LAND EVALUATION, ENVIRONMENTAL PERCEPTION, AND AGRICULTURAL DECISION-MAKING IN LAS CUEVAS WATERSHED, DOMINICAN REPUBLIC

BY

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In memory of

Carmen Clemencia

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Inhabitants of rural areas represent an invaluable but neglected source of information for scientists concerned with land evaluation in the tropics. In this study, site suitability ratings were scientifically developed for six uses--coffee, beans, grazing, pigeon peas, garlic and rice--and compared to farmers' opinions of site suitability. The study area was Las Cuevas watershed, a tropical steepland region in the Dominican Republic.

Suitability indices were computed using a multiplicative model and converted into four ordinal ratings. Chi-square and Kendall's tau-b statistics showed a

clear statistical correlation between the author's ratings and farmers' evaluations of their land, confirming the hypothesis that suitability ratings are meaningful. The majority of farmers who disagreed with the author gave a more optimistic appraisal. This finding is consistent with studies of British farmers who over-estimate poor quality land and present an over-optimistic evaluation of land for familiar uses.

Land dedicated to a specific use would be expected to be associated with more favorable values of the relevant suitability index. Chi-square, Kolmogorov-Smirnov and Wilcoxon tests showed that sites with coffee do tend to have better suitability ratings. Relatively high chi-square and Wilcoxon test statistics suggest that sites used for short-cycle crops also are associated with higher ratings of land suitability for beans; this finding was not, however, supported by the Kolmogorov-Smirnov test. Grazing land does not have significantly higher ratings than land with other uses.

Although coffee and short-cycle crops are generally associated with better land, several farmers were observed growing crops on sites with bad suitability ratings. Point score analysis showed that choice of enterprise on the steep slopes and thin soils of Las Cuevas is motivated more by socio-personal and economic factors than by physical factors.

CHAPTER I
INTRODUCTION

Problem Statement

Developing nations can ill afford to continue neglecting rural areas (Cummings, Jr., 1986). The situation is especially urgent in tropical and subtropical forests, steeplands and arid areas where marginalized peasants are obliged to mine the soil, destroying their only source of livelihood and causing devastating environmental degradation (Eckholm, 1976; Brown and Wolf, 1984; Grindle, 1986). Urban areas are unable to absorb the flood of refugees from the countryside and food production is so inefficient that costly supplies have to be imported to satisfy requirements.

Well-intentioned rural development projects have been initiated in most developing countries but few have been successful (Dickenson et al., 1983). One reason for their failure is that planners involved in evaluation of resources and formulation of management policies have not taken advantage of the knowledge and skills of traditional farmers (Saarinen, 1976). Local inhabitants represent an invaluable but neglected resource for scientists involved in land evaluation because they have intimate knowledge of their own land which is derived from years of empirical experimentation with different uses (de Souza and Porter, 1974). The scientist's indirect evaluation, based on agronomic theory and inferred influence of environmental features, can and should be compared to the direct evaluation of the farmer (Buringh, 1986; Siderius, 1986).

Davidson (1976) and Fisher et al. (1986) related farmers' opinions to scientific evaluations of general land capability in Great Britain, but land evaluators in developing nations have been surprisingly reluctant to seek the opinions of traditional farmers despite growing recognition of their unique skills and the need for such communication (Barlett, 1980; Altieri, 1983; Conant et al., 1983). Indeed, opinions of traditional farmers have not been compared either to general land capability classifications or schemes designed to evaluate suitability of land for specific uses.

Objectives

Site Suitability Analysis

The principal objective of this dissertation is to derive site suitability ratings for selected agricultural uses in Las Cuevas watershed and compare the ratings to opinions formulated by local farmers. The ratings are based on numerical indices--oftentimes referred to as parametric indices--which are computed from scores assigned to land attributes of specific sites according to their suitability for a land use (Riquier, 1974; McRae and Burnham, 1981).

Numerical suitability indices have been applied by soil scientists for many years but their utility has become enhanced in the present decade with the proliferation of computers, the development of geographic information systems and the creation of geo-coded environmental data bases.

It is hypothesized in this study that numerical suitability indices, based on a systematic review of current scientific knowledge of environmental requirements, are meaningful; expressed as ordinal suitability ratings, they correspond to farmers' opinions which are founded upon invaluable empirical experience. The author's numerical indices are computed using standard land evaluation methodology--identification of relevant land uses and their environmental requirements; selection of land characteristics to be used in the analysis; classification of ranges of values of land characteristics into ranked categories; selection of a mathematical model for index computation; and definition of scores to be assigned to ranked categories. The author's method differs from others, however, in the scoring procedure; scores are assigned to ranked categories of land characteristics according to a simple conceptual scale of productivity. This scoring procedure facilitates conversion of numerical index values into ordinal suitability ratings.

Decision-Making Analysis

A secondary objective of this study is to examine Las Cuevas farmers' perceptions of factors which influence selection of principal enterprise. The author interviewed 80 farmers in 1986 and asked them to assign scores to selected decision-making factors according to their significance in his choice of principal land use; the sum of scores given to each factor is considered a measure of its relative importance in the decision-making process.

Existing agricultural patterns do not necessarily reflect land suitability (McRae and Burnham, 1981) and farmers with a profound knowledge of environmental requirements of crops may establish a specific crop on inappropriate land for over-riding socio-personal or economic reasons. It is clear that the planner's ability to evaluate land must be complemented with insight into factors which influence choice of land use.

Las Cuevas watershed is characterized by steep slopes and thin soils and many farmers do not have the privilege of choosing between land which is suitable or inappropriate for their crops. As a result, it is hypothesized that environmental factors have less influence than socio-personal and economic factors in choice of principal enterprise in Las Cuevas.

The overall goal of the author's study, therefore, is to demonstrate a way of integrating knowledge of traditional farmers into rural development studies. Planners concerned with resource management will have more confidence in scientific land suitability evaluations when they are shown to be compatible with local empirical experience.

Rural Development Problems in Dominican Republic

A general appreciation of landscapes and problems of the Dominican Republic can be obtained from texts by West and Augelli (1966), James (1969), de la Fuente Garcia (1976), Bell (1981), USAID (1981), Wiarda and Kryzanek (1982) and Black (1986). The Dominican Republic is approximately one-third the size of Florida and it occupies the eastern portion of Hispaniola, the second largest island of the Caribbean Antilles (see Figure 1). The population, estimated at six million in 1983 (World Bank, 1985), is mostly mulatto or white and Hispanic in culture.

The Dominican Republic, like other developing nations, faces many problems including rapid population growth and food production that does not meet local needs. The national diet is supplemented with food imports while extensive areas of prime farmland are in large holdings which produce sugar-cane, coffee, cacao, tobacco and meat for export. Steeplands have been invaded by less privileged farmers who cut down the forest, cultivate without conservation techniques and promote accelerated soil erosion. Eroded soil is transported by rivers and deposited in costly reservoirs built for water

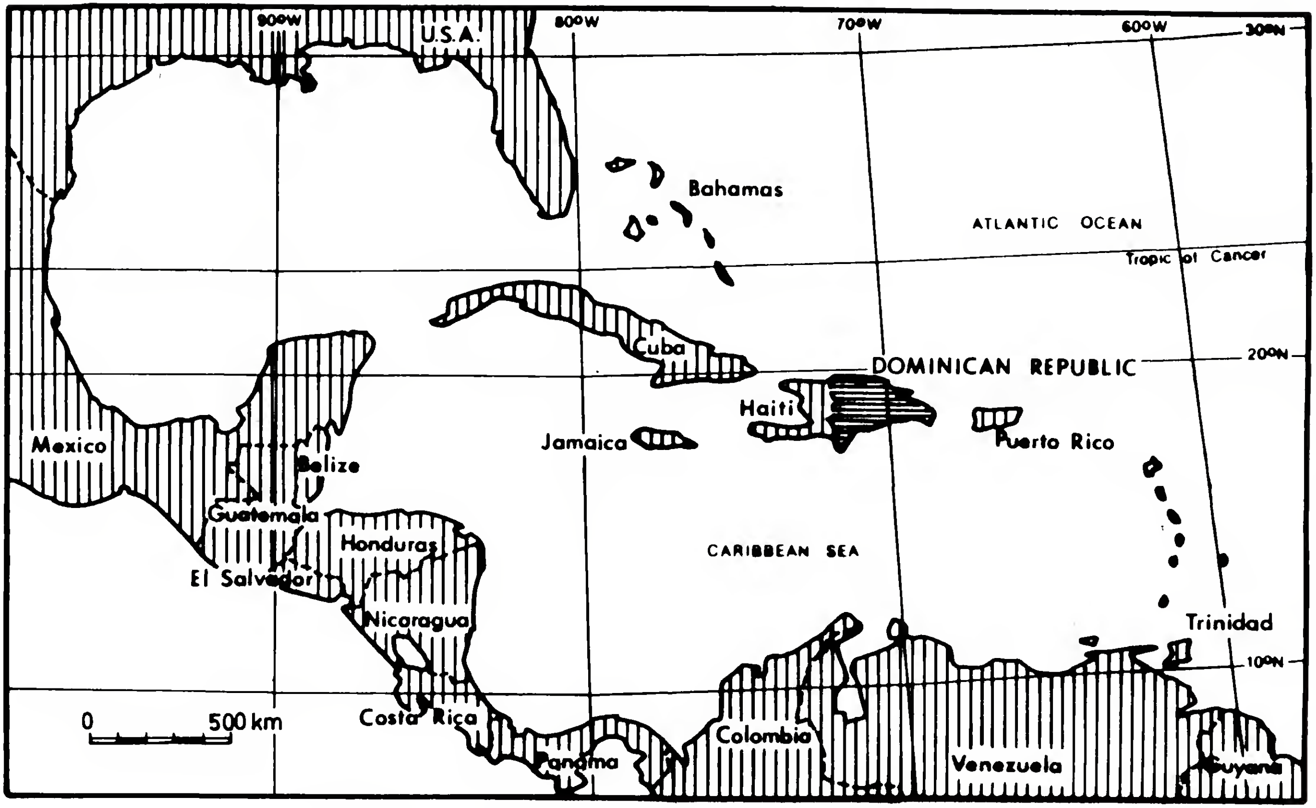

Figure 1. Location of the Dominican Republic

supply, irrigation and hydro-electric energy. Rural poverty has forced many people to migrate to urban areas and, in particular, the capital city of Santo Domingo. Efforts to diversify the economy and absorb the displaced rural population in industrial and service activities have had limited success. Agriculture continues to produce more than 50 percent of the nation's exports and unemployment is in the order of 24 percent (Perez-Luna, 1984).

The author's research is focused on Las Cuevas watershed which is located on the southwestern flank of the Central Cordillera (see Figure 2). This steepland area has been particularly affected by deforestation and soil erosion and is in urgent need of land evaluation and sound resource management policies. A special incentive for investigating natural resources in Las Cuevas is the availability of geo-coded data bases derived from a 1982 soil survey (Antonini et al., 1985) and a 1984 farmer survey (Montanez, 1985). Environmental and agricultural characteristics of the watershed are described in Chapter II.

Plan of Presentation

The flow chart in Figure 3 illustrates the research design of this study. As explained above, the author's objectives are to (1) compare scientific site suitability ratings to farmers' opinions of suitability for specific agricultural uses and (2) examine farmers' perceptions of

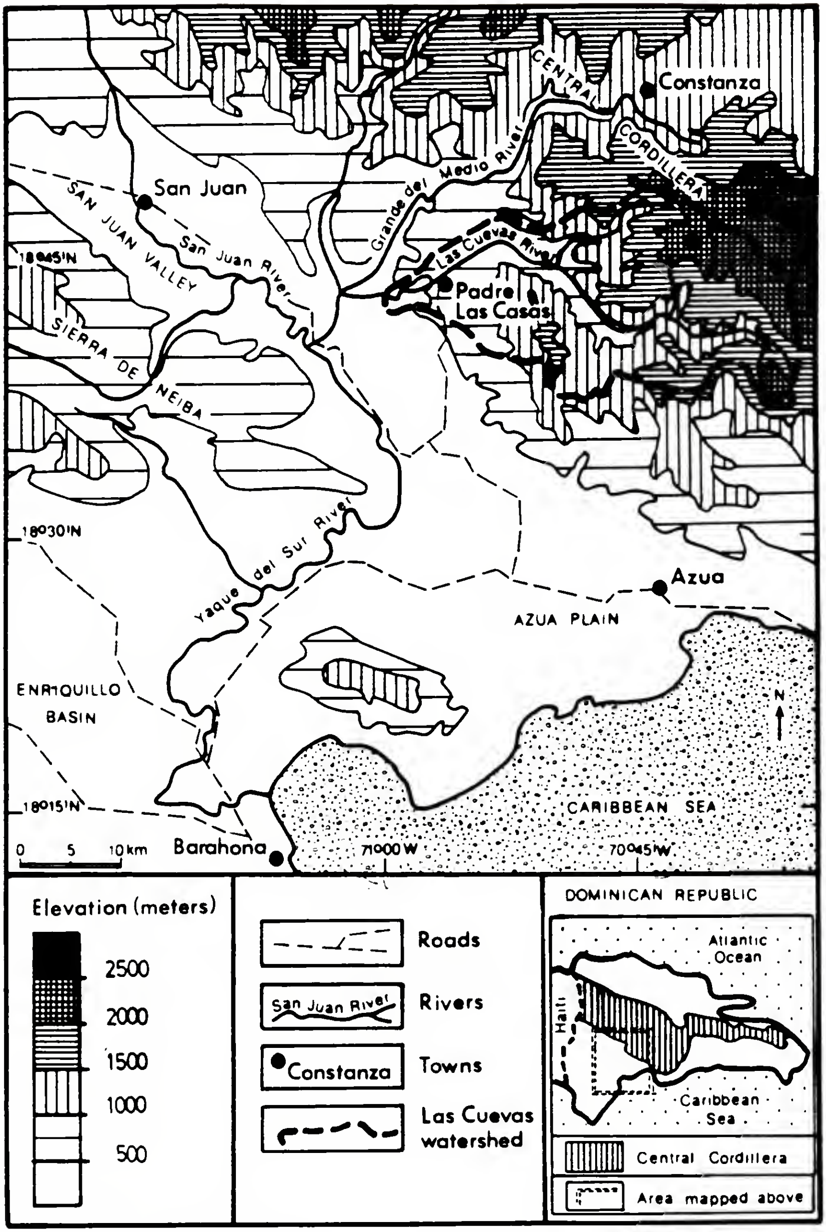

Figure 2. Location of Las Cuevas Watershed

Research Design

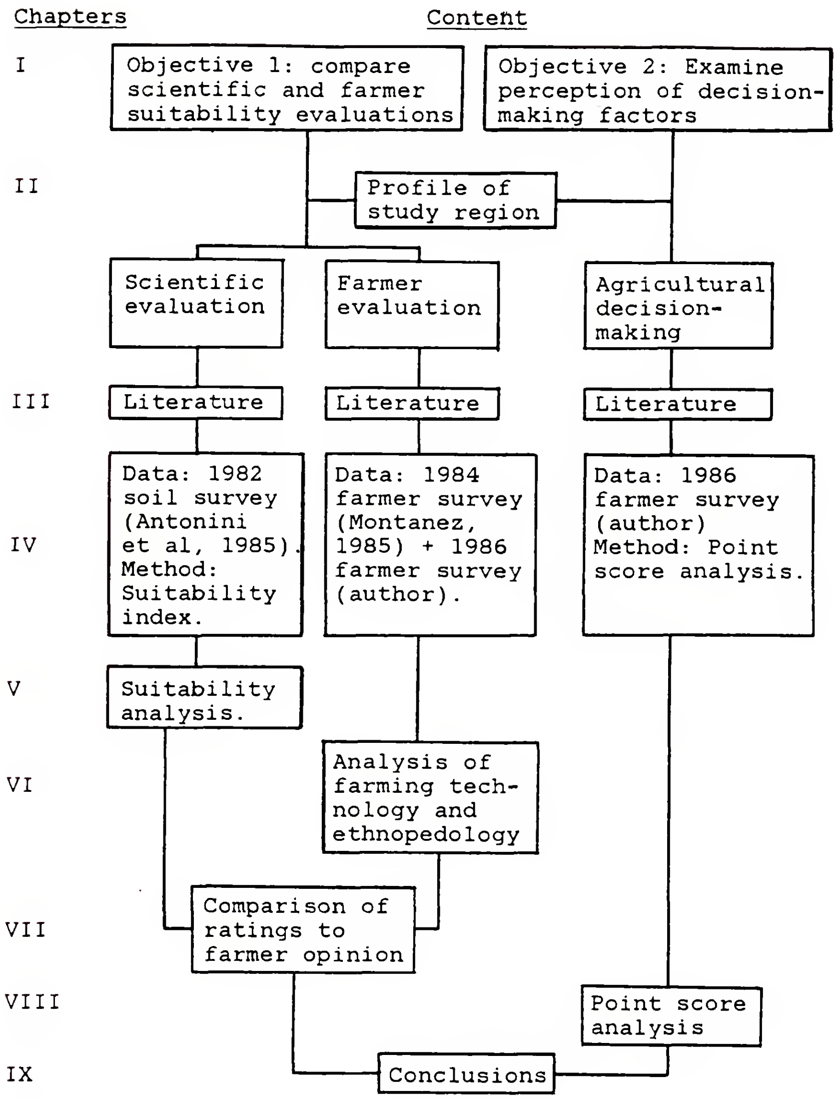

Figure 3. Research Design

factors which influence choice of principal enterprise. Chapter II provides profiles of the environment and agriculture in the study region. Literature relevant to analysis of site suitability, farming skills and agricultural decision-making is reviewed in Chapter III. The literature review also identifies environmental requirements for the six principal land uses of Las Cuevas farmers interviewed by the author in 1986--coffee, beans, pigeon peas, garlic, rice and grazing.

