.2642
CORN	1	SB-P-10%	5/15-6/15	0.15	0.18	0.21	0.0378	
60%	2	10%-50%	6/15-8/15	0.33	0.25	0.18	0.0450	
INITIAL GROUND	3	50%-75%	8/15-9/15	0.58	0.17	0.14	0.0238	
COVER	4	75%-95%	9/15-10/15	0.75	0.15	0.12	0.0180	
NO-TILLAGE	5	HARVEST	10/15-12/15	0.90	0.09	0.06	0.0054	0.130
	6		12/15-	0.99				
	7							
		ROTATION TOTALS			0.84			0.1547

Table A.2.2. Calculation of the C factor for beans planted during the first rainy season with three types of tillage systems.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
BEANS	1	PL-SB	5/1-5/15	0.08	0.07	0.90	0.063	
10%	2	SB-P-10%	5/15-6/1	0.15	0.08	0.73	0.0584	
INITIAL GROUND	3	10%-50%	6/1-7/1	0.23	0.19	0.46	0.0874	
COVER	4	50%-75%	7/1-7/15	0.42	0.05	0.32	0.016	
CONVENTIONAL	5	75%-95%	7/15-8/15	0.47	0.11	0.20	0.022	
TILLAGE 1	6	HARVEST	8/15-9/1	0.58	0.14	0.14	0.0196	0.2664
	7		9/1	0.64				
		ROTATION TOTALS			0.64			0.4162
BEANS	1	PL-SB	5/1-5/15	0.08	0.07	0.65	0.0455	
40%	2	SB-P-10%	5/15-6/1	0.15	0.08	0.35	0.0280	
INITIAL GROUND	3	10%-50%	6/1-7/1	0.23	0.19	0.18	0.0342	
COVER	4	50%-75%	7/1-7/15	0.42	0.05	0.16	0.008	
MINIMUM	5	75%-95%	7/15-8/15	0.47	0.11	0.12	0.0132	
TILLAGE 1	6	HARVEST	8/15-9/1	0.58	0.14	0.09	0.126	0.1415
	7		9/1	0.64				
		ROTATION TOTALS			0.64			0.2211
BEANS	1	SB-P-10%	5/15-6/1	0.15	0.08	0.20	0.016	
60%	2	10%-50%	6/1-7/1	0.23	0.19	0.14	0.0266	
INITIAL GROUND	3	50%-75%	7/1-7/15	0.42	0.05	0.11	0.0055	
COVER	4	75%-95%	7/15-8/15	0.47	0.11	0.07	0.0077	
NO-TILLAGE 1	5	HARVEST	8/15-9/1	0.58	0.14	0.07	0.0098	0.0482
	6		9/1	0.64				
	7							
		ROTATION TOTALS			0.58			0.1477

Table A.2.3. Calculation of the C factor for beans planted during the second rainy season with three types of tillage systems.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
BEANS	1	PL-SB	9/1-9/15	0.64	0.11	0.90	0.099	
10%	2	SB-P-10%	9/15-10/1	0.75	0.10	0.73	0.073	
INITIAL GROUND	3	10%-50%	10/1-11/1	0.85	0.10	0.46	0.046	
COVER	4	50%-75%	11/1-11/15	0.95	0.01	0.32	0.0032	
CONVENTIONAL	5	75%-95%	11/15-12/15	0.96	0.03	0.20	0.006	
TILLAGE 2	6	HARVEST	12/15-1/1	0.99	0.01	0.14	0.0014	0.2286
	7		1/1	0.00				
		ROTATION TOTALS			0.36			0.6377
BEANS	1	PL-SB	9/1-9/15	0.64	0.11	0.65	0.0715	
40%	2	SB-P-10%	9/15-10/1	0.75	0.10	0.35	0.035	
INITIAL GROUND	3	10%-50%	10/1-11/1	0.85	0.10	0.18	0.018	
COVER	4	50%-75%	11/1-11/15	0.95	0.01	0.16	0.0016	
MINIMUM	5	75%-95%	11/15-12/15	0.96	0.03	0.12	0.0036	
TILLAGE 2	6	HARVEST	12/15-1/1	0.99	0.01	0.09	0.0009	0.1306
	7		1/1	0.00				
		ROTATION TOTALS			0.36			0.3627
BEANS	1	SB-P-10%	9/15-10/1	0.75	0.10	0.20	0.02	
60%	2	10%-50%	10/1-11/1	0.85	0.10	0.14	0.014	
INITIAL GROUND	3	50%-75%	11/1-11/15	0.95	0.01	0.11	0.0011	
COVER	4	75%-95%	11/15-12/15	0.96	0.03	0.07	0.0021	
NO-TILLAGE 2	5	HARVEST	12/15-1/1	0.99	0.01	0.07	0.0007	0.0379
	6		1/1	0.00				
	7							
		ROTATION TOTALS			0.25			0.1516

Table A.2.4. Calculation of the C factor for corn-beans intercropped with three types of tillage systems.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
CORN-BEANS 10% INITIAL GROUND COVER CONVENTIONAL TILLAGE	1	PL-SB	5/1-5/15	0.08	0.07	0.90	0.063	
	2	SB-P-10%	5/15-6/15	0.15	0.18	0.75	0.0135	
	3	10%-50%	6/15-8/15	0.33	0.25	0.42	0.105	
	4	50%-75%	8/15-9/15	0.58	0.17	0.33	0.0561	
	5	75%-95%	9/15-10/15	0.75	0.15	0.30	0.045	
	6	HARVEST	10/15-1/1	0.90	0.10	0.25	0.025	0.4291
	7		1/1	0.00				
		ROTATION TOTALS			0.92			0.4664
CORN-BEANS 40% INITIAL GROUND COVER MINIMUM TILLAGE	1	PL-SB	5/1-5/15	0.08	0.07	0.65	0.0434	
	2	SB-P-10%	5/15-6/15	0.15	0.18	0.35	0.063	
	3	10%-50%	6/15-8/15	0.33	0.25	0.22	0.055	
	4	50%-75%	8/15-9/15	0.58	0.17	0.18	0.0306	
	5	75%-95%	9/15-10/15	0.75	0.15	0.15	0.0225	
	6	HARVEST	10/15-1/1	0.90	0.10	0.07	0.007	0.2215
	7		1/1	0.00				
		ROTATION TOTALS			0.92			0.2407
CORN-BEANS 60% INITIAL GROUND COVER NO-TILLAGE	1	SB-P-10%	5/15-6/15	0.15	0.18	0.21	0.0378	
	2	10%-50%	6/15-8/15	0.33	0.25	0.13	0.0325	
	3	50%-75%	8/15-9/15	0.58	0.17	0.11	0.0187	
	4	75%-95%	9/15-10/15	0.75	0.15	0.12	0.0180	
	5	HARVEST	10/15-1/1	0.90	0.09	0.06	0.0054	0.1124
	6		1/1	0.99				
	7							
		ROTATION TOTALS			0.84			0.1322