Chapter IV is a discussion of methodological aspects and includes a description of three data sets used in the analysis. A 1982 soil survey (Antonini et al., 1985) was used to derive suitability ratings at 350 sites while farming skills were examined with data from a 1984 farmer survey (Montanez, 1985) and the author's farmer survey of 1986. The author's survey was also used to study decision-making factors in choice of principal land use. Chapter IV includes an outline of the site suitability analysis procedure; in particular, there is a detailed description of the scoring system devised by the author to facilitate conversion of numerical index values to ordinal suitability ratings.

Chapter V is dedicated entirely to the site suitability analysis. The author classifies values of relevant land characteristics into 5 suitability classes for each land use--very good, good, mediocre, bad, severe. Scores are assigned to suitability classes and used to compute numerical suitability indices with 1982 soil survey data (Antonini et al., 1985). Index values are subsequently converted into four ordinal site suitability ratings--very good, good, mediocre or bad. Principal limiting factors are identified for each land use and maps show spatial distribution of site suitability in the watershed.

Chapter VI focuses on farming skills in Las Cuevas. An index of modern agricultural technology is computed using data collected by Montanez in 1984 (Montanez, 1985) and the author in 1986 to show that few farmers have adopted neotechnic methods. The index is based on absence or presence of 6 major inputs--fertilizer, insecticide, herbicide, irrigation, energy and conservation. There is a discussion of local awareness of soil erosion and soil types. In addition, a comparison is made of farmer and scientific opinions on the importance of selected criteria for agricultural site evaluation--rainfall, temperature, soil depth, color, drainage, texture, stoniness and slope.

The primary research goal is reached in Chapter VII. Suitability ratings for 80 sites with active agricultural use are compared to farmers' opinions of suitability of the same sites. Suitability ratings are also related to existing land cover at all 350 soil survey sites.

In accordance with the secondary research objective, Chapter VIII examines Las Cuevas farmers' perceptions of factors which influence selection of principal enterprise. Point score analysis is used to assess the relative importance of environmental, economic and socio-personal decision-making factors. Chapter IX presents a general summary of the author's research findings.

CHAPTER II
THE STUDY REGION

Environmental Profile

Las Cuevas watershed covers approximately 600 square km on the southwestern flank of the Central Cordillera. It belongs to the drainage basin of the Yaque del Sur, the second largest river in the Dominican Republic (Figure 2). The low western tip of the watershed is linked by an all-weather road to the Azua-San Juan highway. One gravel-surfaced extension of this road connects the watershed's largest village, Padre Las Casas, to Monte Bonito while another follows Las Cuevas River upstream to Guayabal (Figure 4). Other roads skirt the southeastern perimeter of the watershed at Sabana de San Juan and La Nevera but the rugged mountainous interior is inaccessible to vehicles and must be visited on foot or muleback.

Figure 5 shows that elevations generally increase from west to east within the watershed and altitudes range from 420 m near Padre Las Casas to 2659 m at Monte Tina in the eastern mountains. Approximately three-quarters of the watershed is above 1000 m. Figure 6 shows six geomorphic subregions which can be delimited on the basis of elevation, dissection and geological structure (Antonini et al., 1985).

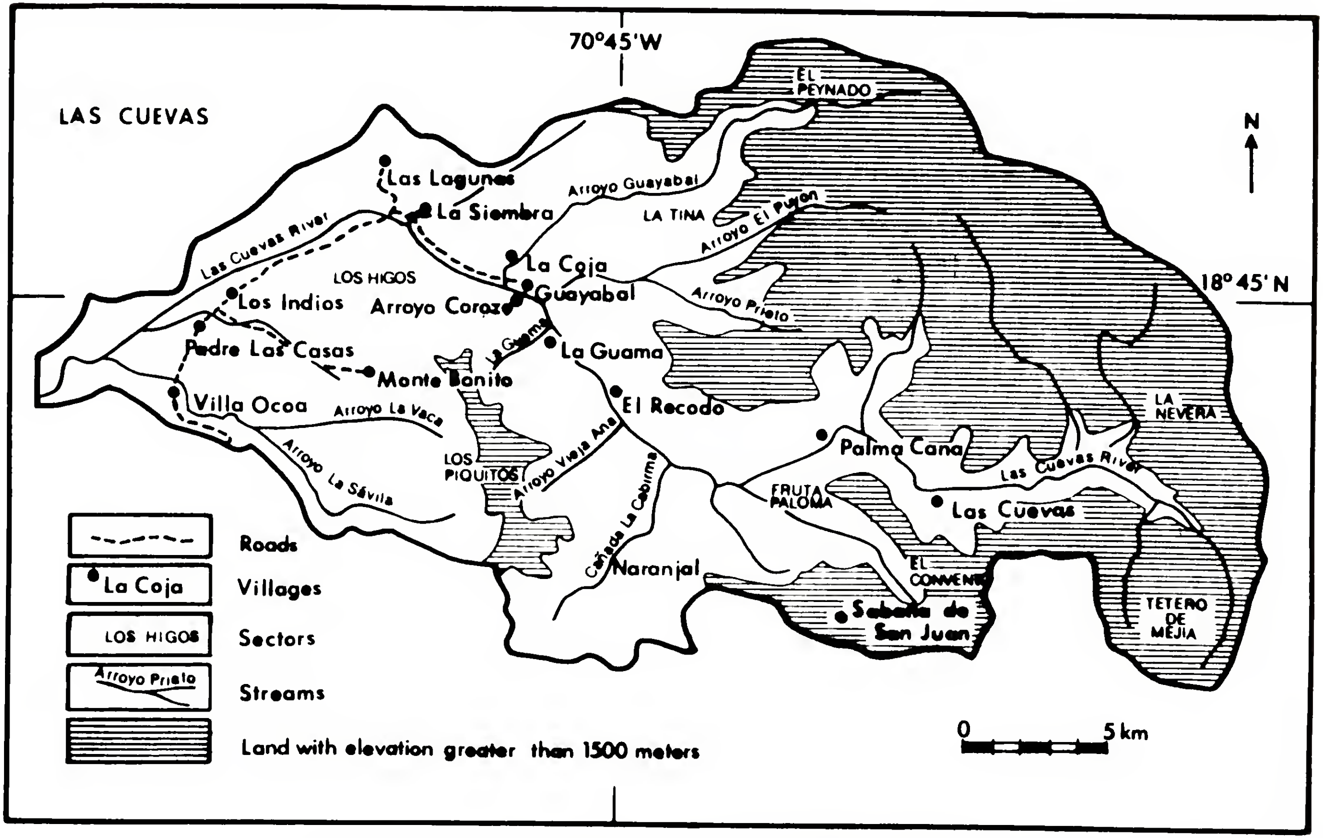

Figure 4. Base Map of Las Cuevas Watershed

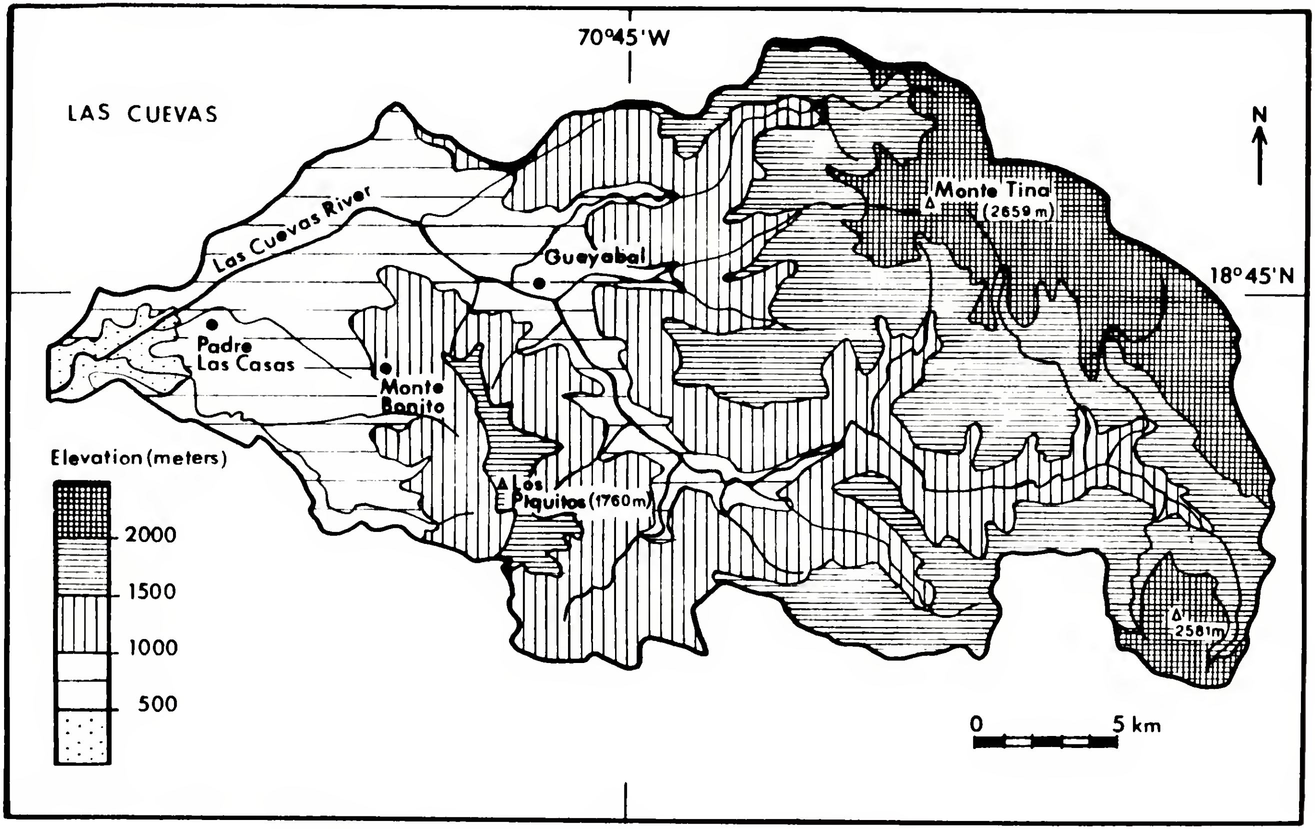

Figure 5. Relief in Las Cuevas Watershed

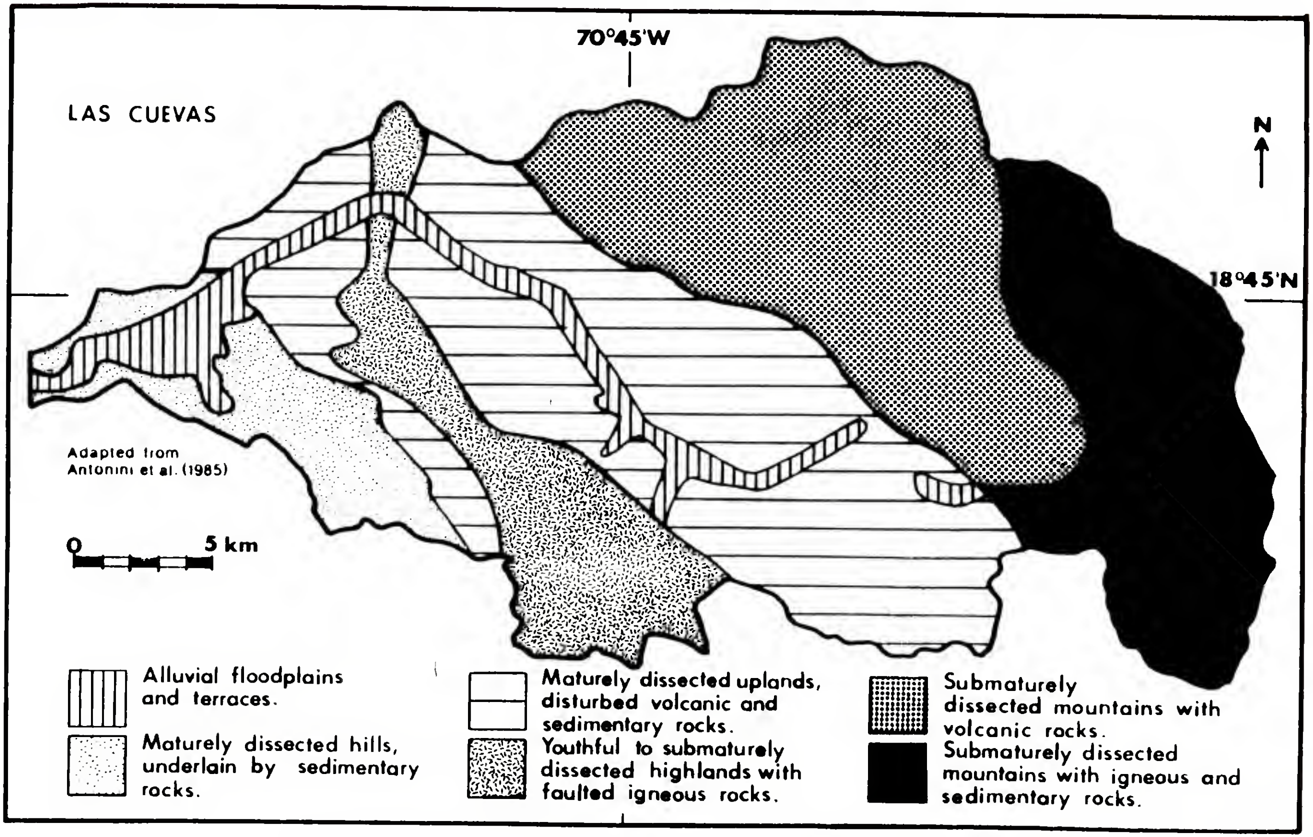

Figure 6. Geomorphic Subregions in Las Cuevas Watershed

The eastern mountains are underlain to the south by a complex of igneous and sedimentary rocks and to the north by volcanic materials. In the central watershed there are igneous highlands and extensive maturely dissected uplands on volcanic and sedimentary structures. Sedimentary rocks prevail in the west where there are low-lying dissected hills. The sixth geomorphological subregion consists of alluvial floodplains and terraces along Las Cuevas River which are relatively well developed in the vicinity of Padre Las Casas.

Temperatures decrease and rainfall increases with elevation in the watershed. This altitudinally-based climatic variation conditions the spatial distribution of life zones observed in Figure 7 (OAS, 1967). The low western part of the watershed belongs to the Subtropical Dry Forest life zone characterized by mean annual temperatures of 23-26 degrees Centigrade and potential evapotranspiration which is 60 percent greater than mean annual rainfall (Holdridge et al., 1971; Holdridge, 1978). At Padre Las Casas the recorded mean annual temperature is 25 degrees Centigrade and mean annual rainfall is only 816 mm (Lois, 1982). The land use map shown in Figure 8 (adapted by the author from SEA, 1985) shows that droughty soils on sloping land within this dry ecological subregion are associated with unimproved pasture and scrub derived from degeneration of xerophytic woodland. Short-cycle crops, including rice, beans and peanuts,

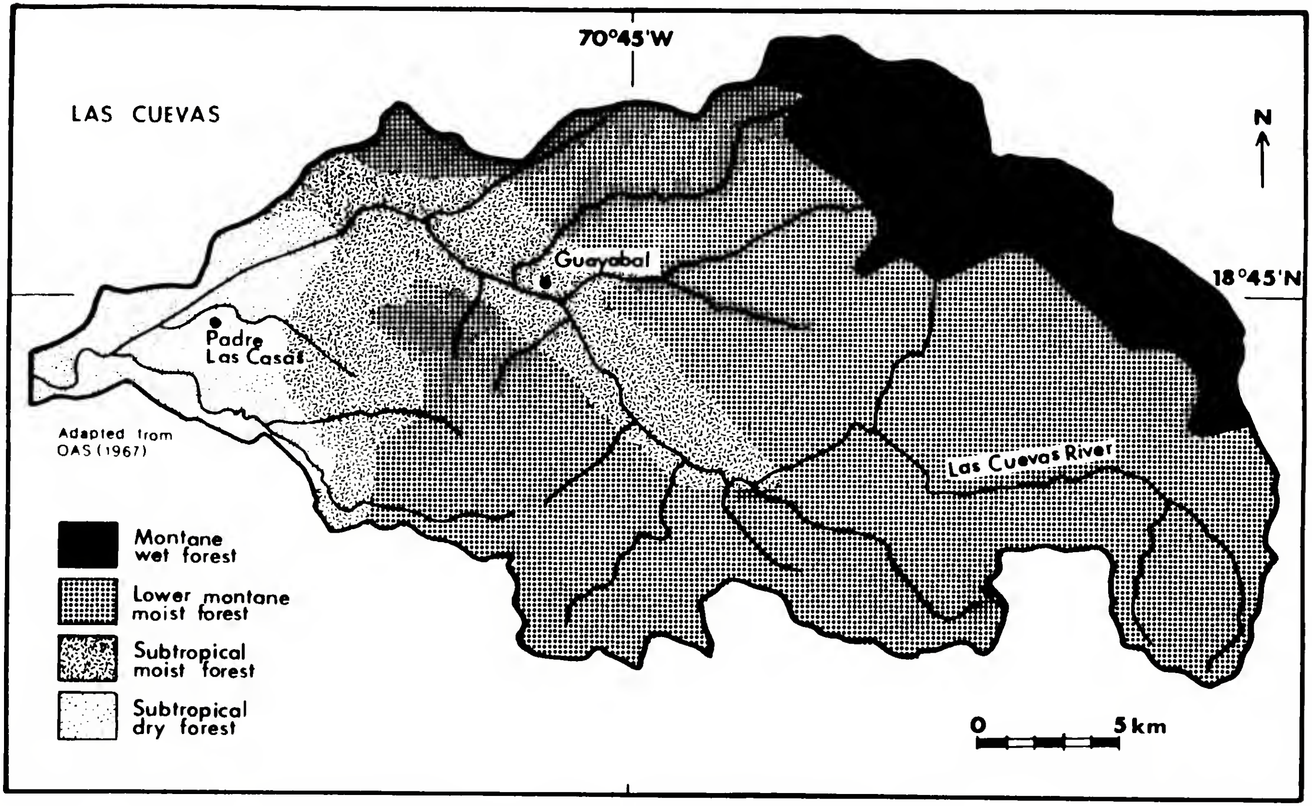

Figure 7. Life Zones of Las Cuevas Watershed

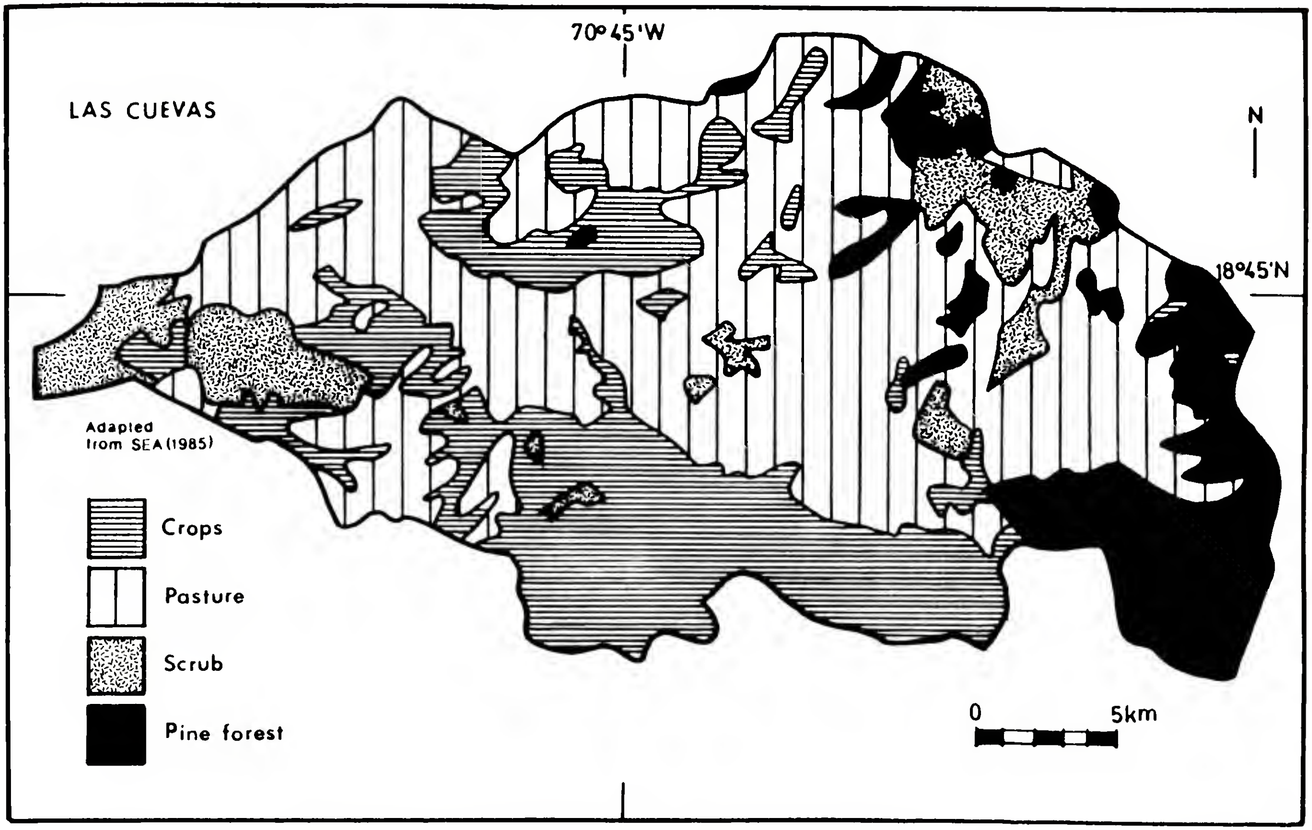

Figure 8. Land Use in Las Cuevas Watershed

however, are grown successfully with irrigation on patches of flat alluvial floodplain.

Temperature conditions in the vicinity of Monte Bonito, and upstream between La Siembra and Fruta Paloma, are somewhat cooler and potential evapotranspiration is 20 percent lower than mean annual precipitation. Although it is classified as Subtropical Moist Forest, this life zone no longer has much woodland. The trees were cleared some decades ago for fuel and agricultural purposes. Present land use consists of permanent crops at Monte Bonito, rainfed short-cycle crops between La Siembra and Guayabal, and unimproved pasture or scrub elsewhere.

Lower Montane Moist Forest and Montane Wet Forest life zones prevail in the east and cover about 70 percent of the watershed. Mean annual temperatures in these ecological subregions are between 12 and 18 degrees Centigrade and nocturnal frosts occur regularly at higher elevations during the first months of the year. The eastern sector of the watershed is appropriately called La Nevera (The Refrigerator). Mean annual rainfall is from 20 to 55 percent greater than mean annual evapotranspiration. A discontinuous cover of short-cycle and permanent crops is observed to the northeast of Guayabal at La Tina and in the southern sector between Los Piquitos and El Convento. Unimproved pasture is widespread elsewhere but higher eastern areas are mostly under scrub or pine forest.

Environmental resources of Las Cuevas were inventoried in 1982 (Antonini et al., 1985). Information collected at 350 soil survey sites confirms the low agricultural potential of the shallow steepland soils of Las Cuevas. Mean values of gradient and soil depth are 34 percent and 41 cm, respectively. Two-thirds of the sites have somewhat excessive or excessive drainage and almost one-quarter have at least 15 percent of the soil surface covered with stones. Chemical properties of the watershed's soils are more favorable than physical properties. Only six percent of the survey sites have soils with extreme acidity (< 5.6) or alkalinity (> 8.4) and the mean organic matter content of 4.5 percent is relatively high. Two-thirds of the sites have high cation exchange capacity (> 25 meq/100 gm) but no fewer than 87 percent have a low phosphate content (< 30 ppm).

Las Cuevas soils also have been photointerpreted, mapped and classified by the Dominican government (SEA, 1987a) using the soil taxonomy of the United States Department of Agriculture (USDA, 1975). Figure 9 is a simplified version compiled by the author. As expected in a steepland region, 75 percent of the watershed has poorly developed Entisols. Troporthents are predominant in the cool, humid high eastern mountains under Montane Wet Forest and Lower Montane Moist Forest life zones. The drier Subtropical Moist Forest life zone, which prevails in the middle course of Las Cuevas River, is associated with

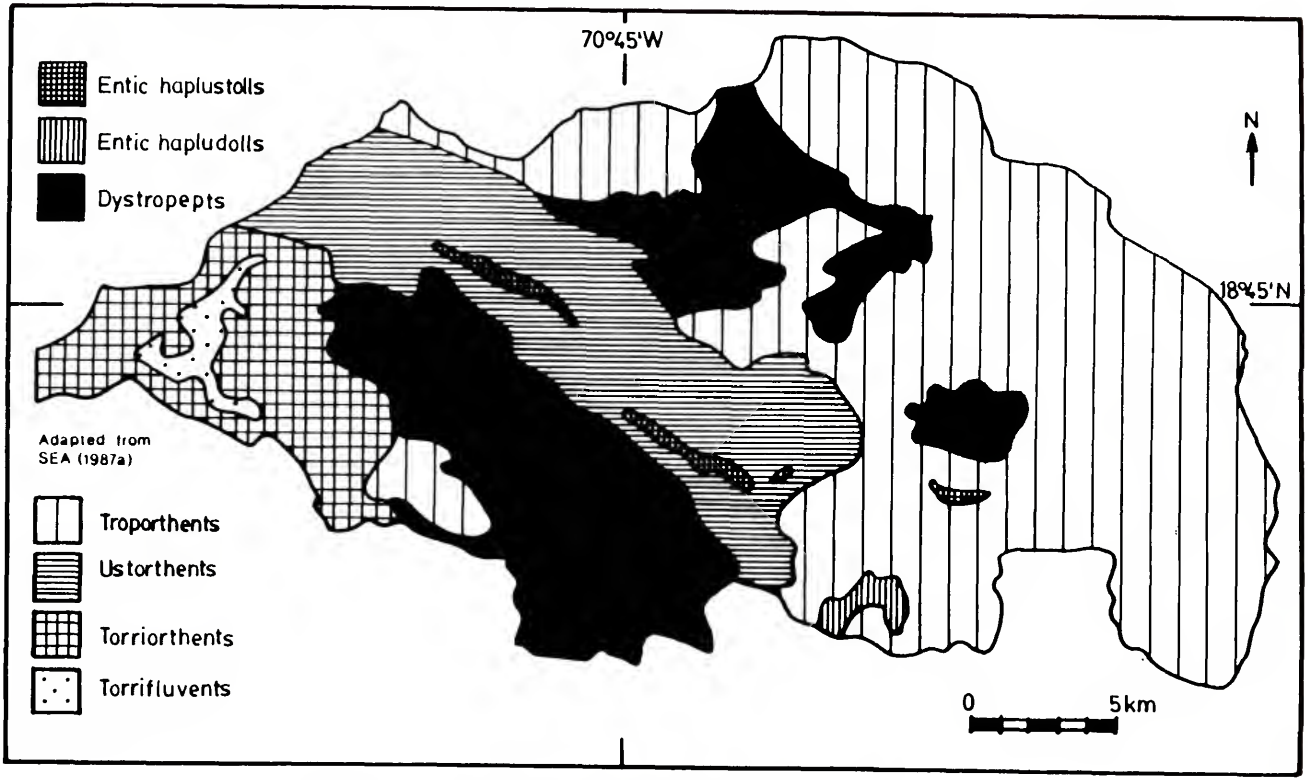

Figure 9. Soils of Las Cuevas Watershed

Ustorthents while the hot environment of the Subtropical Dry Forest has Torriorthents. To the west, the relatively extensive floodplains at Padre Las Casas and Villa Ocoa have Torrifluvents.

Volcanic soils with comparatively well-developed profiles (Dystropepts) are found in the central igneous highlands, between Monte Bonito and Naranjal, and the northeastern mountains at La Tina. Most of the area shown under crops in Figure 8 is located on these soils which cover 23 percent of the basin. The small fertile flat hollow at Sabana de San Juan has Entic Hapludolls while Entic Haplustolls have formed on narrow terraces along Las Cuevas River.

Dominican soil surveyors (SEA, 1987a) consider U.S.D.A. Land Capability ratings VII or VIII appropriate for Las Cuevas Troporthents, Ustorthents and Torriorthents (Klingebiel and Montgomery, 1961). They recommend that Troporthents and Torriorthents, which occupy 57 percent of the watershed, be dedicated almost exclusively to woodland and wildlife. Ustorthents, covering 18 percent of the basin, may be used for pasture or permanent crops in areas with lesser risk of soil erosion. Pasture and permanent crops also are recommended on the Dystropepts, which are assigned a VI rating and cover 23 percent of the area. Limited patches of gently sloping land with Hapludolls, Haplustolls and Torrifluvents belong to classes III and IV and may be cultivated with appropriate conservation techniques.

The author's field observations in the watershed suggest that the soil classification by SEA (1987a) is a reasonable characterization. The Dominican soil surveyors did not, however, build upon their abundant local data base to evaluate suitability of Las Cuevas soils for specific crops. To the contrary, they adopted an earlier independent study by Laureano Perez (1985) based on information provided by a general survey of soils in southwest Dominican Republic (SEA, 1980a). Using only two sources of critical values of factors considered limiting to crop growth, the corresponding report by SEA (1987b) simply estimates if each of 8 physiographic units in Las Cuevas is suitable or unsuitable for a series of crops. The physiographic units are differentiated principally by elevation, estimated rainfall and slope. The report concludes that many crops are limited by moisture deficiency and soil alkalinity in the west; ecologically suitable conditions for most crops were identified on scattered valley floors, benches and hilltops with gentle slopes within the more humid central and eastern parts of the watershed.

Rainfall in tropical regions such as Las Cuevas is frequently concentrated in convectional thunderstorms. Unprotected soils, therefore, are subject to severe erosion. Destruction of vegetation by hurricane winds coupled with abnormally heavy rain also causes catastrophic soil degradation in Las Cuevas watershed and other parts of the

Dominican Republic. Within the ten-day period of August 29 to September 7 of 1979, Hurricane David and Tropical Storm Frederick deposited 700 mm of rain in several parts of the nation (CEPAL, 1979). A mudflow caused by this downpour destroyed part of the village of Villa Ocoa in Las Cuevas watershed and led to substantial loss of life. Fields were being planted at the time and large areas of unprotected soil were affected. Several farmers interviewed by the author believe productivity of their fields was severely diminished by Hurricane David. Severe soil erosion in the watershed has been of particular concern to the Dominican government because Las Cuevas River is depositing large quantities of sediment in a reservoir constructed downstream from Padre Las Casas in order to generate hydroelectric power and irrigation water for the Azua Plain.

Agricultural Profile

Las Cuevas had 19,360 inhabitants in 1960. This figure increased to 31,148 by 1981 and population density was 52/square km (Lois, 1982; ONE, 1982)--less than half the population density of the nation as a whole, estimated at 115 inhabitants per square km (World Bank, 1985). Commercial activities are observed in Padre Las Casas, which has about 10,000 inhabitants, but most people in the watershed live by tilling mountain slopes. They are mulatto, Hispanic farmers who are forced to produce both subsistence and cash crops on marginal land using a fallow system which has promoted deforestation and soil erosion (Antonini et al., 1981; Alba, 1982; Lois, 1982; Espinal, 1983; Nova, 1984; Montanez, 1985). Las Cuevas is one of the most backward regions of the Republic and average household income is only two-thirds of the national average (Espinal, 1983). Malnutrition is widespread but becomes especially severe in smaller isolated villages where farmers have no access to supplementary off-farm income and are unable to acquire animals to provide milk and protein (Bruce, 1984; Cohen, 1986).

Farm size ranges widely in Las Cuevas. Nova (1984) reported that, for a systematic random sample of 182 farmers, 75 percent of the land was concentrated in only 17 farms (9 percent of the total); each of the large farms had an area of more than 400 tareas.[1] In contrast, 141 farmers (77 percent of the sample) cultivated 100 tareas or less (6 hectares or less) and occupied only 14 percent of the land. Small farmers in Las Cuevas, to earn more than the average income of landless hired workers, must cultivate more than 50 tareas (3 hectares) of land (Espinal, 1983).

Las Cuevas participates in the national economy and more than 50 percent of most crops is sold (Espinal, 1983). The principal short-cycle cash crop is beans. Rainfed agriculture predominates and beans are grown in mixed stands with other crops including pigeon peas, corn and cassava.

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[1] 16 tareas = 1 hectare

Rice is cultivated in rotation with beans or peanuts but is restricted to patches of irrigated floodplain in the vicinity of Padre Las Casas.

Coffee is the only major permanent crop grown in the watershed. It is planted together with bananas which offer shade and provide food for home consumption. Although coffee is an important cash crop, the plants are generally more than thirty years old and productivity is low (Alba, 1982). Coffee production in Las Cuevas is no more modernized than rainfed cultivation of short-cycle crops.

Vinas (1982) describes how cattle are kept by some farmers to provide emergency funds in hard times. Commercial ranching has not been considered an important activity in Las Cuevas but a comparison of 1958 aerial photography with 1982 field survey information shows that the area under pasture almost doubled during that time (Antonini et al., 1985). The SEA (1985) land use map (Figure 8) compiled from 1983 aerial photography shows pasture is more extensive than crops, scrub or forest. Tirado and Lugo-Lopez (1984) estimate that 62 percent of the basin is under pasture and believe that approximately one-third of the land grazed is vulnerable to soil erosion. Forty-one of the eighty farmers interviewed by the author in 1986 devoted part of their land to pasture and 10 farmers declared ranching to be their principal activity.

CHAPTER III
LITERATURE REVIEW

Introduction

The principal objective of this dissertation is to derive site suitability ratings for six agricultural uses in Las Cuevas watershed and to compare them to evaluations made by local farmers. It is appropriate, therefore, to review literature on scientific land evaluation and farming skills.

The first part of this chapter examines land evaluation literature. A general review is followed by summaries of literature on basic concepts and procedures; land suitability indices; and agricultural use requirements. Specific requirements for coffee, beans, pigeon peas, garlic, rice and grazing are considered because these are the six principal land uses identified by Las Cuevas farmers in the author's 1986 farmer survey.

The second part of the chapter is concerned with literature on farming skills in developing countries. Attention is given to virtues of true paleotechnic agriculture as practiced by isolated tribal groups; peasant agriculture and its devastating impact on the environment; peasant perception of soil erosion; and folk soil taxonomies. A separate subsection summarizes related literature on characteristics and skills of Dominican peasant farmers. Scientific and farmer evaluations of land suitability have been compared only in Britain; this work is described in the penultimate subsection of the chapter.

Farmers with excellent land evaluation skills may disregard land suitability when selecting their principal land uses; economic or socio-personal reasons may be more influential than environmental considerations. For this reason, the author's secondary objective is to study the Las Cuevas farmer's perception of factors which influence his choice of enterprise. The final part of this chapter, therefore, provides a brief review of literature on agricultural decision-making and, in particular, the use of point score analysis.

Scientific Land Evaluation

General Review

Literature dealing with land evaluation has been reviewed by Trudgill and Briggs (1977-82), Young (1978), McRae and Burnham (1981), Conant et al. (1983), Davidson (1986) and Nortcliff (1987). A well-known early contribution was made in the United States by Storie (1933, 1950, 1954, 1964) who assigned scores to California soils according to conditions of parent material, profile development, texture and slope and multiplied the scores to produce an overall index of land productivity. The Storie Index Rating was used to evaluate agricultural land for taxation purposes. Land ratings also were introduced sixty years ago in Germany for tax assessment and they have since become a standard productivity measure of German farms (McRae and Burnham, 1981). Similar numerical methods have been developed in the Soviet Union and East European countries for planning purposes, including an elaborate system in Rumania used to evaluate suitability of land for specific crops (Teaci and Burt, 1974).