Table A.2.5. Calculation of the C factor for cabbage planted during the first rainy season, second rainy season, and summer season.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
CABBAGE 1 5 % INITIAL GROUND COVER	1	PL-SB	5/1-5/15	0.08	0.07	0.94	0.0658	
	2	SB-P-10%	5/15-6/1	0.15	0.08	0.83	0.0664	
	3	10%-50%	6/1-7/1	0.23	0.19	0.60	0.114	
	4	50%-75%	7/1-7/15	0.42	0.05	0.41	0.0205	
	5	75%-95%	7/15-8/1	0.47	0.05	0.26	0.013	
	6	HARVEST	8/1-8/15	0.52	0.06	0.17	0.0102	0.2899
	7		8/15	0.58				
		ROTATION TOTALS			0.50			0.5798
CABBAGE 2 5 % INITIAL GROUND COVER	1	PL-SB	9/1-9/15	0.64	0.11	0.94	0.1034	
	2	SB-P-10%	9/15-10/1	0.75	0.10	0.83	0.0830	
	3	10%-50%	10/1-11/1	0.85	0.10	0.60	0.060	
	4	50%-75%	11/1-11/15	0.95	0.01	0.41	0.0041	
	5	75%-95%	11/15-12/1	0.96	0.02	0.26	0.0052	
	6	HARVEST	12/1-12/15	0.98	0.01	0.17	0.0017	0.2574
	7		12/15	0.99				
		ROTATION TOTALS			0.35			0.7354
CABBAGE SUMMER 5 % INITIAL GROUND COVER	1	PL-SB	1/15-2/1	0.002	0.002	0.94	0.00188	
	2	SB-P-10%	2/1-2/15	0.004	0.002	0.83	0.00166	
	3	10%-50%	2/15-3/15	0.006	0.012	0.60	0.0072	
	4	50%-75%	3/15-4/1	0.018	0.012	0.41	0.00492	
	5	75%-95%	4/1-4/15	0.03	0.02	0.26	0.0052	
	6	HARVEST	4/15-5/1	0.05	0.03	0.17	0.0051	0.2596
	7		5/1	0.08				
		ROTATION TOTALS			0.58			0.3328

Table A.2.6. Calculation of the C factor for onions planted during the rainy and summer seasons and for tomatoes planted during the summer season.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
ONIONS	1	PL-SB	5/1-5/15	0.08	0.07	0.94	0.0658	
5 %	2	SB-P-10%	5/15-6/15	0.15	0.18	0.83	0.1494	
INITIAL GROUND	3	10%-50%	6/15-9/1	0.33	0.31	0.60	0.1896	
COVER	4	50%-75%	9/1-	0.64	0.21	0.41	0.0861	
	5	75%-95%	-10/1					
	6	HARVEST	10/1-10/15	0.85	0.05	0.17	0.0085	0.4994
	7		10/15	0.90				
		ROTATION TOTALS			0.81			0.6090
ONIONS SUMMER	1	PL-SB	10/15-11/1	0.90	0.05	0.94	0.047	
5 %	2	SB-P-10%	11/1-12/1	0.95	0.03	0.83	0.0249	
INITIAL GROUND	3	10%-50%	12/1-2/15	0.98	0.026	0.60	0.0156	
COVER	4	50%-75%	2/15-	0.006	0.012	0.41	0.00492	
	5	75%-95%	-3/15					
	6	HARVEST	3/15-4/1	0.018	0.012	0.17	0.00204	0.09446
	7		4/1	0.03				
		ROTATION TOTALS			0.13			0.7266
TOMATOES	1	PL-SB	1/15-2/1	0.002	0.002	0.94	0.00188	
5 %	2	SB-P-10%	2/1-2/15	0.004	0.002	0.83	0.00166	
INITIAL GROUND	3	10%-50%	2/15-3/15	0.006	0.012	0.60	0.0072	
COVER	4	50%-75%	3/15-4/1	0.018	0.012	0.41	0.00492	
	5	75%-95%	4/1-4/15	0.03	0.02	0.26	0.0052	
	6	HARVEST	4/15-5/1	0.05	0.03	0.17	0.0051	0.2596
	7		5/1	0.08				
		ROTATION TOTALS			0.58			0.3328

Table A.2.7. Calculation of the C factor for coffee.

1		2	3	4	5	6	7	8
CROP		CROP STAGE BY % OF CANOPY COVER	DATES	RD FACTOR	E.I.	SOIL LOSS RATIO	CROP STAGE "C" VALUE	CROP YEAR "C" VALUE
COFFEE SHADE GROWN 60 %	1	SB-COFFEE	5/1-10/1	0.08	0.77	0.21	0.1617	
	2	10%-50%	10/1-5/1	0.85	0.23	0.18	0.0414	
	3	50%-75%	5/1-1/1	0.08	0.92	0.14	0.1288	
	4	75%-1st Hv.	1/1-1/1	0.00	1	0.07	0.07	
	5	2nd Harvest	1/1-1/1	0.00	1	0.05	0.05	
	6	3rd Harvest	1/1-1/1	0.00	1	0.03	0.03	
	7	4th Harvest	1/1-1/1	0.00	1	0.03	0.03	
	8	5th Harvest	1/1-1/1	0.00	1	0.03	0.03	0.5419
	9	6th Harvest	1/1-					
		ROTATION TOTALS			6.92			0.040

APPENDIX 3

MODEL ACTIVITIES, CONSTRAINTS, AND SOIL EROSION VALUES

This Appendix provides a specific description of all the activities included in the model. Soil erosion values are also presented for each cropping activity. These erosion values rereflect the specific characteristics of the study area; any change in conditions would lead to a different set of values. The abreviations used to describe activities and constraints were adopted to facilitate their incorporation into the linear programming model as well as to facilitate their interpretation. The abreviations used are presented in Table A.3.1.

Activity names are composed of 5 sections that follow this order: (1) CROP - (2) PLANTING SEASON - (3) LAND SLOPE - (4) CONSERVATION PRACTICE - (5) TILLAGE SYSTEM.

(1) Crop: The crops considered include: corn, beans, corn-beans intercropped, cabbage, onions, tomatoes, and coffee.

(2) Planting Season: Planting seasons in which crops are planted and grown include: rainy season running from May through December (corn, corn-beans intercropped, and onions are grown during this period); first rainy season from May through August (beans and cabbage are grown during this period); second rainy season from October through December (beans and cabbage are grown during this period); summer from January through April (onions, cabbage, and tomatoes are grown during this period); coffee is grown all year long.

(3) Land Slope: Land slopes include: a 2% land slope (A land); a 10% land slope (B land); and, a 24% land slope (C land).

(4) Conservation Practice: Soil conservation practices include: contouring, live barriers, hill ditches, and terraces.

(5) Tillage system: Tillage systems include: conventional tillage, minimum tillage and no-tillage.

The description of the abreviations used to represent each section of an activity name is followed by the description of all activities included in the model.

Table A.3.1. Abreviations used to describe activity names.

(1) CROP

CR = CORN
B = BEANS
CRB = CORN-BEANS
CB = CABBAGE
O = ONIONS
T = TOMATOES
CF = COFFEE

(2) PLANTING SEASON

R = RAINY SEASON.
R1 = FIRST RAINY SEASON.
R2 = SECOND RAINY SEASON.
S = SUMMER.
AY = ALL YEAR.

(3) SLOPE

A = 2% SLOPE LAND.
B = 10% SLOPE LAND.
C = 24% SLOPE LAND.

(4) CONSERVATION PRACTICES

C = CONTOURING CULTIVATION.
L = LIVE BARRIERS.
H = HILL DITCHES.
T = TERRACES.

(5) TILLAGE SYSTEMS

C = CONVENTIONAL TILLAGE.
M = MINIMUM TILLAGE.
N = NO-TILLAGE.

Table A.3.2. Cropping activities and soil-erosion values for class A land (2% slope).