An important American contribution at mid-century was the U.S. Department of Agriculture Land Capability Classification, an eight-tiered scheme designed mainly for farm-level evaluation (Klingebiel and Montgomery, 1961). A more extensive land systems approach was developed by the Commonwealth Scientific and Research Organization (CSIRO) and applied in Australia and Papua-New Guinea (Stewart, 1968); land systems have recurring patterns of topography, soils, vegetation and climate (Dent and Young, 1981). In the 1960s, landscape architects demonstrated the usefulness of map overlays in land evaluation (Lewis and Murray, 1964; McHarg, 1969).

Europeans made significant contributions in the 1970s. Vink (1975), building on an Institute for Land Reclamation and Improvement conference (Brinkman and Smyth, 1973), prepared a detailed manual of criteria for agricultural resource evaluation. Young (1976) and Whyte (1976) discussed tropical soil surveys and Beek (1978) compiled guidelines for land evaluation. Young and Beek also influenced a series of United Nations Food and Agriculture Organization (FAO) meetings which focused on a framework for agricultural land evaluation (FAO, 1976 and 1978).

The American Society of Agronomy, in 1979, published a benchmark study demonstrating the application of soil surveys and spatial information systems in planning (Beatty et al., 1979); the Niemann and McCarthy chapter (1979) demonstrated refinements of the traditional map overlay method using remote sensing, geo-coded information, multivariate statistical techniques and computer graphics. European developments in soil data bases and computer mapping were described by the International Soil Science Society (ISSS) Working Group on Soil Information Systems (Burrough and Bie, 1984). The focus of these papers, however, is on data storage, retrieval, manipulation and display. Detailed references to land evaluation are found only in an explanation of procedures used to estimate crop yields in Bulgaria (Sadovski, 1984) and an ambitious proposal for evaluating farmland in Turkey, involving inventory of land characteristics, classification of land utilization types, determination of crop requirements and economic analysis of inputs and outputs (Senol and Burrough, 1984). Basic principles of geographical information systems for land resource assessment were summarized subsequently in a monograph by Burrough (1986).

There were other significant contributions to land evaluation in the 1980s. Davidson (1980), Dent and Young (1981), McRae and Burnham (1981) and Olson (1981) all produced general texts. FAO continued to develop the general framework for land evaluation and produced guidelines for rainfed agriculture (FAO, 1980 and 1984). Meanwhile, a seminar at Wageningen in 1983 reviewed land evaluation procedures in the European community (Haans et al., 1984). An international workshop at Enschede followed in 1984 dealing with land evaluation in sloping areas (Siderius, 1986).

Land evaluation literature reveals current application of a great variety of methods. Mori et al. (1984) in France, for example, describe regional variations in systems for computing numerical suitability indices. In Italy, Magaldi and Ronchetti (1984) compute numerical suitability indices emphasizing climatic variables. In the United Kingdom, the Ministry of Agriculture has developed a land evaluation system based on computer-assisted superimposition of maps of climate, topography and soils (Tarran, 1984). Overall, the literature shows an increasing influence of the FAO framework for land evaluation; general concepts and current procedures in land evaluation are outlined in the following section.

Basic Concepts and Procedures in Land Evaluation

Land evaluation procedures assess suitability of land for one use or several alternative uses. Dent (1978) and Dudal (1978) argue, however, that a basic principle of scientific evaluation is that land suitability is meaningful only in relation to a specific use. Thus, for example, it is preferable to evaluate land for a specific crop than to attempt to do so for agriculture in general because environmental requirements are not exactly the same for all crops.

The majority of land evaluations are limited to an ecological assessment which determines suitability of the natural environment for a specific use. The ideal system would combine the ecological approach with an assessment of economic viability (Beek, 1978; Bie, 1984; Senol and Burrough, 1984; Davidson, 1986). Such a system could be developed by a multi-disciplinary group of scientists who might approach the problem using the framework proposed by Senol and Burrough (1984) for land evaluation in Turkey.

There is still no optimal method of ecological land evaluation and, as already shown, methods vary greatly from one place to another. Three key components are, however, emphasized by Davidson (1986). These are the choice of land use or land uses for which the land suitability will be assessed, the specification of environmental requirements for the land uses, and the selection of relevant land characteristics to be measured and analyzed.

The FAO framework for land evaluation distinguishes land qualities from land characteristics (FAO, 1976). Land qualities such as erosion risk, manageability and the availability of oxygen, water, nutrients and rooting space, are complex and difficult to measure; they are the product of climatic, geomorphic, pedological and other inter-related processes. As a result, scientists observe land characteristics which lend themselves to measurement and can be employed as a means of describing land qualities. Thus, following the example of the Universal Soil Loss Equation (Wischmeier and Smith, 1978), the land quality of erosion risk can be assessed on the basis of measurements of the land characteristics slope angle, slope length, rainfall intensity, texture, structure, organic matter and permeability. In a recent study, Gachene and Weeda (1986) describe an index used to estimate resistance to erosion of Kenyan soils on the basis of four soil characteristics--organic matter, bulk density, silt/clay ratio, flocculation of fine particles--and measures of rainfall, slope and vegetative cover. Similarly, the land quality of moisture availability may be assessed indirectly through measures of the land characteristics mean annual rainfall, evapotranspiration, slope angle, depth of water table, structure, permeability, stoniness, available water capacity, drainage and soil depth.

Certain land characteristics, as can be observed in the preceding examples, may influence more than one land quality. The FAO framework for land evaluation identifies 25 land qualities and over 100 land characteristics relevant to rainfed agriculture (FAO, 1984). FAO does not, however, provide an objective method for assessing land qualities on the basis of land characteristics. Furthermore, considerable effort is required to find in the literature land characteristic requirements for specific crops. There is no authoritative source and recommendations may vary from one text to another (Trudgill and Briggs, 1977; FAO, 1984).

Gordon (1985) describes the standard procedure of land evaluation. First, a list is prepared of land characteristics relevant to environmental requirements of the specific land use. The range of values associated with each land characteristic is classified subsequently into categories ranked according to their suitability for the land use. Maps of the land characteristics are compiled using the selected categories or, if already available, they are acquired from elsewhere. Finally, the maps are superimposed in order to identify areas with distinct combinations of land characteristics which are suitable or inappropriate.

The procedure described above has been used to evaluate land at all scales. A recent example of work in Latin America at the sub-continental level is the classification of steeplands in the northern Andes by Posner et al. (1982); the final map in that study was compiled at the scale of 1:3,125,000. In contrast, within the same geographic region, Antonini (1982) evaluated land for agriculture at the large scale of 1:50,000 within one rural municipality in the Ecuadorean Sierra. At intermediate scales, DETENAL (Direccion de Estudios del Territorio Nacional) in Mexico, and PRONAREG (Programa Nacional de Regionalizacion Agraria) in Ecuador, have been producing maps of natural resources and land use during the past fifteen years in order to evaluate agricultural land at the national level. Land has also been evaluated at the provincial or watershed level and some well-known examples in Latin America--Darien in Panama, Santiago-Mira and Guayas in Ecuador, Cibao in the Dominican Republic--are described in handbooks for such studies published by the Organization of American States (OAS, 1969 and 1984).

Many land evaluations offer no rationale to justify choices of variables and ranks (Gordon, 1985). The selection of land characteristics and ranking of their values should be explicit and based upon scientific reasoning. With the advent of the computer and the development of numerical taxonomy, attempts have been made to achieve a more objective selection of variables. Examples of the application of multivariate statistical techniques to land evaluation using cell-encoded data can be observed in studies by Gordon (1978) and Antonini et al. (1985). Multivariate techniques hold promise but they require a very high level of expertise in order to avoid misinterpretation. Furthermore, variables which explain most statistical variance in a soil data base may have little relevance to the needs of a specific crop.

Indices of Land Suitability

Land suitability index computation is a common variant of the standard land evaluation procedure which is useful for determining land suitability of specific sites, individual cells in a locational grid or specific soil taxa. The ranked categories for each land characteristic are assigned numerical values or scores according to their suitability for the land use concerned and these scores are used to compute an overall suitability index; such an index is oftentimes referred to in the literature as a parametric index (Riquier, 1974; Conant et al., 1983; Davidson, 1986) although the frequency distribution of the values of the index does not necessarily conform to a standard statistical distribution. The scores for individual land characteristics are usually combined simply by addition or multiplication although complex mathematical formulae may also be used. Weights may be applied to the scores before the final index is computed (Bartelli, 1979). Applications of parametric indices in the United States include the early work by Storie (1933, 1950, 1964) in California which was based on the multiplicative approach and research by Fenton (1975) in Iowa and Huddleston (1982, 1984) in Oregon using additive indices. Antonini et al. (1985) also used an additive index to assess the agricultural potential of tropical steeplands.

The additive approach has the advantage of simplicity. When a large number of variables is considered, however, a land characteristic with a very low score will have a relatively small impact on the overall additive index. The impact of such a low score on overall suitability is greater in a multiplicative index as would be expected in reality; the presence of one major constraint may well be sufficient to exclude a range of land use options however favorable the other variables may be (Davidson, 1986). Soil at a particular site may satisfy requirements of depth, organic matter, texture, drainage, pH and nutrients for coffee production but, if the temperature at that location is too cold, that variable alone will make the site unsuitable. Another limiting land characteristic is soil depth. Favorable conditions of slope, drainage, climate, organic matter and pH are insignificant if the soil is extremely shallow. For such variables, therefore, it is necessary to define critical values beyond which they become limiting for a specific land use. For example, soils with depth < 15 cm may be considered limiting for agriculture.

Davidson (1986) describes a relatively complex suitability index proposed by Clarke (1951, 1971) who multiplied scores of texture and depth for each soil horizon, added the products and then multiplied the sum by a drainage factor. The Clarke index correlated well with wheat yields in Britain. Complex functions, however, are rarely used for land suitability indices. Theoretical grounds for a specific complex mathematical relationship between crop response and environmental features have not yet been determined.

Dent (1978) also tested successfully a multiplicative index against yields of wetland rice in Thailand. Validation of suitability indices using yield data is unfortunately no simple task. It is difficult to obtain reliable long-term records of yields from farmers. Furthermore, crops respond not only to land characteristics but also to farm management skills, inputs and short-term vagaries in the weather (Huddleston, 1984). It follows that land suitability indices might be expected to perform more successfully when derived for crops with yields which are less dependent upon inputs. Indices also should be more viable for crops which have a long growth cycle and are less sensitive to fluctuating conditions of temperature and rainfall. They are more reliable if the crop suffers under easily defined critical levels of a small number of soil variables (Trudgill and Briggs, 1977).

Once a land suitability index is defined as a function of specific land characteristics, its application becomes straightforward, quantitative and consistent. The usefulness of an index, however, depends on care taken by the scientist when he selects relevant variables, ranks their values, assigns scores to each rank and adopts a particular mathematical function.

Interaction is a problem in the parametric approach. Thus, imperfect drainage warrants a low score in a corn suitability index if the texture is heavy but may be advantageous and worthy of a higher score in a coarse-textured soil, especially if that soil is located in an area of marginal rainfall (Sys, 1980). Certain interactions can be taken into account using subsidiary tables (Riquier, 1974) but computation becomes more complex (Young, 1976). Interaction also may be reduced somewhat using land qualities rather than land characteristics but, as already indicated, there is still no standard method for determining land qualities.

General Agricultural Use Requirements

Environmental requirements of agricultural land use may be classified into three groups (FAO, 1984). First, there are eco-physiological requirements for crop growth; a suitable site is free of toxic substances, offers substantial rooting space and provides adequate amounts of warmth, water, oxygen and nutrients. Secondly, there are soil management requirements related to the technology of the farming system; for example, a manageable soil is neither too loose nor too compact and it is relatively free of stones. Thirdly, there are conservation requirements; erosion is difficult to control if the soil is unable to absorb runoff and slopes are too steep for conservation practices (Vink, 1975).

Farming technologies exist for every climate and most crops have such a variety of cultivars that they can be grown within a wide range of mean annual temperature and rainfall. For example, maize is cultivated in areas with mean annual rainfall ranging from 300 to 4000 mm and mean annual temperature between 5 and 29 degrees Centigrade (Duke, 1978). Given sufficent capital resources, farmers are able to combat moisture deficiencies with irrigation but they have much more difficulty in supplying warmth. Consequently, crops associated with tropical regions are grown in rainfall regimes as varied as those described for maize but tend to be associated with more restricted thermal ranges. Thus, bananas are reported in areas with mean annual rainfall between 600 and 4200 mm but grow successfully only when mean annual temperature is between 16 and 29 degrees Centigrade.

A site may satisfy requirements of mean annual temperature and rainfall for a specific crop yet be unsuitable because of seasonal or short-term fluctuations in the weather at critical stages of crop development. Crops can be destroyed or harvests reduced by seasonal drought, nocturnal frost, excessive rainfall, hail or hurricane damage. In tropical steeplands, risks of such climatic hazards may vary greatly over short distances because of differences in elevation, slope and aspect. It is difficult, however, to consider microclimatic variation in land evaluation schemes in the tropics because meteorological stations are scarce and reliable long-term records of fluctuations in the weather are not available.

Given climatic conditions suitable for a specific crop, the next most significant factor controlling suitability probably is slope. Steep slopes limit cultivation because of risk of erosion and high cost of conservation practices; flat areas limit cultivation because of poor drainage.

Optimal soil conditions for high fertility differ surprisingly little for the major crops. Most prosper on deep humic soils with free drainage, loamy texture, high cation exchange capacity, slightly acid to neutral pH and a reasonable supply of macro- and micro-nutrients. Crops, however, can differ greatly with respect to tolerance of sub-optimal conditions. Demanding crops, like maize and yams, give high yields on fertile soils but their productivity diminishes rapidly as soil conditions depart from optimum levels. Hardy crops, such as finger millet, suffer less as soils deteriorate (Young, 1976).

Some crops have particular preferences which do not correspond to modal optimal soil conditions described above. For example, root crops grow more successfully on potassium-rich soils which are moderately sandy in texture while rice prefers soils with a high content of clay and silt which reduce seepage into the soil (Young, 1976; ILACO, 1981; Martin, 1984). Pigeon peas also differ from most crops because they prefer soils which are not rich in organic matter (ISA, 1971). Such special requirements and differences in sensitivity to sub-optimal conditions make multi-purpose land evaluation systems less reliable than those designed for specific crops.

Some soil properties are as limiting as climate or slope and by themselves can render a site unsuitable for cultivation. Extremely shallow soils, which offer insufficient foothold for roots, are a prime example, along with stoniness, drainage, salinity and extremely sandy texture.

Other soil properties, such as organic matter content, pH, cation exchange capacity and nutrient status do not limit cultivation by themselves but may do so collectively (Young, 1976). Land evaluation systems in developed nations place little emphasis on pH and nutrient status as modern agriculturalists are accustomed to replace leached minerals with chemical fertilizer and correct acidity with lime. Nutrient requirements, however, are significant in areas of traditional farming where cultivation is characterized by low levels of inputs and is dependent upon inherent soil fertility (McRae and Burnham, 1981; FAO, 1984). Furthermore, addition of lime to highly acid soils of the humid tropics, according to standards and procedures of temperate regions, has often done more harm than good (Committee on Tropical Soils, 1972).

Specific Agricultural Use Requirements

This section will describe environmental requirements for principal land uses identified in the author's 1986 survey of Las Cuevas farmers--coffee, beans, pigeon peas, rice, garlic and pasture.

Coffee. The principal species of cultivated coffee are arabica (coffea arabica), robusta (coffea canephora/coffea robusta Linden) and liberica (coffea liberica). Although many requirements discussed below apply to all three species, attention is focussed on arabica which is considered to have the best flavor, accounts for 75 percent of world exports (van der Vossen, 1985) and is predominant in the Dominican Republic.

The U.S.D.A. Plant Genetics and Germplasm Institute has received reports of coffee cultivated in areas with mean annual temperature ranging from 16 to 27 degrees Centigrade (Duke, 1978). High temperatures, however, inhibit growth of arabica because net photosynthesis begins to decrease. The literature suggests that mean annual temperatures > 24 degrees Centigrade are not suitable (Ochse et al., 1961; Alvim and Kozlowski, 1977; Willson, 1985a).

Optimum mean annual rainfall is between 1250 and 2000 mm (Coste, 1955-61; ISA, 1971; Alvim and Kozlowski, 1977; ILACO, 1981; Willson, 1985a). Shade, mist and deep soil can compensate for low rainfall (Wellman, 1961). At the other extreme, coffee can withstand excessive rainfall but it is highly susceptible to stagnant ground water and poorly drained soils should be avoided (Wellman, 1961; ISA, 1971; Young, 1976; Willson, 1985a).

The value of natural soil fertility for sustained high coffee yields is stressed by Young (1976) and Opeke (1982). Most specialists point out the significance of humus in coffee soils (Mohr, 1944; Moss, 1956; Haarer, 1958; Wellman, 1961; Young, 1976; ILACO, 1981; Willson, 1985b). Organic matter, not only provides nitrogen and other nutrients, but, improves the capacity of the soil to retain moisture. Morgan (1979) believes that soils with an organic matter content < 2 percent are generally vulnerable to erosion.

Coffee can be cultivated over a wide range of soil pH but prevailing opinion is that soils should be acid. Optimum pH has not been precisely determined but most literature refers to values between 4.2 and 6.5 (Coste, 1955-61; Moss, 1956; Ochse et al., 1961; Wellman, 1961; ILACO, 1981). The range 5.0-6.5 is recommended by ISA

(1971) for coffee in the Dominican Republic. Poor performance of coffee at high pH levels may be related to iron deficiency (Williams, 1975). Coffee has not been observed on soils with pH > 8.0 (Duke, 1978).

Coffee requires well-drained loamy-textured conditions with sufficient moisture retention during dry periods. For this reason, coarse-textured soils and clays are undesirable (Coste 1955-61; Moss, 1956; Haarer, 1958; Wellman, 1961; Ochse et al. (1961); Young, 1976; Opeke, 1982; Willson, 1985a). Abundant stones may reduce the soil's ability to retain moisture (Young, 1976; Willson, 1985a).

The significance of humus in fertility of coffee soils already has been pointed out. Indeed, for most crops in the tropics it is the decline in organic matter and its supply of nitrogen which most likely gives rise to declining yields (Committee on Tropical Soils, 1972). Potassium also is considered a key nutrient for coffee (Coste 1955-61; Moss, 1956; Wellman, 1961; Malavolta et al., 1962). Most Dominican Republic soils are rich in potassium (ISA, 1971), but agronomists in Las Cuevas watershed recommend its application in local fields. Phosphate is not required in large amounts by coffee (Willson, 1985b) but Las Cuevas soils are characterized by low levels of phosphate and it is also included in local fertilizer. Calcium and magnesium deficiencies are rarely observed in coffee soils (Malavolta et al., 1962; Willson, 1985b). ISA (1971) recommends application of fertilizer twice a year in Dominican coffee plantations. It is important for the soil to have sufficient cation exchange capacity to hold added nutrients (Young, 1976).

Coffee absorbs most of its nutrients through fine roots in the top 30 cm of the soil profile (Willson, 1985b) but the plant has roots which can descend to 3 m to tap moisture (Moss, 1956). Most specialists stress, therefore, the importance of deep soils in coffee production (Quintiliano, 1951; Coste, 1955-61; Haarer, 1958; Wellman, 1961; Williams, 1975; Young, 1976; ILACO, 1981; Willson, 1985a). Williams (1975) recommends soils which are > 1 m in depth while Young (1976) considers preferable more than 180 cm of soil; such soils, however, are not easy to find in tropical steeplands.

Stringent conservation guidelines of developed nations cannot be adopted in densely populated tropical steeplands without denying many small farmers their only access to available land. FAO (1977) and Morgan (1979) refer to Sheng's (1972) marginal steepland classification for the humid tropics which permits all crops on slopes < 27 percent. A wide variety of crops may be produced on slopes between 27 and 36 percent although short-cycle crops should be grown together with semi-perennial crops; it is difficult to use animals or tractors on these slopes and cultivation must be done by hand (Muchena, 1979). Slopes between 37 and 65 percent should be dedicated to tree crops although these may be combined with other crops on gradients of up to 42 percent. Within all of these slope classes, Sheng assumes that the farmer will use appropriate methods of soil conservation, especially terracing. Steep land with slopes > 65 percent should be reserved for forest. Coffee can be cultivated on slopes of up to 65 percent according to this classification scheme. While it is sensible to reserve flat and gently sloping land for short-cycle crops, these areas are also ideal for coffee as long as there is good drainage (Young, 1976; Opeke, 1982). Coffee plantations on steeper slopes are less accessible and require more costly conservation practices.

Beans. Climatic requirements of beans (phaseolus vulgaris) are flexible (Duke, 1978). Beans are reported in areas with mean annual temperature of 5 to 28 degrees Centigrade and are associated with mean annual rainfall of 300 to 4600 mm. Most tropical varieties grow well from sea level to 1950 m elevation (Tindall, 1983). Very humid areas with no dry periods are unsuitable for beans because they favor development of plant diseases which lower productivity (Martin, 1984). On the other hand, beans are not resistant to drought (Young, 1976). Even a relatively short dry period may cause a substantial loss if it occurs in a critical phase of the growing season.

Beans have the ability to fix atmospheric nitrogen but are not as efficient as many other legumes; they still require additional nitrogen from organic matter and fertilizer (Tindall, 1983). High quantities of phosphorus are required and this is the principal ingredient of fertilizer recommended by ISA (1971) for cultivation of beans in the Dominican Republic. Fertilization is more effective when the soil has sufficient cation exchange capacity to hold added nutrients (Young, 1976).

Soils used for beans should be relatively deep (ISA, 1971), loamy (SEA, 1976a), well-drained (Tindall, 1983; Martin, 1984) and have sufficient aeration to avoid root and stem sicknesses (ISA, 1971). Moderately heavy loams are acceptable as long as they are well-drained (Tindall, 1983). Sandy soils tend to be too droughty in dry climates and moisture retention is reduced by excessive stoniness (Young, 1976).

Beans are grown in soils with pH varying from 4.2 to 8.7 (Duke, 1978); the literature suggests a range of 5.5 to 7.0 is optimal. Lower pH values are associated with reduced activity of Rhizobium nitrogen-fixing bacteria and, when pH < 5.2, there can be toxicity of manganese (Tindall, 1983).

Sheng (1972) recommends short-cycle crops such as beans on gradients of up to 27 percent. Given conditions of free drainage, however, it is preferable to cultivate these crops on slopes of 0-12 percent which require less expensive conservation practices. Short-cycle crops may be produced within agroforestry systems on slopes > 27 percent; they may be grown together with semi-perennials on 28 to 36 percent slopes and are permissible with tree crops on 37 to 42 percent slopes.

Pigeon Peas. Pigeon peas (cajanus cajan) are associated with varied moisture regimes. They have a long main root and resist drought (Tindall, 1983) while some cultivars are adapted to wet climates as long as the soil is well-drained (Young, 1976; Martin, 1984). Mean annual rainfall, therefore, may be as low as 300 mm or as high as 4000 mm (Duke, 1978). Cool climates, however, are not suitable and pigeon peas have not been reported in areas with mean annual temperature $<$ 15 degrees Centigrade (Duke, 1978). Low to moderate elevations are preferred (ISA, 1971; Martin, 1984) and Tindall (1983) points out that pigeon peas produce well at altitudes of up to 1500 m.

Soils with very heavy texture are unfavorable. Like other legumes, pigeon peas require well-aerated conditions which will promote fixation of atmospheric nitrogen (Yamaguchi, 1983). The soil should be deep and permeable but a high level of fertility is not required (Tindall, 1983). Experiments with pigeon peas in Dominican Republic and Puerto Rico have demonstrated that it is not worth applying fertilizer to the crop (ISA, 1971). It is even suggested by ISA that pigeon peas prefer soil which is not rich in organic matter.

Pigeon peas grow on soils with pH from 4.3 to 8.4 (Duke, 1978), but conditions are most suitable between 5.6 and 7.3 and, within that range, they are optimal from 5.6 to 6.5 (Tindall, 1983; Yamaguchi, 1983). Like beans and other legumes, pigeon peas do not grow well under strongly acid (pH < 5.6) conditions or on soils with pH > 7.3.

Pigeon peas have a longer growth cycle than beans. While beans can be harvested in less than three months, pigeon peas do not begin to yield until after 140 days and the harvest continues for several months (Tindall, 1983). Pigeon peas, therefore, do not promote as much soil erosion as beans but tillage is still involved and, in agreement with Sheng's classification of slopes for agriculture in tropical steeplands, they should be restricted to slopes of < 42 percent (Sheng, 1972). Pigeon peas should be incorporated into agroforestry systems on gradients of 28-42 percent. As long as there is free drainage, it is preferable to cultivate them on slopes of 0-12 percent which are less vulnerable to erosion and facilitate tasks of clearance, planting, weeding and harvest. Farming operations also are made easier when the soil is relatively free of stones.

Garlic. Garlic (allium sativum L.) is grown under a variety of climatic conditions; mean annual temperature may range from 6 to 27 degrees Centigrade (Duke, 1978). Very warm conditions are not recommended, however, and garlic bulbs do not form properly in the intense heat of tropical lowlands (Yamaguchi, 1983). Tindall (1983) believes that growing conditions are unsuitable in areas with elevation less than 500 m. It is difficult to determine an upper altitudinal limit for garlic cultivation. Tindall (1983) believes that conditions are only suitable up to 2000 m and Yamaguchi (1983) points out that garlic bulbs tend to be small and rough at high elevations in the tropics. On the other hand, ISA (1971) states that garlic prefers cold conditions in the Dominican Republic.

Garlic has been reported under cultivation in areas with mean annual rainfall ranging from 300 to 2600 mm (Duke, 1978). While this precipitation range is remarkable, it is much more restricted than ranges reported for other crops, most of which have been grown in areas with mean annual rainfall > 4000 mm. Tindall (1983) points out that excessive humidity and rainfall are detrimental to both vegetative growth and bulb formation; he indicates that garlic is normally grown in drier areas with irrigation being applied whenever necessary during the initial stage of the growth cycle.

Soil depth is a critical land characteristic for garlic and Yamaguchi (1983) recommends at least 45 to 60 cm of soil for satisfactory results. Another prerequisite is free drainage; thus, heavy soils should be avoided. Garlic bulbs also tend to be malformed in soils with heavy or very heavy textures (Tindall, 1983). Medium textures are ideal but loose light-textured soils also are suitable provided there is sufficient moisture available from precipitation or irrigation.

In contrast with pigeon peas, garlic demands fertile soil. High contents of organic matter are desirable (ISA, 1971) and deficiencies of nutrients must be made up with fertilizer, especially nitrogen and phosphorus (Yamaguchi, 1983). Fertilization is more effective if the soil has a high cation exchange capacity and is able to retain added nutrients (Young, 1976).

Garlic has never been reported grown on soils with pH below 4.5 or above 8.3 (Duke, 1978). Strongly acid conditions (pH < 5.6) are not tolerated very well (ISA, 1971). Moderate acidity (5.6-6.0) is acceptable while slightly acid (6.1-6.8) conditions are ideal (ISA, 1971). Neutral reactions (6.9-7.3) also are acceptable but productivity is affected by alkalinity (7.4-8.3).

Production of all vegetables, including garlic, involves intensive soil use. Gentle slopes are preferred and, in agreement with Sheng (1972), these crops should never be grown on gradients of more than 42 percent. It is also advantageous to have stone-free soils.

Rice. Wetland rice (oryza sativa) has been reported in areas with mean annual temperature ranging from 9 to 29 degrees Centigrade (Duke, 1978). Mean annual rainfall associated with rice also varies from 500 to 4200 mm but this is less surprising because the crop is cultivated in irrigated paddies. The necessity of irrigation makes slope requirements particularly demanding and gradients > 8 percent are generally considered unsuitable (ISA, 1971; Dent, 1978). Ideal conditions for wetland rice are found on slopes < 2 percent.

Rice differs from the majority of crops in its preference for poor drainage (Young, 1976). Excessively drained paddy soils are undesirable because they require too much water to be practicable (Williams, 1975). Some drainage is necessary, however, to prevent excessive reduction of the soil and very poor drainage is less suitable than poor or imperfect drainage (Williams, 1975; Dent, 1978). Another unusual requirement of rice is its preference for soils with heavy texture which reduce seepage of water (ILACO, 1981; Martin, 1984).

Paddy construction and maintenance also is facilitated by soil which is deep and free of stones; Dent (1978) recommends profiles > 40 cm for rice cultivation. Fertile soils are advantageous and rice benefits from high levels of organic matter, cation exchange capacity and added nutrients, including potassium and phosphorus (Dent, 1978). Rice may be cultivated on soils with pH between 3.5 and 8.5 (Williams, 1975) but optimal conditions of pH appear to be between 5.0 and 6.5 (ISA, 1971; Dent, 1978), especially in the initial stages of the growth cycle.

Grazing. Most pasture in Las Cuevas is unimproved. Environmental requirements of natural grasslands are unknown but they are generally adapted to infertile soils, periods of moisture stress and even abuse from overgrazing. Exotic tropical forages introduced from other parts of the world permit higher densities of cattle per hectare but their maintenance demands costly inputs. It would appear, therefore, that beef and dairy production of tropical steeplands must be improved mainly through development of systems which maximize natural grasslands and species which are best adapted to the environment (Mott and Popenoe, 1977).

Natural grasses are less dependent upon soil fertility than crops; therefore, several fundamental soil characteristics, e.g. organic matter content, cation exchange capacity, available phosphate, drainage, texture and pH (Young, 1976; ILACO, 1981), need not be considered in site evaluation. Mobility of livestock also makes grazing relatively independent of local variations in temperature and rainfall; altitudinal migration brings comfort to animals in periods of excess heat or cold and they can be taken to a source of water when rainfall becomes scarce in a specific area.

Grazing, however, promotes soil erosion (Vink, 1975) and land suitability can be evaluated on the basis of slope and soil depth. Gentle slopes and deep soils are preferable for pasture although land which satisfies these conditions is also in demand for cropping. Another relevant variable is stoniness (Young, 1976). Grass cover may be rendered discontinuous by abundant stones. In addition, livestock may lose their balance and come to harm on stony land.

Farming Skills in Developing Countries

Paleotechnic Farming Skills

Modern agricultural techniques have had limited success in raising small farm productivity in tropical steeplands (Stamp, 1977; Stevens, 1977; Staatz and Eicher, 1984; Chambers, 1985). Required chemical inputs are too costly and monoculture of exotic high-yielding varieties in tropical areas without irrigation, fertilizer or pesticides is both unreliable and conducive to soil degradation (Dickenson et al., 1983). This failure suggests that rural development projects should no longer attempt to replace paleotechnic agriculture with the neotechnic approach. Effective development can be achieved if planners recognize and build upon the knowledge and unique skills of traditional farmers (de Souza and Porter, 1974; Morss et al., 1976; Hawkes, 1978; Barlett, 1980; Ruddle and Rondinelli, 1983; Cummings, Jr., 1986).

Advantages of traditional polyculture have been described by Dickenson III (1972), Igbozurike (1978), Belshaw (1980), Ruthenberg (1980), Denevan (1981), Altieri

(1983), Dickenson et al. (1983), Goodland et al. (1984), Stocking (1986) and Tull (1987). It has no need of imported fossil fuels to drive machinery. There is no soil compaction by tractors. Its intensive use of labor is appropriate because developing countries offer limited alternative sources of employment. The mixture of crops in each field simulates the diversity of local ecosystems and reduces risk of total crop failure due to weeds, pests or disease. The environment is not polluted with pesticides (Pimentel, 1978; Lal, 1986a). Specific cultivars are closely adapted to local environments and their immense variety represents an invaluable gene bank (Cherret and Sager, 1977; Chrispeels and Sadava, 1977; Rindos, 1984; Rigg, 1985).

Polyculture also allows the farmer to use space in his field more efficiently and raise total food production in his fields. Some social scientists argue that small farms in developing countries can produce more per hectare than large farms (Feder, 1971; Griffin, 1976; Brown and Eckholm, 1977; Brown, 1978; Berry and Cline, 1979; Thiesenhusen, 1979; Johnston and Clark, 1982; Berry, 1984; Bradley, 1986). In addition, when smaller crops are planted between large crops, the leaf canopy is both stratified and extensive and offers more protection to soil from the erosive impact of raindrops and runoff than row crops associated with monoculture (Greenland and Lal, 1977).

While knowledge systems of paleotechnic farmers must not be idealized, they present invaluable guidelines for planners who wish to promote rural development in any part of the world (Brokensha et al., 1980; Altieri, 1983; Dickenson et al., 1983; Weinstock, 1984; Aubert, 1985; Chambers, 1985; McNeely and Pitt, 1985; Blaikie and Brookfield, 1987; Tull, 1987). Neotechnic procedures should be critically reviewed in the light of the accumulated experience of traditional farmers and attempts made to develop alternative farming systems which combine the ecological rationality of paleotechnic agriculture with the high productivity of modern agribusiness (Harwood, 1979; Baquer et al., 1979). Experiments with agroforestry systems based on combined production of a variety of crops and woody perennials, minimum tillage, mulches, legumes and green manures offer promise and can take advantage of experiences in both developed and developing countries (Myers, 1984; Lal, 1976, 1977a, 1977b, 1986a; Smith, 1985; Young, 1986; Nair, 1987).

Peasant Agriculture and Environmental Degradation

Although paleotechnic agriculture is distinguished by its rational use of natural resources, many agricultural regions in the Latin American tropics are paradoxically afflicted by severe environmental degradation. True paleotechnic cultivation is associated mainly with dwindling indigenous or tribal groups which are ethnically and culturally distinct from the majority of the population, live in relative isolation within the forest, cultivate principally for subsistence and do not participate in the market economy (Goodland, 1982). They have cultivated their territories for millenia without destroying the forest environment. Most Latin American farmers, however, are peasants who belong to the world economic system and make use of both traditional and modern farming techniques (Denevan, 1981); their ability to cultivate in harmony with the environment has been affected by forces beyond their control.

Some peasants are as ethnically unique as tribal groups but do not live in isolation. An example of these assimilated indigenous peasants are Andean Indians who retain certain traditional techniques but no longer display the remarkable engineering skills of their pre-Columbian ancestors who constructed sophisticated systems of irrigated terraces and raised fields (Ryder, 1970; Knapp and Ryder, 1982). They have become de-skilled during centuries of exploitation by an alien culture (Baker, 1984) and their fields are subject to severe soil degradation.

Other peasants are Hispanic in culture but they are equally poor. Like Andean Indians, they are victims of an unequal distribution of prime agricultural land and are obliged to occupy arid or steepland areas which are of little value for cultivation (Eckholm, 1976; de Janvry and Garramon, 1977; Barraclough, 1978; Brown, 1978; FAO, 1979; Plumwood and Routley, 1982; Baker, 1984; Ashby, 1985; George, 1985; Grindle, 1986). The marginal land is too populated to permit conservation of soil fertility using lengthy fallow periods, and the peasants do not have resources required to obtain the inputs of neotechnic agriculture. As a result, productivity is low, the peasants are compelled to mine the soil to survive and they cause severe soil erosion.