DESCRIPTION	SOIL LOSS (TON/MN./YEAR)
1. Conventional-tillage corn (CRRACC).	6.20
2. Minimum-tillage corn (CRRACM).	3.19
3. No-till corn (CRRACN).	1.87
4. Conventional-tillage corn with live barriers (CRRALC).	4.93
5. Minimum-tillage corn with live barriers (CRRALM).	2.54
6. No-till corn with live barriers (CRRALN).	1.48
7. Conventional-tillage corn double-cropped with beans (CRBRACC).	5.62
8. Minimum-tillage corn double-cropped with beans (CRBRACM).	2.90
9. No-till corn double-cropped with beans (CRBRACN).	1.59
10. Conventional-tillage corn double-cropped with beans and live barriers (CRBRALC).	4.48
11. Minimum-tillage corn double-cropped with beans and live barriers (CRBRALM).	2.31
12. No-till corn double-cropped with beans and live barriers (CRBRALN).	1.27
13. Conventional-tillage beans 1 (BR1ACC).	5.02
14. Minimum-tillage beans 1 (BR1ACM).	2.67
15. No-till beans 1 (BR1ACN).	1.78
16. Conventional-tillage beans 1 with live barriers (BR1ALC).	4.00
17. Minimum-tillage beans 1 with live barriers (BR1ALM).	2.12
18. No-till beans 1 with live barriers (BR1ALN).	1.42
19. Conventional-tillage beans 2 (BR2ACC).	7.69
20. Minimum-tillage beans 2 (BR2ACM).	4.37
21. No-till beans 2 (BR2ACN).	1.83
22. Conventional-tillage beans 2 with live barriers (BR2ALC).	6.13
23. Minimum-tillage beans 2 with live barriers (BR2ALM).	3.48
24. No-till beans 2 with live barriers (BR2ALN).	1.46
25. Conventional-tillage cabbage 1 (CBR1ACC).	6.99
26. Conventional-tillage cabbage 1 with live barriers (CBR1ALC)	5.57
27. Conventional-tillage cabbage 2 (CBR2ACC).	8.67
28. Conventional-tillage cabbage 2 with live barriers (CBR2ALC)	7.07
29. Conventional-tillage cabbage summer (CBSACC).	4.01
30. Conventional-tillage cabbage summer with live barriers (CBSALC).	3.20
31. Conventional-tillage onions (ORACC).	7.34
32. Conventional-tillage onions with live barriers (ORALC).	5.85
33. Conventional-tillage onions summer (OSACC).	8.76
34. Conventional-tillage onions summer with live barriers (OSALC).	6.98
35. Conventional-tillage tomatoes summer (TSACC)	4.01
36. Conventional-tillage tomatoes summer with live barriers (TSALC).	3.20

Table A.3.3. Cropping activities and soil-erosion values for class B land (10% slope).

	DESCRIPTION	SOIL LOSS (TON/MN./YEAR)
37.	Conventional-tillage corn (CRRBCC).	51.07
38.	Minimum-tillage corn (CRRBCM).	26.31
39.	No-till corn (CRRBCN).	15.41
40.	Conventional-tillage corn with live barriers (CRRBLC).	20.49
41.	Minimum-tillage corn with live barriers (CRRBLM).	10.56
42.	No-till corn with live barriers (CRRBLN).	6.18
43.	Conventional-tillage corn with hill ditches (CRRBHC).	18.86
44.	Minimum-tillage corn with hill ditches (CRRBHM).	9.72
45.	No-till corn with hill ditches (CRRBHN).	5.69
46.	Conventional-tillage corn with terraces (CRRBTC).	11.43
47.	Minimum-tillage corn with terraces (CRRBTM).	5.89
48.	No-till corn with terraces (CRRBTN).	3.45
49.	Conventional-tillage corn double-cropped with beans (CRBRBCC).	46.43
50.	Minimum-tillage corn double-cropped with beans (CRBRBCM).	23.96
51.	No-till corn double-cropped with beans (CRBRBCN).	13.16
52.	Conventional-tillage corn double-cropped with beans and live barriers (CRBRBLC).	18.63
53.	Minimum-tillage corn double-cropped with beans and live barriers (CRBRBLM).	9.62
54.	No-till corn double-cropped with beans and live barriers (CRBRLN).	5.28
55.	Conventional-tillage corn double-cropped with beans and with hill ditches (CRBRBHC).	17.15
56.	Minimum-tillage corn double-cropped with beans and with hill ditches (CRBRBHM).	8.85
57.	No-till corn double-cropped with beans and with hill ditches (CRBRBHN).	4.86
58.	Conventional-tillage corn double-cropped with beans and with terraces (CRBRBTC).	10.39
59.	Minimum-tillage corn double-cropped with beans and with terraces (CRBRBTM).	5.36
60.	No-till corn double-cropped with beans and with terraces (CRBRBTN).	2.95
61.	Conventional-tillage beans 1 (BR1BCC).	41.44
62.	Minimum-tillage beans 1 (BR1BCM).	22.01
63.	No-till beans 1 (BR1BCN).	14.70
64.	Conventional-tillage beans 1 with live barriers (BR1BLC).	16.63
65.	Minimum-tillage beans 1 with live barriers (BR1BLM).	8.83
66.	No-till beans 1 with live barriers (BR1BLN).	5.90
67.	Conventional-tillage beans 1 with hill ditches (BR1BHC).	15.31
68.	Minimum-tillage beans 1 with hill ditches (BR1BHM).	8.13
69.	No-till beans 1 with hill ditches (BR1BHN).	5.43

Table A.3.3. (Continuation) Cropping activities and soil-erosion values for class B land (10% slope).

	DESCRIPTION	SOIL LOSS (TON/MN./YEAR)
70.	Conventional-tillage beans 1 with terraces (BR1BTC).	9.28
71.	Minimum-tillage beans 1 with terraces (BR1BTM).	4.93
72.	No-till beans 1 with terraces (BR1BTN).	3.29
73.	Conventional-tillage beans 2 (BR2BCC).	63.49
74.	Minimum-tillage beans 2 (BR2BCM).	36.11
75.	No-till beans 2 (BR2BCN).	15.10
76.	Conventional-tillage beans 2 with live barriers (BR2BLC).	25.48
77.	Minimum-tillage beans 2 with live barriers (BR2BLM).	14.49
78.	No-till beans 2 with live barriers (BR2BLN).	6.06
79.	Conventional-tillage beans 2 with hill ditches (BR2BHC).	23.45
80.	Minimum-tillage beans 2 with hill ditches (BR2BHM).	13.34
81.	No-till beans 2 with hill ditches (BR2BHN).	5.58
82.	Conventional-tillage beans 2 with terraces (BR2BTC).	14.21
83.	Minimum-tillage beans 2 with terraces (BR2BTM).	8.08
84.	No-till beans 2 with terraces (BR2BTN).	3.38
85.	Conventional-tillage cabbage 1 (CBR1BCC).	57.72
86.	Conventional-tillage cabbage 1 with live barriers (CBR1BLC).	23.16
87.	Conventional-tillage cabbage 1 with hill ditches (CBR1BHC).	21.32
88.	Conventional-tillage cabbage 1 with terraces (CBR1BTC).	12.92
89.	Conventional-tillage cabbage 2 (CBR2BCC).	73.21
90.	Conventional-tillage cabbage 2 with live barriers (CBR2BLC).	29.38
91.	Conventional-tillage cabbage 2 with hill ditches (CBR2BHC).	27.04
92	Conventional-tillage cabbage 2 with terraces (CBR2BTC).	16.39
93.	Conventional-tillage cabbage summer (CBSBCC).	33.13
94.	Conventional-tillage cabbage summer with live barriers (CBSBLC).	13.30
95.	Conventional-tillage cabbage summer with hill ditches (CBSBHC).	12.24
96.	Conventional-tillage cabbage summer with terraces (CBSBTC).	7.42
97.	Conventional-tillage onions (ORBCC).	60.63
98.	Conventional-tillage onions with live barriers (ORBLC).	24.33
99.	Conventional-tillage onions with hill ditches (ORBHC).	22.39
100.	Conventional-tillage onions with terraces (ORBTC).	13.57
101.	Conventional-tillage onions summer (OSBCC).	72.34
102.	Conventional-tillage onions summer with live barriers (OSBLC).	29.03
103.	Conventional-tillage onions summer with hill ditches (OSBHC).	26.72

Table A.3.3. (Continuation) Cropping activities and soil-erosion values for class B land (10% slope).

DESCRIPTION	SOIL LOSS (TON/MN./YEAR)
104. Conventional-tillage onions summer with terraces (OSBTC).	16.19
105. Conventional-tillage tomatoes summer (TSBCC).	33.13
106. Conventional-tillage tomatoes summer with live barriers (TSBLC).	13.30
107. Conventional-tillage tomatoes summer with hill ditches (TSBHC).	12.24
108. Conventional-tillage tomatoes summer with terraces (TSBTC)	7.42

Table A.3.4. Cropping activities and soil-erosion values for class C land (24% slope).