Some peasants in marginal areas resort to outmigration in search of land. They are ecological refugees who follow the soil downslope and colonize newly accessible tropical forests (Eckholm, 1976; Brown, 1978). Not to be confused with tribal shifting cultivators, these pioneers or "shifted" cultivators (Myers, 1984) are unfamiliar with tropical forest environments and cause enormous devastation within a few years (Goodland, 1982).

Peasant Perception of Soil Erosion

Few studies probe whether peasants in marginal areas are aware of soil erosion on their land and the negative impact of such practices as plowing on steep slopes, burning crop residues and leaving soil exposed to wind and rainfall. Blaikie (1985) points out that early FAO reports put these practices down to ignorance (FAO, 1960, 1965, 1966).

Conflicting views of scientists on the subject are revealed by Blaikie and Brookfield (1987). Thus, extensive field observations have led Hudson (1981) to believe that small farmers are unaware of soil loss, while studies in Tanzania (Berry and Townshend, 1972), Nepal (Johnson et al., 1982) and West Africa (Richards, 1985) report conclusive evidence of farmer perception of soil erosion.

Hallsworth (1986), in a recent study of farmers from several developing nations, concludes that farmers are almost always aware of declining productivity on their land but few associate the decline with soil erosion. Blaikie's work in Morocco, Zambia, India and Nepal reflects the uncertainty of the literature and suggests that some farmers are perceptive of environmental decline while others seem to be totally unaware of the process. Montanez (1985) demonstrated that Las Cuevas farmers consider erosion a threat only when it has reached a critical stage with formation of gullies and severe soil loss.

Pearson and Pryor (1978) and Blaut (1984) suggest that farmer perception is not a key factor in explaining why soil erosion occurs in developing countries. Aware of erosion or not, marginalized peasants must continue to mine the soil unless there are political and economic changes which will provide them with secure access to good agricultural land, credit, technical assistance, marketing facilities and communications. To consider only the individual decision-maker is to ignore forces at large which promote rural poverty and make the individual migrate into marginal areas; these forces include unjust distribution of land and national policies which help agribusinesses to export cash crops but suppress prices of foodstuffs produced by peasants in order to pacify urban pressure groups (Chou et al., 1977; Brown, 1978; Feder, 1980; Preston, 1980; Tobis, 1980; Blaikie, 1985). For this reason, conservation projects limited to promoting peasant awareness and diffusing conservation technology are doomed to failure. Poor farmers cannot be expected to participate in long-term plans to protect steepland soils without assistance in satisfying immediate requirements of food and fuel (Eckholm, 1976).

Folk Soil Taxonomies

Although there have been few attempts to judge farmer awareness of soil erosion, there are a number of studies of the farmer's cognition and classification of soil types. Differences in soil quality have been recognized by human groups since the beginnings of agriculture and are still part of traditional knowledge used by many contemporary agriculturalists (Conant et al., 1983; Nortcliff, 1987). Related research is inspired by ethnoecologists and cultural ecologists who study the environment as perceived by specific human groups (Fowler, 1977; Hardesty, 1977); this literature deals principally with folk taxonomies of tribal groups. Allan (1965) demonstrated the expertise of the African shifting cultivator who can identify hundreds of plants and rate fertility of land on the basis of natural vegetation and physical soil characteristics. Other examples of African folk soil taxonomy are found in studies of the Nyiha (Knight, 1974) in Tanzania and the Yoruba (Osunade, 1988) in Nigeria. Rutz (1977) has described how the Waimaro of Fiji locate crops according to conditions of soil color, texture, drainage and fertility while Conklin's classic study of the Hanunoo in the Philippines reveals their remarkable knowledge of 1600 different plants and acute understanding of crop requirements (Conklin, 1957).

Studies of Latin American folk soil taxonomy are scarce. Johnson (1980) examined the way Brazilian shifting cultivators select specific sites for manioc, beans, cotton, squash and potatoes. They locate crops according to moisture and fertility status which depend on time since clearance of the natural vegetation. Ashby (1985) shows how Colombian Cauca mountain farmers refer to black soil, red soil and soil which is mixed in color. These soils, however, are degradational stages of one soil type. Black soil corresponds to the complete soil profile with a dark humic A horizon; red soil owes its color to the clayey subsoil which is exposed by erosion. Mixed color soil represents the intermediate stage of erosion in which remaining black topsoil is mixed with subsoil as fields are cultivated.

Ashby implies that farmers are aware of the erosive process but are unconcerned because they cultivate cassava for a local processing plant and red soil is considered suitable for that crop. Farmer awareness of the ability of cassava to grow well on depleted soil is confirmed by Cock (1985) in his study of the Campa Indians of Peru.

Williams and Ortiz-Solorio (1981) stress the need for further investigation of ethnopedology in Latin America. They reviewed 130 ethnographic studies of Hispanic and Indian communities in Middle America and found only six which devote more than one paragraph to aspects of folk soil nomenclature and classification. The properties most commonly used by Middle Americans for identifying soil types are color and texture which are tangible and reflect qualities of great significance for agriculture. "Tierra negra" is a term which refers to the black coloring of the soil but its use by farmers also may imply good moisture retention, workability and fertility. Other internal characteristics used to describe soils in certain parts of Middle America are consistency, salts and parent materials such as "tepetate". Some ethnographic research examined by Williams and Ortiz-Solorio refers to soils which are identified by external features. For example, shifting cultivators in southern Mexico and Guatemala classify soils according to associated vegetative cover. In some ethnographic studies, soils are classified using climatic and geomorphological terms such as "tierra caliente" or "tierra de ladera" but these terms may be coined by the investigator rather than the farmer.

Williams and Ortiz-Solorio also compared the folk classification of soils in the vicinity of a Mexican village with a scientific classification of the same soils using the Comprehensive Soil Classification System (USDA, 1975). There was little correspondence between soil classes defined under the two systems. Peasants classify soils according to spatial variation in surface soil while scientists perceive soil in three dimensions and place emphasis on presence or absence of diagnostic soil horizons.

Dominican Peasant Farmers

Several studies of the Dominican Republic help place its peasant agriculture in the context of paleotechnic farming and environmental degradation in the developing world. The nation is almost completely inhabited, the indigenous population has been eliminated and there are no isolated groups living in harmony with the natural environment. Most Dominican farmers are peasants who produce crops both for subsistence and cash. They are predominantly mulatto and speak Spanish (Black, 1986). The 1971 Dominican Agricultural Census revealed that < 2 percent of the farms possess one-half of the agricultural land; 75 percent of the farms must make do with only 15 percent of the tilled land

(Vargas, 1982; Black, 1986). This unequal land distribution was almost identical in 1950 (Blume, 1974).

Legislation exists to hasten agrarian reform but wealthy land-owners have influenced the government and assured that only token reformist attempts are made (Cedeno Jimenez, 1975; Dore y Cabral, 1982). What little land has been redistributed to peasants is generally of poor quality and there has been no provision of needed technical and financial assistance (Black, 1986). While much fertile land on large farms is devoted to plantations or pasture, in order to produce sugar and meat for export (Dore y Cabral, 1982; Black, 1986), food production on small farms for domestic consumption is insufficient and the nation frequently has to import beans, rice, edible oils, wheat and other commodities (SEA, 1976b; Vargas, 1982; Vicens, 1982).

Six decades ago, Durland (1922) reported that the Dominican Republic was quite different from deforested Puerto Rico because it still had a sparsely populated interior covered with luxuriant mountain vegetation; 75 percent of the country was covered with forest. He pointed out, however, a threat of deforestation by peasants who had cleared large woodland areas near San Jose de Ocoa.

Destruction of woodland for lumber, fuel and agriculture reduced forest cover to 11 percent by the 1960s (Rodriguez Liriano and Ovalle de Morel, 1982). Deforestation continues to be one of the most serious problems of the Dominican Republic (FAO, 1979; USAID, 1981; Graham and Edwards, 1984; Tirado and Lugo-Lopez, 1984; Lugo and Brown, 1985). Peasant invasion of steeplands is blamed on population growth and expansion of large estates which occupy a greater proportion of the lowlands and employ cheap seasonal Haitian labor (West and Augelli, 1966).

Population density in the Dominican steeplands is too high to allow rational paleotechnic shifting cultivation with fallows of sufficient duration to regenerate soil fertility. On the other hand, Dominican peasants are unable to acquire inputs associated with neotechnic production (Sharpe, 1977). The introduction of new varieties of beans has not raised production because small farmers cannot fertilize their fields (INESPRE, 1983). Fertilizer and irrigation are associated only with large farms, principally sugar and rice plantations (Aquino Gonzalez, 1978; Dore y Cabral, 1982; Vicens, 1982). As a result, soil erosion is widespread, productivity has fallen and reservoirs constructed for hydro-electric power and irrigation are being filled with sediments (Vicens, 1982).

There are no more agricultural frontiers to be put under the plow (Vargas, 1982) and many peasants are fleeing the poverty of the steeplands to look for alternative employment in cities or abroad (Bell, 1981; Wiarda and Kryzanek, 1982). In 1960, 30 percent of the population lived in urban areas (Black, 1986); by 1980, this proportion had increased to 51 percent and it is projected to reach 66 percent by the year 2000 (Graham and Edwards, 1984). More than 800,000 Dominicans already have emigrated to the United States (Black, 1986).

The knowledge which Dominican farmers have of soil types and their potential for agriculture has not been determined. Dominican peasants have occupied the mountains only during the last 60 years and they are unlike tribal groups in other countries who draw upon centuries of local environmental experience passed on from generation to generation. While shifting cultivation may have been practised some time ago when the population was smaller, contemporary Dominican agriculture corresponds to the fallow system (Ruthenberg, 1980). Length of fallow is too short for regeneration of forest, and soil organic matter is not sufficiently restored by fallow vegetation of bush or grass. Dwellings are permanent and, although fencing is not widespread, holdings are clearly defined. The approach to cultivation is basically paleotechnic and polyculture is more common than monoculture. Without a long fallow, however, the soil is mined and falling productivity lowers the farmer's self-esteem and makes him desire inputs associated with neotechnic production, especially fertilizer and irrigation.

While poverty prevails in steepland regions of the Dominican Republic, some inhabitants have less than others.

Sharpe (1977), in a community study of the Central Cordillera, distinguishes four social strata. Ten percent of the farmers are virtually landless. They may participate in share-cropping but most depend on selling their labor on a daily basis to make ends meet. They live a precarious day-to-day existence and are permanently in debt. About 55 percent of the farmers are small-holders who have sufficient land to satisfy some of the family's food demands and occasionally may sell part of their crop. Small-holders must also sell their labor to supplement income and are severely affected by any crisis in health or natural hazards, such as droughts or hurricanes. Twenty percent of the farmers have middle-sized holdings. This group is able to complement short-cycle production with some coffee or livestock and does not depend on sale of labor. Life is still a struggle for these farmers but they have access to loans. Large land-holders constitute 15 percent of the population and they are able to diversify and produce short-cycle crops, coffee and cattle. They still need loans but can invest in more land, animals, new coffee trees or a small business and they educate their children.

Although population in the Dominican steeplands is not homogeneous, it appears that socioeconomic status has little bearing on environmental perception. Montanez (1985) discovered that farmer perception of soil erosion and the need for conservation in Las Cuevas is not related to age, education or farm size. A study of 10,000 farmers in various developing countries organized by the "Save our Soils" project (Hallsworth, 1986) similarly showed that extent of erosion on the farm and farmer awareness of declining fertility are unrelated to farm area, family size or literacy.

Dominican farmers, therefore, can be compared to many other Latin American peasants. They are mostly poverty-stricken, Hispanic farmers who use a mixture of paleotechnic and neotechnic methods and produce both subsistence and cash crops. They have been obliged to occupy marginal, overpopulated steeplands, which, because of population pressure, cannot remain in long-term fallow. At the same time, they have insufficient resources to acquire modern inputs. As a result, their activities have led to very severe deforestation and soil erosion.

Scientific Land Evaluations and Assessments by Farmers

Many farmers experiment with different crops. This empirical experience of trial and error has allowed them to make a direct evaluation of the suitability of their land for specific agricultural uses. Even literate farmers in developed nations make little or no use of soil survey maps; while this is largely the result of ignorance of the existence of such maps (Fisher et al., 1986), it can be argued that farmers are more knowledgeable of their soils than the surveyor (Dent and Young, 1981).

Scientists concerned with indirect methods of land evaluation, based on inferred significance of site characteristics, should go into the field, communicate with farmers and take advantage of their empirical knowledge to verify results obtained in the laboratory (Buringh, 1986; Siderius, 1986). Crop yields can be used for verification but reliable long-term records are difficult to obtain and the scientist must determine the relative impact of site characteristics, farm management practices and vagaries in the weather (Huddleston, 1984).

Two studies in Britain have compared scientific site evaluations to assessments made by farmers. Davidson (1976) derived a capability index based on soils and slopes of 81 farms in northeastern Scotland and compared results to farmers' opinions of their land. Farmers on good land had conflicting opinions about its capability; while one farmer might consider a slope too steep for plowing and sowing grass, another possessing land with the same slope would believe its use for improved pasture posed no threat of erosion. Farmers with poor land had an over-optimistic view of its capability.

Fisher et al. (1986) asked a sample of 100 farmers in the Welsh Marches to assess the overall capability of their fields. The fields also were rated by the farmers according to soil workability, soil droughtiness, suitability for grassland and suitability for drilling of combine-harvested crops. The farmers' ratings subsequently were compared to those specified by the Soil Survey of England and Wales. Only 58 percent of the fields were placed in exactly the same overall capability class by farmer and soil surveyor but there was a general overall correlation between the ratings. On the other hand, 38 percent of the farmers under-rated the soil's workability while 58 percent over-estimated suitability of the land for grassland. Bias towards grassland and the pessimistic view of workability and arable farming reflect local use of the land which traditionally has been dominated by livestock and dairy production. There is a tendency for the farmer to rank soil better than it actually is for familiar uses and to downgrade its suitability for less familiar activities.

Agricultural Decision-Making Factors

In an ecologically rational agricultural system farmers would select and locate all of their land uses according to environmental requirements. The real world is complex, however, and crop selection is a function of both natural and cultural factors. A secondary objective of this study is to study the Las Cuevas farmer's perception of factors which influence selection of enterprise.

Techniques for studying agricultural decision-making have been reviewed by Ilbery (1978 and 1985a) and Hart (1980). Several mathematical models are used to examine decision-making processes in a farm environment of risk and uncertainty; game theory (Gould, 1963; Agrawal and Heady, 1968), and linear programming (Howes, 1967; Low, 1974) are associated with this approach. An alternative strategy is to study farmers' perceptions of factors affecting their decisions; examples of this approach include the application of repertory grids (Floyd, 1979; Ilbery and Hornby, 1983), decision trees (Gladwin, 1980) and point score analysis (Gasson, 1973; Ilbery, 1977, 1979, 1983a, 1983b and 1985b). Many studies of perception have failed to relate attitudes to observed patterns of behavior and development of general theory has been slow (Bunting and Guelke, 1979). Ilbery (1985a) points out, however, that difficulties have also been encountered in the search for mathematical models which will provide realistic explanations of agricultural use patterns; the farmer's decision environment, comprising information which is available to the decision-maker, is often quite different from the extended environment assumed by most mathematical models and is affected by the farmer's perceptions (Found, 1971). Empirical behavioral studies take into account a wide range of decision-making factors, including socio-personal aspects, and Ilbery (1985a) argues that they have provided valuable insights into the farmer's decision-making process.

Point score analysis was incorporated into the author's 1986 survey of Las Cuevas farmers. In this procedure, decision-making factors are assigned a point score by each interviewed farmer according to his perception of their significance in his choice of enterprise; the sum of scores assigned to each factor by all farmers under study is considered a measure of its relative importance in the decision-making process. Point score analysis has not been applied in the Third World and it is useful to test its applicability in that context. An advantage of point score analysis is that the farmer is not required to provide detailed information on income, farm size, yields and other sensitive issues. The farmer is encouraged to express his points of view on environmental, economic and socio-personal aspects to the scientist and, as a result, point score analysis promotes the cross-cultural communication which is increasingly recommended by international development specialists (de Souza and Porter, 1974; Morss et al., 1976; Dickenson et al., 1983; Blaikie and Brookfield, 1987).

Table 1 is a list of decision-making factors considered significant in British agriculture and Table 2 shows their relative importance as perceived by 127 hop farmers and 205 horticulturalists (Ilbery, 1983b, 1984 and 1985b). It is clear that perceived significance of decision-making factors varies according to type of farming practiced. For example, skilled labor supply was ranked in fifth place by hop farmers but occupied one of the lowest positions in the list of decision-making factors ranked by horticulturalists.

TABLE 1

Decision-Making Factors in British Agriculture

(A) SOCIO-PERSONAL FACTORS

(1) Personal preference.	(2) Area tradition.
(3) Agricultural training.	(4) Personal experience.
(5) Free time.	(6) Family tradition.

(B) ECONOMIC FACTORS

(1) Market/demand.	(2) Regular income.
(3) Skilled labor supply.	(4) Available capital.
(5) Transport costs.	(6) Buildings/machinery.
(7) Size of farm.	(8) Low levels of risk.
(9) Government policy.	

(C) PHYSICAL FACTORS

(1) Distance to market.	(2) Soil type.
(3) Drainage.	(4) Rainfall.
(5) Frosts.	(6) Temperature.
(7) Height of water table.	(8) Volume of water supply.
(9) Shelter.	(10) Slope.