DESCRIPTION	SOIL LOSS (TON/MN/YEAR.)
109. Conventional-tillage corn (CRRCCC).	315.96
110. Minimum-tillage corn (CRRCCM).	162.77
111. No-till corn (CRRCCN).	95.32
112. Conventional-tillage corn with live barriers (CRRCLC).	115.99
113. Minimum-tillage corn with live barriers (CRRCLM).	59.75
114. No-till corn with live barriers (CRRCLN).	34.99
115. Conventional-tillage corn with hill ditches (CRRCHC).	112.25
116. Minimum-tillage corn with hill ditches (CRRCHM).	57.83
117. No-till corn with hill ditches (CRRCHN).	33.86
118. Conventional-tillage corn with terraces (CRRCTC).	74.83
119. Minimum-tillage corn with terraces (CRRCTM).	38.55
120. No-till corn with terraces (CRRCTN).	22.57
121. Conventional-tillage corn double-cropped with beans (CRBRCCC).	287.26
122. Minimum-tillage corn double-cropped with beans (CRBRCCM).	148.25
123. No-till corn double-cropped with beans (CRBRCCN).	81.42
124. Conventional-tillage corn double-cropped with beans and live barriers (CRBRCLC).	105.45
125. Minimum-tillage corn double-cropped with beans and live barriers (CRBRCLM).	54.42
126. No-till corn double-cropped with beans and live barriers (CRBRCLN).	29.89
127. Conventional-tillage corn double-cropped with beans and with hill ditches (CRBRCHC).	102.05
128. Minimum-tillage corn double-cropped with beans and with hill ditches (CRBRCHM).	52.67
129. No-till corn double-cropped with beans and with hill ditches (CRBRCHN).	28.93
130. Conventional-tillage corn double-cropped with beans and with terraces (CRBRCTC).	68.03
131. Minimum-tillage corn double-cropped with beans and with terraces (CRBRCTM).	35.11
132. No-till corn double-cropped with beans and with terraces (CRBRCTN).	19.28
133. Conventional-tillage beans 1 (BR1CCC).	256.37
134. Minimum-tillage beans 1 (BR1CCM).	136.18
135. No-till beans 1 (BR1CCN).	90.97
136. Conventional-tillage beans 1 with live barriers (BR1CLC).	94.11
137. Minimum-tillage beans 1 with live barriers (BR1CLM).	49.99
138. No-till beans 1 with live barriers (BR1CLN).	33.39
139. Conventional-tillage beans 1 with hill ditches (BR1CHC).	91.08
140. Minimum-tillage beans 1 with hill ditches (BR1CHM).	48.38

Table A.3.4. (Continuation) Cropping activities and soil-erosion values for class C land (24% slope).

	DESCRIPTION	SOIL LOSS (TON/MN/YEAR.)
141.	No-till beans 1 with hill ditches (BR1CHN).	32.32
142.	Conventional-tillage beans 1 with terraces (BR1CTC).	60.72
143.	Minimum-tillage beans 1 with terraces (BR1CTM).	32.25
144.	No-till beans 1 with terraces (BR1CTN).	21.54
145.	Conventional-tillage beans 2 (BR2CCC).	392.76
146.	Minimum-tillage beans 2 (BR2CCM).	223.39
147.	No-till beans 2 (BR2CCN).	93.39
148.	Conventional-tillage beans 2 with live barriers (BR2CLC).	144.18
149.	Minimum-tillage beans 2 with live barriers (BR2CLM).	82.00
150.	No-till beans 2 with live barriers (BR2CLN).	34.29
151.	Conventional-tillage beans 2 with hill ditches (BR2CHC).	139.53
152.	Minimum-tillage beans 2 with hill ditches (BR2CHM).	79.36
153.	No-till beans 2 with hill ditches (BR2CHN).	33.18
154.	Conventional-tillage beans 2 with terraces (BR2CTC).	93.02
155.	Minimum-tillage beans 2 with terraces (BR2CTM).	52.91
156.	No-till beans 2 with terraces (BR2CTN).	22.12
157.	Conventional-tillage cabbage 1 (CBR1CCC)	357.10
158.	Conventional-tillage cabbage 1 with live barriers (CBR1CLC).	131.09
159.	Conventional-tillage cabbage 1 with hill ditches (CBR1CHC).	126.86
160.	Conventional-tillage cabbage 1 with terraces (CBR1CTC).	84.58
161.	Conventional-tillage cabbage 2 (CBR2CCC).	452.94
162.	Conventional-tillage cabbage 2 with live barriers (CBR2CLC).	166.27
163.	Conventional-tillage cabbage 2 with hill ditches (CBR2CHC).	160.91
164.	Conventional-tillage cabbage 2 with terraces (CBR2CTC).	107.27
165.	Conventional-tillage cabbage summer (CBSCCC).	204.97
166.	Conventional-tillage cabbage summer with live barriers (CBSCLC).	75.25
167.	Conventional-tillage cabbage summer with hill ditches (CBSCHC).	72.82
168.	Conventional-tillage cabbage summer with terraces (CBSCTC)	48.55
169.	Conventional-tillage onions (ORCCC).	375.08
170.	Conventional-tillage onions with live barriers (ORCLC).	137.69
171.	Conventional-tillage onions with hill ditches (ORCHC).	133.25
172.	Conventional-tillage onions with terraces (ORCTC).	88.84
173.	Conventional-tillage onions summer (OSCCC).	447.52
174.	Conventional-tillage onions summer with live barriers (OSCLC).	164.28
175.	Conventional-tillage onions summer with hill ditches (OSCHC).	158.98

Table A.3.4. (Continuation) Cropping activities and soil-erosion values for class C land (24% slope).

	DESCRIPTION	SOIL LOSS (TON/MN/YEAR.)
176.	Conventional-tillage onions summer with terraces (OSCTC).	105.99
177.	Conventional-tillage tomatoes summer (TSCCC).	204.97
178.	Conventional-tillage tomatoes summer with live barriers (TSCLC).	75.25
179.	Conventional-tillage tomatoes summer with hill ditches (TSCHC).	72.82
180.	Conventional-tillage tomatoes summer with terraces (TSCTC)	48.55
181.	Conventional-tillage coffee (CFAYCCC).	24.64

APPENDIX 4

CROP BUDGETS

Budgets for the crops included in the study are presented in this Appendix. They are presented for each type of tillage system. Conventional, minimum, and no-tillage are considered for beans, corn, and corn-beans intercropped; whereas for cabbage, onions, and tomatoes only conventional tillage is considered. Coffee is also grown under a conventional tillage system.

The relevant information provided by these budgets is yield produced, sale prices of the crops, total variable cost of production, and amount of labor required for each crop each month.

Yields are expressed in Quintales/Manzana. A Quintal (QQ.), is a national weight measure equivalent to one hundred pounds. Total income for each crop is the result of multiplying price per quintal times the crop yield (quantity).

Variable costs of production include the cost of purchasing inputs such as seeds, fertilizers, chemicals, pesticides, etc., plus the cost of labor required to perform every crop activity. A ten percent extra cost is included in the budgets to avoid any underestimation of the values.

Labor use is expressed in man-days (M.D.). That is, the amount of days required for a man to complete a determined activity. A M.D. is valued at L.8.00. Preparation of the land (tillage), is expressed in Manzanas (MN.). Other inputs are expressed in different units: Quintales (QQ.), Pounds (LB.), Liters (LT.), etc. For some special inputs like pesticides and insecticides, a wide range of products within each category are being used. VAR. (Various) expresses the fact that more than one product is being used.

The monthly labor requirements refer to the amount of labor (expressed in man-days per month) needed for each crop during each month. In cases when a crop is planted in more than one ocassion, monthly labor requirements are determined for each planting season.

The field survey provided information on:

- The type of practices used in each crop.
- Labor cost.
- Tillage cost.
- Crop sales prices.
- Crop yields.
- Cost of organic fertilization and doses used.
- Transport cost.

Crop budgets published for the Central Region provided information on:

- Amount of labor used in crop production activities.
- Input use (fertilizers, pesticides, etc.).

Bulletins published by the Agricultural Development Bank provided information on:

- Crops seed cost.
- Pesticides cost.

Table A.4.1. Budget for corn, conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Corn Grain	QQ.	70.00	32	2240.00
Total Income				
2. Variable Costs:				
Tillage	M.D	8.00	4	32.00
Tillage	MN.	100.00	1	100.00
Corn seed	LB.	0.70	20	14.00
Seeding	M.D.	8.00	2	16.00
Weed control	M.D.	8.00	12	96.00
Fertilization	M.D.	8.00	2	16.00
Insect control	M.D.	8.00	2	16.00
Chemicals	QQ.	80.00	1.5	120.00
Pesticides	LB.	1.33	30	40.00
Harvest	M.D.	8.00	9	72.00
+ 10%				52.20
Total Vbl. Cost of Prod.				574.20

PROFIT = L. 1665.80 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	7
JUNE	3
JULY	4
AUGUST	4
SEPTEMBER	4
OCTOBER	--
NOVEMBER	--
DECEMBER	9
TOTAL	31

Table A.4.2. Budget for corn, minimum tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Corn Grain	QQ.	70.00	25	1750.00
Total Income				
2. Variable Costs:				
Tillage	M.D.	8.00	14	112.00
Corn seed	LB.	0.70	20	14.00
Seeding	M.D.	8.00	2	16.00
Weed control	M.D.	8.00	18	144.00
Fertilization	M.D.	8.00	4	32.00
Organic Fert.	QQ.	3.50	20	70.00
Break plant	M.D.	8.00	1	8.00
Harvest	M.D.	8.00	7	56.00
+ 10%				45.20
Total Vbl. Cost of Prod.				497.20

PROFIT = L. 1252.80 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	18
JUNE	4
JULY	4
AUGUST	6
SEPTEMBER	3
OCTOBER	3
NOVEMBER	1
DECEMBER	7
TOTAL	46

Table A.4.3. Budget for corn, no-tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Corn Grain	QQ.	70.00	15	1050.00
Total Income				
2. Variable Costs:				
Till. + Seed.	M.D.	8.00	3	24.00
Corn seed	LB.	0.70	20	14.00
Weed control	M.D.	8.00	29	232.00
Fertilization	M.D.	8.00	2	16.00
Organic Fert.	QQ.	3.50	10	35.00
Break plant	M.D.	8.00	1	8.00
Harvest	M.D.	8.00	5	40.00
+ 10%				36.90
Total Vbl. Cost of Prod.				405.90

PROFIT = L. 644.10 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	4
JUNE	6
JULY	6
AUGUST	7
SEPTEMBER	6
OCTOBER	5
NOVEMBER	1
DECEMBER	5
TOTAL	40

Table A.4.4. Budget for beans, conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Beans Grain	QQ.	150.00	14	2100.00
Total Income				
2. Variable Costs:				
Tillage	M.D.	8.00	4	32.00
Tillage	MN	100.00	1	100.00
Beans seed	LB.	2.00	70	140.00
Seeding	M.D.	8.00	2	16.00
Weed control	M.D.	8.00	12	96.00
Fertilization	M.D.	8.00	1	8.00
Insect control	M.D.	8.00	1	8.00
Chemical	QQ.	80.00	1	80.00
Pesticides	LT.	100.00	2	200.00
Harvest	M.D.	8.00	11	88.00
+ 10%				76.80
Total Vbl. Cost of Prod.				844.80

PROFIT = L. 1255.20 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH	M.D./MONTH
MAY	9	--
JUNE	6	--
JULY	5	--
AUGUST	11	--
SEPTEMBER	--	9
OCTOBER	--	6
NOVEMBER	--	5
DECEMBER	--	11
TOTAL	31	31

Table A.4.5. Budget for beans, minimum tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Beans Grain	QQ.	150.00	8	1200.00
Total Income				
2. Variable Costs:				
Tillage	M.D.	8.00	25	200.00
Beans seed	LB.	1.50	60	90.00
Seeding	M.D.	8.00	4	32.00
Weed control	M.D.	8.00	18	144.00
Insect control	M.D.	8.00	1	8.00
Pesticides	LT.	100.00	1	100.00
Harvest	M.D.	8.00	8	64.00
+ 10%				63.80
Total Vbl. Cost of Prod.				701.80

PROFIT = L. 498.20 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH	M.D./MONTH
MAY	31	--
JUNE	7	--
JULY	7	--
AUGUST	11	--
SEPTEMBER	--	31
OCTOBER	--	7
NOVEMBER	--	7
DECEMBER	--	11
TOTAL	56	56

Table A.4.6. Budget for beans, no-tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Beans Grain	QQ.	150.00	5	750.00
Total Income				
2. Variable Costs:				
Beans seed	LB.	1.50	50	75.00
Seeding	M.D.	8.00	4	32.00
Weed control	M.D.	8.00	29	232.00
Insect control	M.D.	8.00	1	8.00
Pesticides	LT.	100.00	0.5	50.00
Harvest	M.D.	8.00	6	48.00
+ 10%				44.50
Total Vbl. Cost of Prod.				489.50

PROFIT = L. 251.50 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH	M.D./MONTH
MAY	10	--
JUNE	9	--
JULY	9	--
AUGUST	12	--
SEPTEMBER	--	10
OCTOBER	--	9
NOVEMBER	--	9
DECEMBER	--	12
TOTAL	40	40

Table A.4.7. Budget for cabbage 1,2 , conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Total Income	QQ.	20.00	250	5000.00
2. Variable Costs:				
Nursery prep.	M.D.	8.00	4	32.00
Chemical aplic.	M.D.	8.00	4	32.00
Maintenance	M.D.	150.00	1	150.00
Transplant	M.D.	8.00	20	160.00
Weed control	M.D.	8.00	10	80.00
Fertilization	M.D.	8.00	8	64.00
Chemical aplic.	M.D.	8.00	20	160.00
Irrigation	M.D.	8.00	12	96.00
Harvest	M.D.	8.00	10	80.00
Cabbage seed	ONZ.	5.00	6	30.00
Org. Fertil.	QQ.	3.50	20	70.00
Fertilizer	QQ.	80.00	2	160.00
Fertilizer	QQ.	70.00	2	140.00
Fungicides	VAR.	130.00	1	130.00
Insecticides	VAR.	550.00	1	550.00
Bags	UNIT.	2.00	50	100.00
Field Prep.	MN.	100.00	1	100.00
Transport	QQ.	1.50	250	375.00
+ 10%				250.90
Total Vbl. Cost of Prod.				2759.90

PROFIT = L. 2240.10 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH	M.D./MONTH
MAY	35	--
JUNE	17	--
JULY	20	--
AUGUST	17	--
SEPTEMBER	--	35
OCTOBER	--	17
NOVEMBER	--	20
DECEMBER	--	17
TOTAL	89	89

Table A.4.8. Budget for cabbage summer, conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Total Income	QQ.	20.00	250	5000.00
2. Variable Costs:				
Nursery prep.	M.D.	8.00	4	32.00
Chemical aplic.	M.D.	8.00	4	32.00
Maintenance	M.D.	150.00	1	150.00
Transplant	M.D.	8.00	20	160.00
Weed control	M.D.	8.00	10	80.00
Fertilization	M.D.	8.00	8	64.00
Chemical aplic.	M.D.	8.00	20	160.00
Irrigation	M.D.	8.00	25	200.00
Harvest	M.D.	8.00	10	80.00
Cabbage seed	ONZ.	5.00	6	30.00
Org. Fertil.	QQ.	3.50	20	70.00
Fertilizer	QQ.	80.00	2	160.00
Fertilizer	QQ.	70.00	2	140.00
Fungicides	VAR.	130.00	1	130.00
Insecticides	VAR.	550.00	1	550.00
Bags	UNIT.	2.00	50	100.00
Field Prep.	MN.	100.00	1	100.00
Transport	QQ.	1.50	250	375.00
+ 10%				261.30
Total Vbl. Cost of Prod.				2874.30