Sources: Ilbery (1983b and 1985b)

TABLE 2

Rankings of Decision-Making Factors by British Hop Farmers and Horticulturalists

Rank	Hop Farmers	Horticulturalists
1.	Buildings/machinery.	Experience.
2.	Market/demand.	Drainage.
3.	Drainage.	Personal preference.
4.	Soil type.	Soil type.
5.	Skilled labor.	Water supply.
6.	Available capital.	Temperature.
7.	Experience.	Available capital.
8.	Regular income.	Rainfall.
9.	Hop disease.	Frosts.
10.	Shelter.	Size of farm.
11.	Personal preference.	Transport costs.
12.	Rainfall.	Regular income.
13.	Water-table height.	Market/demand.
14.	Water supply.	Distance to market.
15.	Temperature.	Slope.
16.	Area tradition.	Shelter.
17.	Slope.	Low risk.
18.	Family tradition.	Area tradition.
19.	Frosts.	Water-table height.
20.	Training.	Government policy.
21.	Size of farm.	Family tradition.
22.	Free time.	Grower cooperatives.
23.	Low risk.	Skilled labor.
24.	Distance to market.	Training.
25.	------------	Free time.

Sources: Ilbery (1983b and 1985b)

Experience and personal preference are ranked very highly by horticulturalists but the other socio-personal factors--area and family traditions, training, free time--are relatively unimportant. The only socio-personal attribute included among the ten factors considered most important by hop farmers was experience. Economic aspects are much more influential in hop-growing; infrastructure, demand, skilled labor, capital and income are all included among the ten most influential decision-making factors.

Horticulturalists place special emphasis on physical features which occupy six of the ten highest ranks. Drainage and soil type, however, are perceived as being very important by both groups of farmers.

CHAPTER IV
METHODOLOGY

Introduction

The principal objective of this study is to use scientific knowledge to derive site suitability ratings for six agricultural uses in Las Cuevas watershed and to compare the results to site evaluations formulated by local farmers on the basis of their empirical knowledge. The secondary objective is to examine the farmer's perception of factors which influence choice of principal enterprise and to determine the relative importance of environmental factors in that decision.

The first part of this chapter describes three data sets used to achieve the aforementioned objectives:

1. The 1982 soil survey: geo-coded information collected at 350 sites in Las Cuevas by the Dominican State Secretariat for Agriculture (SEA) according to a spatially random sampling design stipulated by researchers at the University of Florida (Antonini et al., 1985). These data are used by the author to compute site suitability ratings.
2. The 1984 farmer survey: characteristics of 211 Las Cuevas farmers interviewed by Montanez (1985). These

data are used to determine if the author's 1986 farmer survey is representative. The data also are used to derive an index of farming technology.

3. The 1986 farmer survey: 80 farmers interviewed by the author to obtain farmers' opinions of site suitability for comparison with scientific suitability ratings. The survey also provided data for examining farmer perception of decision-making factors.

The second section of this chapter is a brief comparison of selected characteristics of farmers sampled in the 1984 and 1986 surveys. It shows that there is no significant difference in farmer residences, farmer age, farmer education, farm ownership or farm fragmentation.

The third section of the chapter is a discussion of the scoring system devised by the author for site suitability analysis in Las Cuevas watershed. Ranked suitability classes of land characteristics are assigned scores in such a way that resultant land suitability index values range from 0 to 1 on a simple conceptual scale of site productivity. The scale facilitates conversion of numerical index values into four ordinal site suitability ratings--very good, good, mediocre and bad.

The final section describes point score analysis which is used to study farmer perception of the relative importance of decision-making factors in choice of principal enterprise.

Data

The 1982 soil survey

The author computed site suitability ratings using data collected in 1982 by Dominican soil scientists who applied a sampling design devised by Antonini et al. (1985). A two-stage sampling procedure was adopted in the soil survey. First, a map of the watershed was covered by a grid containing 2312 cells with dimension 0.5 x 0.5 km. A random selection was made of 15 percent, or 350, of the cells; this sample was stratified according to the areas of the six geomorphic subregions described in Chapter II. Secondly, each chosen cell was subdivided into 25 sites of 100 x 100 m of which one was selected at random for field investigation. Field surveyors were allowed to repeat the selection of the 100 x 100 m site if they considered the initial selection atypical of the 0.5 x 0.5 km cell. Figure 10 shows the spatial distribution of soil survey sites. Soils were described in the field and samples were collected for laboratory analysis in the Dominican Republic and at the University of Florida.

The 1984 farmer survey

Data collected in a 1984 survey of 211 farmers in Las Cuevas (Montanez, 1985) also were analyzed to show that the author's 1986 sample of 80 farmers is representative of the watershed's farmers in fundamental characteristics. The

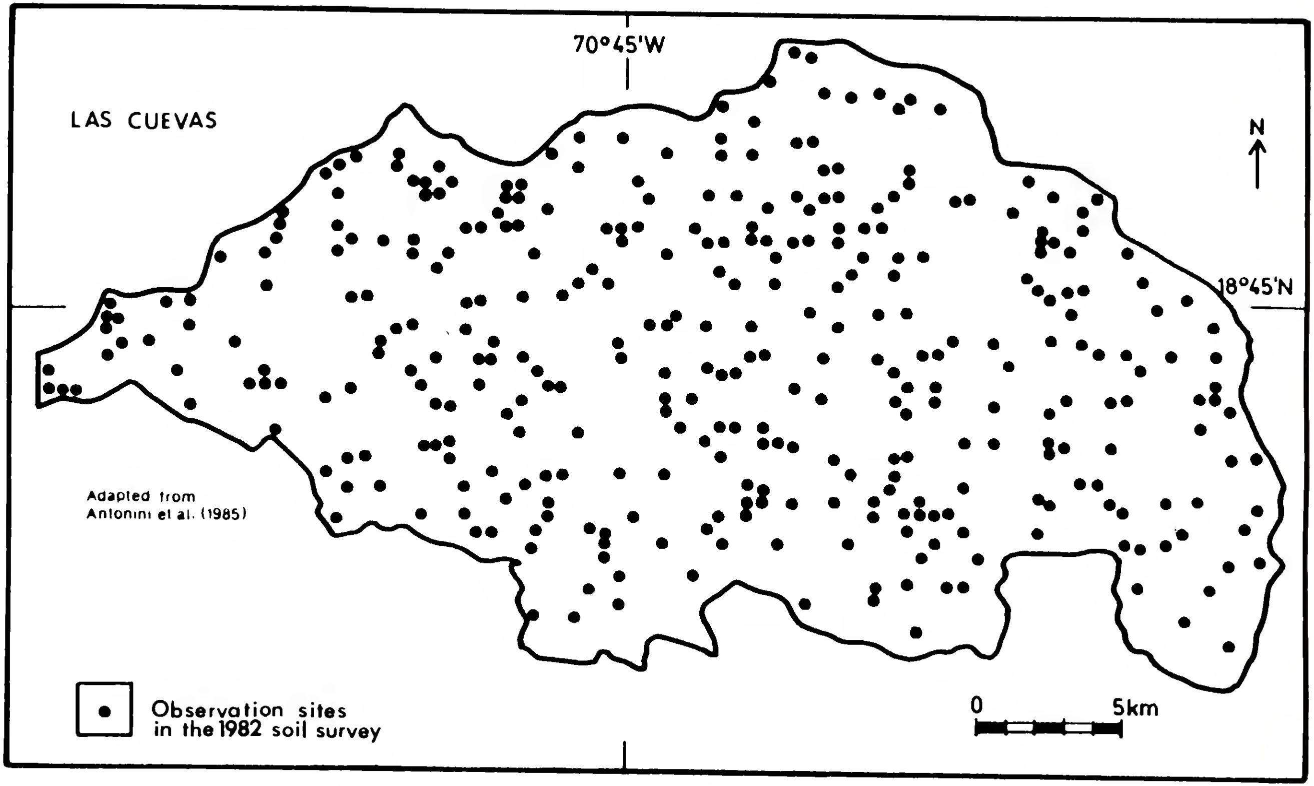

Figure 10. 1982 Soil Survey Sites in Las Cuevas (Antonini et al., 1985)

1984 sample was extracted in a random manner from a list of 2154 farms registered in the Dominican Cadastral Office. Montanez visited each of the selected farms and obtained information on farmer characteristics, technological inputs, land use and yields; he also investigated farmer perception of soil erosion. Figure 11 illustrates the location of the main parcel of each farm. The sampled farms are concentrated in the western and central parts of the watershed because there is limited agricultural development in the high eastern mountains.

The 1986 farmer survey

The principal objective of the author's research was to build upon the valuable geo-coded environmental data base established by Antonini et al. (1985), compute suitability ratings with soil survey site information and compare the ratings to local farmers' opinions.

Farmer skills are founded on empirical experience. The author decided, therefore, to ask Las Cuevas farmers to evaluate only a subset of soil survey sites under active agricultural use including crops, pasture and recent fallow. Opinions on the agricultural potentials of land under woodland and scrub may be speculative rather than the result of trial and error. The subset of 80 sites was selected in the field using a three-step procedure involving (1) prior restriction of the study area, (2) field inspection of land use, and (3) interviews with farmers.

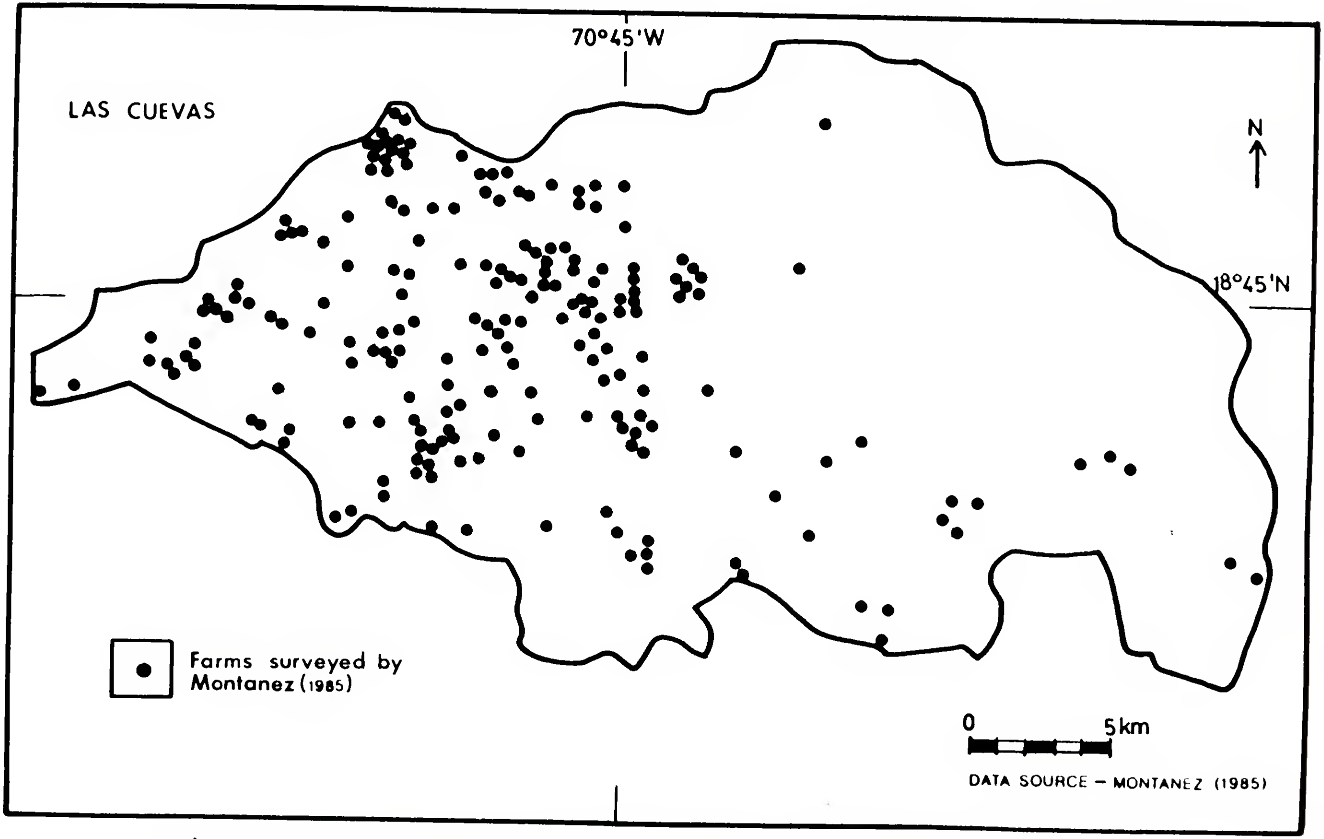

Figure 11. Las Cuevas Farms Surveyed in 1984 by Montanez (1985)

Initial reduction of the study area. 1982 soil survey records show that cropping is unimportant in the high eastern mountains. Limited agricultural development in the east is confirmed by local guides. It is also evident in the land use map prepared from airphoto imagery by SEA in 1985 (see Figure 8 in Chapter II). As a result, the author decided to limit his field inspection to 224 survey sites located in the four geomorphic regions of the western and central watershed--the alluvial floodplain, the low western hills, the central igneous highlands and the maturely dissected uplands--and at La Tina in the northeastern mountains. Remaining sites in the high eastern mountains were not considered.

Field inspection of land use. The 224 western and central soil survey sites were located on topographic maps, scale 1:50,000, using coordinates corresponding to 0.5 x 0.5 km cells and 100 x 100 m sites. The sites were identified subsequently in the field, to observe current use and to determine present ownership, using contours, stream networks, trails and other cultural map features. Distinguishable environmental site characteristics-- slope, drainage, erosion, stoniness, soil depth--were compared to those recorded in the 1982 soil survey in order to confirm site identification. Local farmers served as field guides and aided in determining ownership patterns. A total of 99 sites belonging to 80 farmers were found to be dedicated to crops, fallow or pasture. Figure 12 shows their spatial distribution.

Interviews with farmers. Once located, each of the 80 farmers was interviewed using the questionnaire in Appendix A which was pre-tested with the assistance of 4 farmers in Padre Las Casas recommended by SEA officials. It includes questions on farm and farmer characteristics but places emphasis on factors perceived important in choice of principal enterprise; environmental characteristics considered significant in that enterprise; and the farmer's evaluation of land suitability at the soil survey site located on his land. Farmers with land containing more than one survey site evaluated only the site which they considered of most importance to their livelihood. As a result, farmers' opinions of site suitability were recorded for 80 soil survey sites.

Comparison of 1984 and 1986 Farmer Surveys

Soil survey sites belonging to farmers interviewed in 1986 are located in the central and western watershed (see Figure 12). The farmers' residences, however, are clustered along the Padre Las Casas-Guayabal road. Table 3 shows that 59 percent of the farmers live in the immediate vicinities of Padre Las Casas or Guayabal, the two largest villages of the basin. An additional 13 percent of the interviewees live

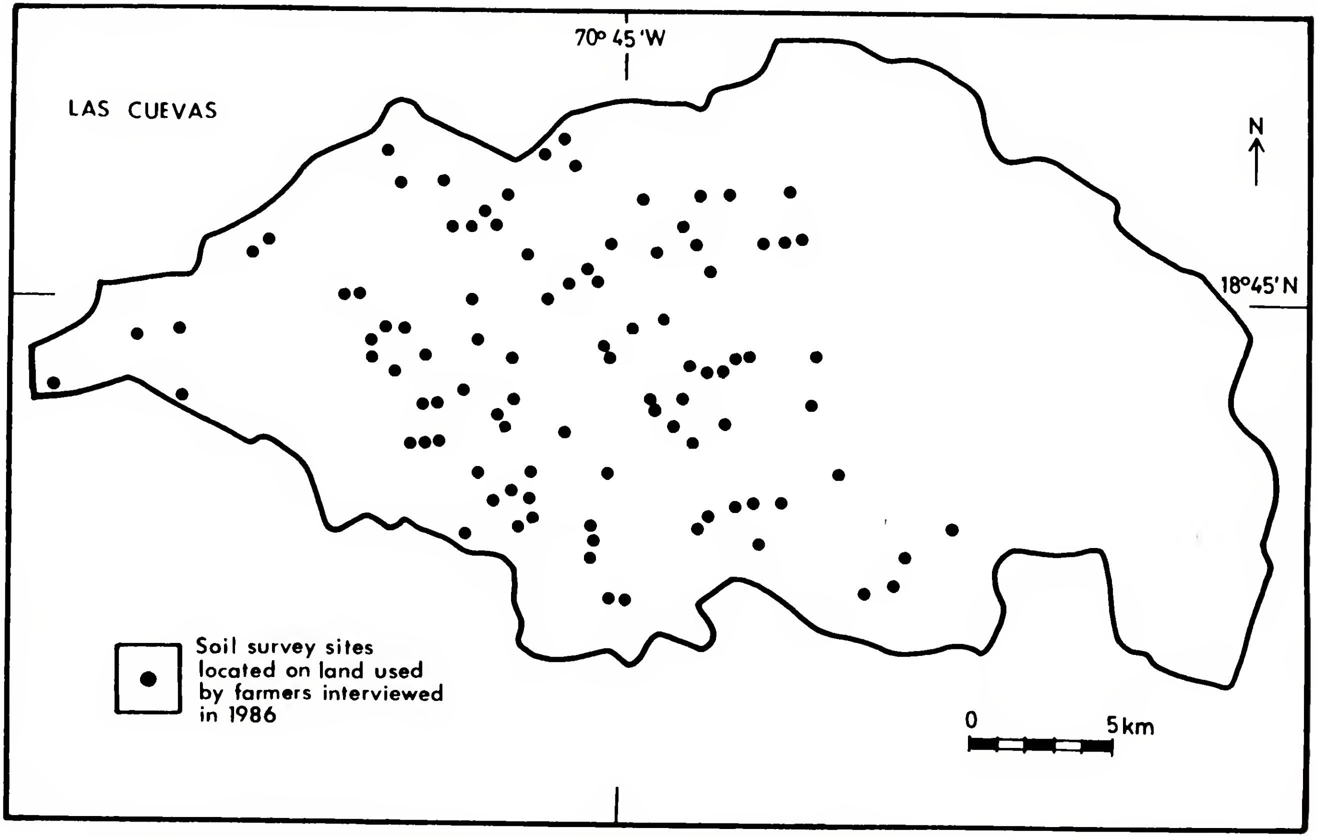

Figure 12. 99 Soil Survey Sites Belonging to 80 Farmers Interviewed in 1986

TABLE 3

Residences of Farmers Surveyed in 1984 and 1986

Residence	1986 Survey (sample: 80 farms)		1984 Survey (sample: 211 farms)	
	No. farmers	Percent	No. farmers	Percent
Vicinity of Padre Las Casas*	19	24	46	22
Vicinity of Guayabal**	28	35	66	31
Communities on Padre Las Casas-Guayabal road ***	10	12	28	13
Elsewhere in the watershed	23	29	71	34
Total	80	100	211	100

* includes Villa Ocoa and Los Indios
** includes La Coja and Arroyo Corozo
*** includes Las Lagunas, La Siembra, El Desecho, Periquito and Los Naranjos.