PROFIT = L. 2125.70 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
JANUARY	--
FEBRUARY	46
MARCH	26
APRIL	30
MAY	--
TOTAL	102

Table A.4.9. Budget for onions, conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Total Income	QQ.	35.00	150	5250.00
2. Variable Costs:				
Nursery prep.	M.D.	8.00	4	32.00
Chemical aplic.	M.D.	8.00	4	32.00
Maintenance	M.D.	150.00	1	150.00
Transplant	M.D.	8.00	25	200.00
Weed control	M.D.	8.00	13	104.00
Fertilization	M.D.	8.00	8	64.00
Chemical aplic.	M.D.	8.00	20	160.00
Irrigation	M.D.	8.00	12	96.00
Harvest	M.D.	8.00	12	120.00
Onions seed	LBS.	62.50	3	187.50
Org. Fertil.	QQ.	3.50	20	70.00
Fertilizer	QQ.	80.00	2	160.00
Fertilizer	QQ.	70.00	2	140.00
Fungicides	VAR.	130.00	1	130.00
Insecticides	VAR.	550.00	1	550.00
Bags	UNIT.	2.00	50	100.00
Field Prep.	MN.	100.00	1	100.00
Transport	QQ.	1.50	150	225.00
+ 10%				262.05
Total Vbl. Cost of Prod.				2882.55

PROFIT = L. 2367.45 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	34
JUNE	13
JULY	13
AUGUST	13
SEPTEMBER	13
OCTOBER	13
TOTAL	99

Table A.4.10. Budget for onions summer, conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Total Income	QQ.	35.00	150	5250.00
2. Variable Costs:				
Nursery prep.	M.D.	8.00	4	32.00
Chemical aplic.	M.D.	8.00	4	32.00
Maintenance	M.D.	150.00	1	150.00
Transplant	M.D.	8.00	25	200.00
Weed control	M.D.	8.00	13	104.00
Fertilization	M.D.	8.00	8	64.00
Chemical aplic.	M.D.	8.00	20	160.00
Irrigation	M.D.	8.00	25	200.00
Harvest	M.D.	8.00	12	120.00
Onions seed	LBS.	62.50	3	187.50
Org. Fertil.	QQ.	3.50	20	70.00
Fertilizer	QQ.	80.00	2	160.00
Fertilizer	QQ.	70.00	2	140.00
Fungicides	VAR.	130.00	1	130.00
Insecticides	VAR.	550.00	1	550.00
Bags	UNIT.	2.00	50	100.00
Field Prep.	MN.	100.00	1	100.00
Transport	QQ.	1.50	150	225.00
+ 10%				272.45
Total Vbl. Cost of Prod.				2996.95

PROFIT = L. 2253.05 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
NOVEMBER	40
DECEMBER	17
JANUARY	17
FEBRUARY	17
MARCH	21
TOTAL	112

Table A.4.11. Budget for tomatoes summer, Conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Total Income	QQ.	14.00	300	4200.00
2. Variable Costs:				
Nursery prep.	M.D.	8.00	4	32.00
Chemical aplic.	M.D.	8.00	4	32.00
Maintenance	M.D.	150.00	1	150.00
Transplant	M.D.	8.00	23	184.00
Weed control	M.D.	8.00	15	120.00
Fertilization	M.D.	8.00	8	64.00
Chemical aplic.	M.D.	8.00	20	160.00
Irrigation	M.D.	8.00	25	200.00
Harvest	M.D.	8.00	15	120.00
Tomatoe seed	ONZ.	10.00	6	60.00
Org. Fertil.	QQ.	3.50	20	70.00
Fertilizer	QQ.	80.00	2	160.00
Fertilizer	QQ.	70.00	2	140.00
Fungicides	VAR.	430.00	1	430.00
Insecticides	VAR.	310.00	1	310.00
Bags	UNIT.	2.00	50	100.00
Field Prep.	MN.	100.00	1	100.00
Transport	QQ.	1.50	300	450.00
Ropes	LB.	2.00	140	280.00
+ 10%				316.20
Total Vbl. Cost of Prod.				3478.20

PROFIT = L. 721.80 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
JANUARY	--
FEBRUARY	50
MARCH	28
APRIL	37
MAY	--
TOTAL	115

Table A.4.12. Budget for corn-beans, Conventional tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Corn Grain	QQ.	70.00	24.00	1680.00
Beans Grain	QQ.	150.00	8.40	1260.00
Total Income				2940.00
2. Variable Costs:				
Tillage	M.D.	8.00	4	32.00
Tillage	MN.	100.00	1	100.00
Corn seed	LB.	0.70	20	14.00
Beans seed	LB.	1.50	35	52.50
Seeding	M.D.	8.00	3	24.00
Weed control	M.D.	8.00	12	96.00
Fertilization	M.D.	8.00	3	24.00
Insect control	M.D.	8.00	3	24.00
Chemicals	QQ.	80.00	2.5	200.00
Pesticides	MN.	240.00	1	240.00
Harvest	M.D.	8.00	15	120.00
+ 10%				92.60
Total Vbl. Cost of Prod.				1018.60

PROFIT = L. 1921.40 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	6
JUNE	4
JULY	4
AUGUST	4
SEPTEMBER	4
OCTOBER	2
NOVEMBER	--
DECEMBER	15
TOTAL	39

Table A.4.13. Budget for corn-beans, Minimum tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Corn Grain	QQ.	70.00	18.75	1312.50
Beans Grain	QQ.	150.00	4.80	720.00
Total Income				2032.50
2. Variable Costs:				
Tillage	M.D.	8.00	14	112.00
Corn seed	LB.	0.70	20	14.00
Beans seed	LB.	1.50	30	45.00
Seeding	M.D.	8.00	6	48.00
Weed control	M.D.	8.00	18	144.00
Fertilization	M.D.	8.00	4	32.00
Pest. control	M.D.	8.00	4	32.00
Organic Fert.	QQ.	3.50	20	70.00
Pesticides	LT.	100.00	1	100.00
Break plant	M.D.	8.00	1	8.00
Harvest	M.D.	8.00	11	88.00
+ 10%				69.30
Total Vbl. Cost of Prod.				762.30

PROFIT = L. 1270.20 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	22
JUNE	5
JULY	5
AUGUST	7
SEPTEMBER	4
OCTOBER	3
NOVEMBER	1
DECEMBER	11
TOTAL	58

Table A.4.14. Budget for corn-beans, No-tillage.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Corn Grain	QQ.	70.00	11.25	787.50
Beans Grain	QQ.	150.00	3.00	450.00
Total Income				1237.50
2. Variable Costs:				
Till. + Seed.	M.D.	8.00	7	56.00
Corn seed	LB.	0.70	20	14.00
Beans seed	LB.	1.50	25	37.50
Weed control	M.D.	8.00	23	184.00
Fertilization	M.D.	8.00	1	8.00
Pest. control	M.D.	8.00	2	16.00
Organic Fert.	QQ.	3.50	10	35.00
Pesticides	LT.	100.00	0.5	50.00
Break plant	M.D.	8.00	1	8.00
Harvest	M.D.	8.00	8	64.00
+ 10%				57.25
Total Vbl. Cost of Prod.				629.75

PROFIT = L. 607.75 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
MAY	7
JUNE	7
JULY	7
AUGUST	5
SEPTEMBER	5
OCTOBER	3
NOVEMBER	1
DECEMBER	8
TOTAL	42

Table A.4.15. Budget for coffee.

ACTIVITY	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST(L./MN.)
1. Gross Income				
Coffee	LATAS[a]	20.00	180	3600.00
Total Income				3600.00
2. Variable Costs:				
Stabilization	MN.	240.00	1	240.00
Weed Control	M.D.	8.00	24	192.00
Fertilization (UREA)	M.D.	8.00	12	96.00
Fertilization (COMPLETE)	M.D.	8.00	12	96.00
Chemicals				
UREA	QQ	70.00	2	140.00
COMPLETE	QQ	80.00	2	160.00
Pesticides	MN.	50.00	1	50.00
Harvest	M.D.	8.00	50	400.00
+ 10%				137.40
Total Vbl. Cost of Prod.				1511.40

PROFIT : L. 2088.60 /MN.

MONTHLY LABOR REQUIREMENTS (M.D./MONTH)

LABOR REQUIRED	M.D./MONTH
JANUARY	50
FEBRUARY	--
MARCH	--
APRIL	--
MAY	--
JUNE	24
JULY	--
AUGUST	--
SEPTEMBER	12
OCTOBER	--
NOVEMBER	12
DECEMBER	--
TOTAL	98

[a] 18 latas of green coffee equal 100 pounds of processed coffee.

APPENDIX 5

ASSORTED TABLES

Table A.5.1. Budgets for construction and maintenance of live barriers, hill ditches, and terraces.

	PRACTICE						
	LIVE BARRIERS			HILL DITCHES		TERRACES	
SLOPE	2 %	10 %	24 %	10 %	24 %	10 %	24 %
METERS MAN/DAY	128[a]	128[a]	128[a]	15[a]	13[a]	8[b]	5[b]
DISTANCE BETWEEN STRUCTURES (MTS.)[d]	30.5[c]	12[c]	9[c]	11[c]	9[c]	2.8[c]	3.2[c]
MTS./MN.[e]	229.51	583.33	777.77	636.36	777.77	2500	2187.5
MAN-DAY/ MN.	1.79	4.56	6.07	42.42	59.83	312.5	437.5
BARRIERS PLANTING[f]				4.97	6.07	19.53	17.09
TOTAL MAN-DAY/MN.	1.79	4.56	6.07	47.39	65.90	332.03	454.59
ANNUAL MAINTENANCE (10%)	0.179	0.456	0.607	4.739	6.59	33.2	45.46
MAN-DAY/ MN. NEEDED	1.97	5.02	6.67	52.13	72.49	365.23	500.05

Sources:

[a] Almendariz, Roque, 1990.

[b] Michaelsen, Tage, 1980.

[c] Federick and Mungía, 1986.

[d] Refers to the horizontal separation between each soil conservation structure.

[e] Refers to the amount of linear meters of each structure that can be built in a manzana.

[f] Refers to the amount of man-days needed to plant barriers that accompany each soil conservation structure.

Table A.5.2. Crop Yields 1985 - 1990 (QQ./MN.)

	YEAR					
Crop	1985	1986	1987	1988	1989	1990
CORN						
Conv.[f]	27.15	28.40	24.06	26.32	26.06	32.00
Minim.[a]	21.21	22.19	18.80	20.56	20.36	25.00
No-Till[g]	12.73	13.31	11.28	12.34	12.22	15.00
BEANS						
Conv.[h]	8.89	12.39	11.58	16.71	7.00	14.00
Minim.[b]	5.08	7.08	6.62	9.55	4.00	8.00
No-Till[i]	3.17	4.43	4.14	5.97	2.50	5.00
CORN-BEANS						
CORN						
Conv.[f]	20.35	21.30	18.05	19.74	19.55	24.00
Minim.[c]	15.90	16.64	14.10	15.42	15.27	18.75
No-Till[g]	9.54	9.98	8.46	9.25	9.16	11.25
BEANS						
Conv.[h]	5.34	7.44	6.95	10.03	4.20	8.40
Minim.[d]	3.05	4.25	3.97	5.73	2.40	4.80
No-Till[i]	1.91	2.66	2.48	3.58	1.50	3.00
CABBAGE						
Conv.[e]	143.00	143.00	145.00	145.00	145.00	250.00
ONIONS						
Conv.[e]	77.91	77.00	77.00	77.00	77.00	150.00
TOMATOES						
Conv.[e]	137.00	144.00	141.20	139.40	139.40	300.00
COFFEE						
Conv.[e]	9.32	9.60	9.76	11.13	10.83	10.00

Sources:

[a] INTSORMIL.

[b] Compendio estadístico agropecuario (no asistida).

[c] Corn minimum * 0.75.

[d] Beans minimum * 0.60.

[e] FAO year book.

[f] Corn minimum * 1.28.

[g] Corn minimum * 0.6.

[h] Beans minimum * 1.75.

[i] Beans minimum * 0.625.

Table A.5.3. Crop prices 1985 - 1990 (L./QQ.)

	YEAR					
Crop	1985	1986	1987	1988	1989	1990
CORN						
No-defl.[a]	14.15	15.76	16.17	16.04	17.62	70.00
Deflated[b]	20.60	21.77	21.94	20.81	21.41	70.00
BEANS						
No-defl.[a]	35.63	32.08	32.08	54.88	52.40	150.00
Deflated[b]	51.88	44.32	43.53	71.22	63.68	150.00
CABBAGE						
No-defl.[a]	15.82	12.95	12.95	12.95	10.00	20.00
Deflated[b]	23.03	17.89	17.57	16.80	12.15	20.00
ONIONS						
No-defl.[a]	39.73	42.35	42.35	42.35	25.00	35.00
Deflated[b]	57.85	58.50	57.47	54.96	30.38	35.00
TOMATOES						
No-defl.[a]	10.12	9.60	9.60	9.60	7.00	14.00
Deflated[b]	14.74	13.26	13.03	12.46	8.51	14.00
COFFEE						
No-defl.[a]	129.38	217.36	131.77	151.93	154.00	360.00
Deflated[b]	188.38	300.26	178.82	197.16	187.17	360.00
GDP DEFLATOR[c]	0.6868	0.7239	0.7369	0.7706	0.8228	1.00

Sources:
[a] Compendio estadístico agropecuario.
[b] Deflated prices were deflated using the GDP deflator.
[c] International financial statistics yearbook 1991.

Table A.5.4. Income values used in the calculation of risk (L./MN.)[a]

	CROP					
YEAR	CORN C	CORN M	CORN N	BEANS C	BEANS M	BEANS N
1985	559.34	436.98	262.19	461.19	263.54	164.71
1986	618.36	483.09	289.85	549.06	313.75	196.09
1987	528.04	412.53	247.52	504.33	288.19	180.12
1988	547.78	427.95	256.77	1190.21	680.12	425.07
1989	558.08	436.00	261.60	445.79	254.73	159.21
AVERAGE	562.32	439.31	263.58	630.12	360.07	225.04
1985	- 2.98	- 2.33	- 1.39	-168.93	- 96.53	- 60.33
1986	56.04	43.78	26.27	- 81.05	- 46.32	- 28.95
1987	- 34.28	- 26.78	- 16.07	-125.78	- 71.87	- 44.92
1988	- 14.54	- 11.36	- 6.82	560.09	320.05	200.03
1989	- 4.24	- 3.31	- 1.98	-184.33	-105.33	- 65.83

YEAR	CR-B C	CR-B M	CR-B N	CABBAGE	ONIONS	TOMATOES
1985	696.20	485.81	295.44	3293.91	4506.93	2018.69
1986	793.30	550.60	335.07	2558.15	4504.69	1909.65
1987	698.48	482.22	293.65	2548.17	4425.22	1839.49
1988	1124.96	729.04	447.62	2436.73	4231.70	1736.62
1989	686.03	479.84	291.73	1762.27	2339.57	1185.95
AVERAGE	799.80	545.50	332.70	2519.85	4001.63	1738.08
1985	-103.59	- 59.69	- 37.26	774.06	505.31	280.61
1986	- 6.50	5.10	2.37	38.30	503.07	171.57
1987	-101.32	- 63.28	- 39.05	28.32	423.60	101.41
1988	325.17	183.53	114.92	- 83.11	230.07	- 1.46
1989	-113.76	- 65.66	- 40.98	-757.58	-1662.05	-552.13

YEAR	COFFEE	COFFEE
1985	1755.71	-365.26
1986	2882.52	761.55
1987	1745.25	-375.72
1988	2194.37	73.40
1989	2027.00	- 93.96
AVERAGE	2120.97	

[a] The first block of values refers to crop income and the second block gives the difference in crop income from its mean. These differences were used in the risk calculations.

BIBLIOGRAPHY

Almendariz, Roque D. 1990. "Estimación de rendimientos y costos de zanjas de ladera en suelos de la cuenca del río Bonito La Ceiba, Atlántida". Tesis de Ingeniero Agrónomo. Centro Universitario Regional del Litoral Atlántico. La Ceiba, Honduras.

American Society of Agronomy. 1982. "Soil Erosion and Conservation in the Tropics". ASA Special Publication Number 43.

Berglund, S.H. and E.L. Michalson. 1981. "Soil Erosion Control in Idaho's Cow Creek Watershed: An Economics Analysis". Journal of Soil and Water Conservation 36:158-161.

Binswanger, H.P. 1980. "Attitudes Toward Risk: Experimental Measurement in Rural India". American Journal of Agricultural Economics 62(3):395-407.

Burt, O.R. 1981. "Farm-Level Economics of Soil Conservation in the Palaouse Area of the Northwest." American Journal of Agricultural Economics 63(1):83-92.

Byers, A.C. 1990. "Erosion Processes on Tropical Watersheds: A Preliminary Assessment of Measurement Methods, Action Strategies, and Information Availability in the Dominican Republic, Ecuador, and Honduras". Prepared for the Agency for International Development under A.I.D. Contract # DHR 5438-C-00-6054-00.

CPLEX Organization Inc. 1991. "The CPLEX Optimizer and Callable Library". Version 2.1.

Consejo Superior de Planificación Económica. Dirección Ejecutiva del Catastro. 1983. "Estudio de suelos a reconomiento de las cabeceras del río Choluteca". Tegucigalpa, Honduras. Enero 1983.

Dillon, J.L., and P.L. Scandizzo. 1978. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach". American Journal of Agricultural Economics 60(3):425-35.

Dirección General de Recursos Hídricos. Información de precipitación. Estación Lepaterique. 1978-1987.

Ervin, C.A. and D.E. Ervin. 1982. "Factors Affecting the Use of Soil Conservation Practices: Hypothesis, Evidence, and Policy Implications". Land Economics 58(3):277-292.

Ervin, D.E. and R.A. Washburn. 1981. "Profitability of Soil Conservation Practices in Missouri". Journal of Soil and Water Conservation 36:107-111.

Feder, Gershon and T. Onchan. 1987. "Land Ownership Security and Farm Investment in Thailand". American Journal of Agricultural Economics 69(2):311-320.

Food and Agricultural Organization (FAO), United Nations, 1990. "1990 Production Yearbook", Rome.

Franklin, Ralph. 1990. "Identifying poverty groups in Honduras". Some preliminary estimates and scenarios. Prepared for USAID: Sigma One Corporation; Raleigh, NC.

Garcia, M., R.D. Norton, M.P. Cambar, and R.V. Hoefen. 1988. "Agricultural Development policies in Honduras", Tegucigalpa, Honduras, U.S. Dept. of Agriculture and U.S. Agency for International Development.

Gonzáles-Rey, David, Miguel López-Pereira and John H. Sanders. 1991. "The impact of new sorghum cultivars and other associated technologies in Honduras". INTSORMIL project.

Hazell, P. and R.D. Norton. 1986. "Mathematical Programming for Economic Analysis in Agriculture". Macmillan. New York.

International Monetary Fund (IMF), 1990. "International Financial Statistics", Washington, DC.

Kamal, K.B. and J.R. Anderson. 1982. "A Note on Decreasing Absolute Risk Among Farmers in Nepal". Australian Journal of Agricultural Economics 26(3):220-225.

Kramer, R.A., W.T. McSweeney, and R.W. Stavros. 1983. "Soil Conservation with Uncertain Revenues and Input Supplies". American Journal of Agricultural Economics 65(4):694-701.

Lee, Linda K. 1980. "The Impact of Landownership Factors on Soil Conservation". American Journal of Agricultural Economics 62(5):1070-1076.

McQueen, A.D., R.N. Shulstad, and T.C. Osborn. 1982. "Controlling Agricultural Soil Loss in Arkansas' North Lack Chicot Watershed: A Cost Analysis". Journal of Soil and Water Conservation. 37:182-185.

Michaelsen, Tage. 1980. "Manual Práctico de Conservación de suelos para tierras de ladera" Ordenación Integrada de Cuencas Hidrográficas, Documento de trabajo No. 3. COHDEFOR/PNUD/FAO, HON/77/006. Tegucigalpa, Honduras.

Recursos Hidricos. 1983. "Estudio de Suelos a Reconocimiento de las Cabeceras del Río Choluteca (La Hoya de Tegucigalpa)". Tegucigalpa, Honduras.

Reinhardt, Nola. 1987. "Modernizing Peasant Agriculture: Lesson from El Palmar, Colombia". World Development 15(2):221-247.

Segarra, E., R.A. Kramer, and D.B. Taylor. 1985. "A Stochastic Programming Analysis of the Farm Level Implications of Soil Erosion Control". Southern Journal of Agricultural Economics.

Segarra, E. and D.B. Taylor. 1987. "Farm Level Dynamic Analysis of Soil Conservation: An Application to the Piedmont Area of Virginia". Southern Journal of Agricultural Economics.

Seitz, W.D., C.R. Taylor, R.G.F. Spitze, C. Osteen, and M.C. Nelson. 1979. "Economic Impacts of Soil Erosion Control". Land Economics 55(1):28-42.

Tracy, Federick, C. 1988. "The Natural Resource Management Project in Honduras" in Conservation Farming on Steep Lands. W.C. Moldenhauer and N.W. Hudson (Editors). Soil and Water Conservation Society. USA.

Tracy, Federick and Perez Mungia, J. Ricardo. 1986. "Manual Práctico de Conservación de Suelos". Proyecto Manejo de Recursos Naturales. USAID proyecto No. 522-0168. Tegucigalpa, Honduras.

Unidad de Planificación Sectorial Agricola. 1990. Secretaría de Recursos Naturales. "Compendio Estadístico Agropecuario 1990". Tegucigalpa, Honduras.

USDA-SCS. 1991. Information received from Ing. José Martinez. San Juan, Puerto Rico.

Walker, D.J. and J.F. Simmons. 1980. "Cost of Alternative Policies for Controlling Agricultural Soil Loss and Associated Stream Sedimentation". Journal of Soil and Water Conservation. 35(4):177-183.

Welchez, L. Personal interview, LUPE Project, August 19, 1991.

White, G.H. and E.J. Partenheimer. 1980. "Economic Impacts of Erosion and Sedimentation Control Plans: Case Studies for Pennsylvania Dairy Farms". Journal of Soil and Water Conservation. 35:76-78.

Wischmeier, W.H. and D.D. Smith. 1978. "Predicting Rainfall Erosion Losses" A Guide to Conservation Planning. USDA, Agricultural Handbook No. 537.

Wouters, Rick. 1980. "Resultados de un proyecto de investigación de la erosión en la cuenca Los Laureles". Corporación Hondureña de Desarrollo Forestal. Tegucigalpa, Honduras.

VITA

Julio Antonio Cárcamo Rodríguez was born December 3, 1967, in Tegucigalpa, Honduras, the son of Julio Antonio Cárcamo of Danlí, El Paraíso and Maura Orestila de Cárcamo of Jacaleapa, El Paraíso. He lived with his parents until graduating from the Instituto Salesiano San Miguel High School in 1984. He attended the Escuela Agrícola Panamericana in Honduras from January, 1985 to December, 1987, graduating with the degree of Agronomist. Between May, 1988 and April, 1989 he attended the Escuela Agrícola Panamericana, graduating with a B.S. in Agricultural Economics.

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