Null hypothesis: No significant difference.
Alternative hypothesis: Significant difference.
a = 0.80, df = 3
Critical value of chi-square statistic = 1.005
Computed value of chi-square statistic = 0.793 < 1.005
Cannot reject null hypothesis.

Data sources: 1984 survey - Montanez (1985).
1986 survey - the author.

in smaller communities located along the roadway--Las Lagunas, La Siembra, El Desecho, Periquito and Los Naranjos.

The third column of Table 3 shows that farmers surveyed by Montanez in 1984 also reside mainly in Padre Las Casas, Guayabal or along the connecting road. The similarity of the spatial distributions described in Table 3 can be examined using the chi-square test of statistical association. The chi-square statistic of 0.793 is so low that the null hypothesis of no significant difference cannot be rejected even at the 20 percent level of confidence.[1] It can be assumed, therefore, that the spatial distribution of farmer residences does not vary significantly from one sample to the other.

The author processed additional information from the 1984 farmer survey to determine if his 1986 sample is representative of Las Cuevas farmers. Comparative frequency distributions of farmer age, farmer education, farmer ownership and farm fragmentation are tabulated in Appendix B. The similarity of the two samples is confirmed for all the above variables by chi-square statistics with values so low (2.69, 0.23, 0.03 and 2.24 respectively) that the null hypothesis of no significant difference cannot be rejected

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[1] The author wishes to demonstrate that there is no significant difference between the two spatial distributions of residences. This objective is supported by the null hypothesis. As a result, the chi-square test becomes more rigorous at a low level of confidence (20 percent; a = 0.80) which favors rejection of the null hypothesis.

when a = 0.40. Farmer age, farmer education and farm fragmentation, expressed as ordinal variables, also can be examined using the Kolmogorov-Smirnov test (Siegel, 1956). In all cases, the value of the corresponding D statistic (0.09, 0.02 and 0.05 respectively) is low and, as with the chi-square test, the hypothesis cannot be rejected with a = 0.40.

Preceding comments demonstrate that the farmers interviewed in 1986 are similar to those surveyed in 1984. It can be concluded, therefore, that the sample of 1986 is representative of Las Cuevas farmers in certain fundamental characteristics. However, it must be taken into account that the surveys of 1984 and 1986 are both directed towards land owners and virtually ignore landless peasants who till the land as day-laborers. The 1984 sample was extracted from a list of registered landowners and, in the 1986 survey, the author interviewed the managers--normally owners--of randomly located sites. The 1984 sample includes a relatively large number of small farmers because they are dominant in the Cadastral Register (see Table 4). In contrast, as the 1986 survey was derived from a spatial pattern of soil survey sites, this sample favors the selection of middle-sized and large land-holdings (Phillips et al., 1980); the author's land-based survey places more emphasis, therefore, on the decision-makers who determine the greater part of the land cover of the watershed.

TABLE 4

Farm Size in 1984 and 1986

Declared Farm Area (tareas)	1986 Survey (sample: 80 farms)	1984 Survey (sample: 211 farms)
	Percent	Percent
<250	34	60
250-750	32	17
751-5000	28	12
>5000	6	11
Total	100	100

Data sources: 1984 survey - Montanez (1985).
1986 survey - the author.

Site Suitability Analysis

The procedure adopted for deriving site suitability ratings in Las Cuevas consists of eight steps:

1. Identification of relevant land uses.
2. Identification of environmental requirements
3. Choice of site characteristics for the suitability analysis.
4. Classification of ranges of values of site characteristics.
5. Choice of a scale for the numerical suitability index.
6. Choice of appropriate mathematical model.
7. Definition of scores for ranked categories of site characteristics.
8. Computation of the index and conversion to suitability ratings.
9. Cartography of ratings.

Identification of relevant land uses. The author analyzed site suitability for coffee, beans, pigeon peas, garlic, rice and grazing because these were the land uses of sites evaluated by Las Cuevas farmers in the author's 1986 survey.

Identification of environmental requirements. The author identified specific environmental requirements for each of the six selected land uses in the scientific literature reviewed in Chapter III.

Choice of site characteristics. The choice of site characteristics for deriving suitability ratings was guided by the literature review of environmental requirements and conditioned by data collected in the 1982 soil survey (Antonini et al., 1985). Information on slope and most relevant soil characteristics was available. Climatic data were not available but elevation was used as a crude surrogate for temperature regime.

Classification of ranges of values. Ordinal classes of suitability of site characteristics were defined for each land use as shown in Chapter V on the basis of literature reviewed in Chapter III. Altitudinal preferences of crops are not well-known; as a result, elevation was classified dichotomously as very good or severe. Values of other site characteristics were assigned to five ranked classes--very good, good, mediocre, bad, severe. A site characteristic classified as bad for a specific land use has a negative impact on yields but it cannot by itself make a site bad; it may lead to a bad site suitability rating only when it acts collectively with other land characteristics with bad rankings. On the other hand, a limiting site characteristic classified as severe is by itself capable of making a site bad for a specific use.

Choice of scale. The author's method of site suitability analysis departs from others by incorporating a procedure which assigns scores to ranked categories of site characteristics according to a simple conceptual scale of productivity (see Table 5); this procedure facilitates conversion of numerical suitability index values to ordinal suitability ratings which can be compared subsequently to farmers' opinions.

The numerical site suitability index S may be considered a percentage of maximum productivity with optimum value 1.00 and minimum value 0.00. Thus, when all site characteristics used to derive the index are classified as very good for a specific use, the site being evaluated should produce the maximum yield expected for a given farming system and the value of S will be 1.00. It is assumed that unmeasured environmental requirements are also very good.

Given the multiplicity of site characteristics affecting productivity, few sites can be expected to provide optimum yields. Let it be assumed that farmers consider yields from 90 percent (0.90) to 100 percent (1.00) of the optimum as very good. Let it also be assumed that farmers consider yields good if between 0.70 and 0.90 of the optimum, mediocre between 0.50 and 0.70, and bad when < 0.50. These hypothetical values are shown in Table 5 and constitute the conceptual scale of productivity.

<u>Choice of mathematical model</u>. Scores for ranked site characteristics are usually combined simply by addition or

TABLE 5

Scale of Values for Suitability Index S

SUITABILITY RATINGS	INDEX VALUES
	1.00 (optimum value)
VERY GOOD	
	0.90
GOOD	
	0.70
MEDIOCRE	
	0.50
BAD	
	0.00 (minimum value)

multiplication. The author adopted the latter approach because, as pointed out in Chapter III, the multiplicative model allows limiting variables to have a major impact on the final outcome whenever they have unfavorable values and represent a severe constraint to production. Table 6 illustrates the model.

Definition of scores. As shown in Table 5, optimum productivity is represented by a value of 1.00 on the scale. The multiplicative suitability index model in Table 6 will only have a value of 1.00 when the score assigned to each site characteristic is 1.00; this score, therefore, must be assigned to site characteristics which are classified as very good.

Elevation is classified simply as very good or severe while other site characteristics are classified as very good, good, mediocre, bad or severe. When elevation is worthy of a very good suitability ranking with a score of 1.00 and the remaining (n-1) site characteristics are classified as good, the product of their scores should be 0.80, the midpoint of the class which corresponds to good yields (0.70-0.90). It follows that, when the value of a site characteristic is classified as good for a specific land use, an appropriate numerical score for computation of the site suitability index is the (n-1)th root of 0.80. Similarly, as yields which are from 0.50 to 0.70 of the optimum are mediocre, the appropriate score for a site

TABLE 6

The Site Suitability Index

$$S_i = \prod_{j=1}^{n} X_{ij}$$

where S_i = the suitability of land at site i for a given land use.

n = the total number of land characteristics used to compute S_i.

X_{ij} = the score assigned to the jth land characteristic at site i according to its suitability for the given land use.

$\prod_{j=1}^{n} X_{ij}$ = the product of scores assigned to land characteristics at site i.

characteristic with a mediocre suitability rating is the (n-1)th root of the midpoint of this class (0.60). The equivalent score for a site characteristic with a bad suitability rating is the (n-1)th root of 0.25, the midpoint of the category corresponding to bad yields (0.00 to 0.50 of the optimum). A limiting site characteristic classified as severe, by itself, is capable of making yields bad even if all other land characteristics are considered very good; the appropriate numerical score in this case is 0.25.

The coffee suitability index is derived from scores assigned to 10 land characteristics including elevation. Therefore, the appropriate scores for land characteristics classified as good, mediocre and bad are the 9th roots of the midpoints of these classes, i.e. 0.9756 (good), 0.9449 (mediocre), and 0.8573 (bad). Table 7 shows a specific application of this scoring system.

Site suitability indices for beans, rice and garlic also are derived using elevation and nine additional site characteristics. Thus, the numerical scores assigned to ranked classes for computing the site suitability index for coffee are appropriate too for beans, garlic and rice. Table 8 illustrates how the scores are used to compute site suitability for rice.

The site suitability index for pigeon peas is derived from values of elevation and seven other site characteristics. For pigeon peas, therefore, it is necessary

TABLE 7

Computation of Site Suitability Index for Coffee

Class	Very Good	Good	Mediocre	Bad	Unsuitable
Scores	1.0000	0.9756	0.9449	0.8573	0.2500

Example of computation (soil survey site #123):

Land Characteristic	Value	Rank	Score
Elevation (m)	1330	Very good	1.0000
Slope (percent)	45	Bad	0.8573
Soil depth (cm)	30	Mediocre	0.9449
Stoniness (percent)	0.1-2.9	Good	0.9756
Drainage	Well-drained	Very good	1.0000
Texture	Medium	Very good	1.0000
Reaction (pH)	7.20	Mediocre	0.9449
Organic matter (percent)	3.34	Mediocre	0.9449
Cation exchange capacity (meq/100 gm)	16.1	Mediocre	0.9449
Avail. phosphate (ppm)	10.0	Mediocre	0.9449

Suitability index = 1.0000 x 0.8573 x 0.9449 x 0.9756
x 1.0000 x 1.0000 x 0.9449
x 0.9449 x 0.9449 x 0.9449
= 0.6299

The index value of 0.6299 falls within the range of 0.50-0.70 which corresponds to MEDIOCRE suitability.

Data source: Antonini et al. (1985).

TABLE 8

Computation of Site Suitability Index for Rice

Class	Very Good	Good	Mediocre	Bad	Unsuitable
Scores	1.0000	0.9756	0.9449	0.8573	0.2500

Example of computation (soil survey site #123):

Land Characteristic	Value	Rank	Score
Elevation (m)	1330	Very good	1.0000
Slope (percent)	45	Severe	0.2500
Soil depth (cm)	30	Bad	0.8573
Stoniness (percent)	0.1-2.9	Good	0.9756
Drainage	Well-drained	Mediocre	0.9449
Texture	Medium	Mediocre	0.9449
Reaction (pH)	7.20	Good	0.9756
Organic matter (percent)	3.34	Mediocre	0.9449
Cation exchange capacity (meq/100 gm)	16.1	Mediocre	0.9449
Avail. phosphate (ppm)	10.0	Mediocre	0.9449

Suitability index = 1.0000 x 0.2500 x 0.8573 x 0.9756
x 0.9449 x 0.9449 x 0.9756
x 0.9449 x 0.9449 x 0.9449
= 0.1537

The index value of 0.1537 falls within the range of 0.00-0.50 which corresponds to BAD suitability.

Data source: Antonini et al. (1985).

to obtain the seventh root of the midpoints of the yields categories. The resultant numerical scores for pigeon peas are 1.0000 (very good), 0.9687 (good), 0.9297 (mediocre), 0.8204 (bad) and 0.25 (severe); Table 9 illustrates their application.

Site suitability for grazing is calculated using only three site characteristics. Elevation is not considered. Numerical scores to be assigned to ranked categories of these land characteristics are obtained from the third root of the midpoints of the yields categories. The scores are 1.00 (very good), 0.9284 (good), 0.8435 (mediocre), 0.6300 (bad) and 0.2500 (severe). Table 10 demonstrates computation of the site suitability index for grazing.

Weights are not assigned to site characteristics when computing the site suitability indices because it is difficult to judge the relative importance of each variable. The indices, however, share the virtue of all multiplicative indexing systems; as in reality, least favorable site characteristics have a profound impact on the final result (McRae and Burnham, 1981). When classified as severe, limiting variables have the power to reduce the index to its lowest level. The limiting power of slope is observed in the site suitability index computed for rice (Table 8); steep slopes render a site bad for rice cultivation even when other site characteristics are acceptable.

TABLE 9

Computation of Site Suitability Index for Pigeon Peas

Class	Very Good	Good	Mediocre	Bad	Unsuitable
Scores	1.0000	0.9687	0.9297	0.8204	0.2500

Example of computation (soil survey site #82):

Land Characteristic	Value	Rank	Score
Elevation (m)	1020	Very good	1.0000
Slope (percent)	10	Very good	1.0000
Soil depth (cm)	70	Good	0.9687
Stoniness (percent)	<0.1	Very good	1.0000
Drainage	Well-drained	Very good	1.0000
Texture	Heavy	Good	0.9687
Reaction (pH)	6.70	Good	0.9687
Organic matter (percent)	5.60	Good	0.9687

Suitability index = 1.0000 x 1.0000 x 0.9687 x 1.0000
x 1.0000 x 0.9687 x 0.9687
x 0.9687
= 0.8806

The index value of 0.8806 falls within the range of 0.70-0.90 which corresponds to GOOD suitability.

Data source: Antonini et al. (1985)

TABLE 10

Computation of Site Suitability Index for Grazing

Class	Very Good	Good	Mediocre	Bad	Unsuitable
Scores	1.0000	0.9284	0.8435	0.6300	0.2500

Example of computation (soil survey site #82):

Land Characteristic	Value	Rank	Score
Slope (percent)	10	Very good	1.0000
Soil depth (cm)	70	Good	0.9284
Stoniness (percent)	<0.1	Very good	1.0000

Suitability index = 1.0000 x 0.9284 x 1.0000 = 0.9284

The index value of 0.9284 falls within the range of 0.90-1.00 which corresponds to VERY GOOD suitability.

Data source: Antonini et al. (1985).

Computation of numerical indices and ordinal ratings. Information needed to compute the suitability indices and ratings was available in a computer file created by Antonini et al. (1985). The data were processed in the IBM 3090-400 mainframe computer of the University of Florida using the Statistical Analysis System (SAS, 1983). Results are discussed in Chapter V.

Cartography. Relevant computer cartography was generated using SYMAP--the Synagraphic Mapping System (Dougenik and Sheehan, 1979). Suitability ratings were plotted at each soil survey site (see Chapter V). No attempt was made to extrapolate the suitability indices or ratings; further research is needed in order to develop an appropriate technique for extrapolation of variable values in tropical steeplands.

Farmer Decision-Making Analysis

Farmers with excellent land evaluation skills may disregard land suitability when selecting their principal land uses; economic or socio-personal motives can be more influential than environmental considerations. For this reason, point score analysis was incorporated into the 1986 farmer survey to study the farmer's perception of factors which influence selection of principal enterprise. The basic procedure, as implemented by Ilbery (1977), can be summarized as follows. The farmer is asked to identify his principal land use and indicate which of the factors in a standardized list have influenced his decision to dedicate particular efforts to that enterprise. Each relevant decision-making factor is assigned a point score by the farmer according to a graduated scale of significance which in Ilbery's studies of British farmers ranged from 1 for "not really important" to 4 for "essential". Factors considered irrelevant are awarded a score of zero.

While the choice of factors is subjective, the aim is to consider a wide variety of physical, economic and socio-personal influences which are hypothesized as being significant in the area under study. The sum of scores assigned to each factor by the farmers under investigation is considered a measure of its relative importance in the decision-making process. Consequently, the decision-making factors can be ranked in order of significance. An alternative expression of the importance of each factor is obtained by transforming the corresponding summed score into a percentage of its maximum possible value which is a function of sample size.

The author modified Ilbery's set of 25 decision-making factors on the basis of personal Latin American experience and assistance from Dominican colleagues. The shorter, revised, list shown in Table 11 demands less interviewee time and the 18 selected factors were deemed appropriate for Las Cuevas. Rainfall, temperature, shelter and frosts were

TABLE 11

Decision-Making Factors in Las Cuevas Agriculture

(A) SOCIO-PERSONAL FACTORS

(1) Personal preference.	(2) Area tradition.
(3) Family tradition.	(4) Previous occupant.

(B) ECONOMIC FACTORS

(1) Demand.	(2) Regular income.
(3) Low risk.	(4) Available credit.
(5) Intermediaries.	(6) Production costs.
(7) Long-term security.	(8) Government policy.
(9) Mass media.	

(C) PHYSICAL FACTORS

(1) Distance to market.	(2) Soil type.
(3) Drainage.	(4) Climate.
(5) Slope.	

converted into one general climatic factor. Experience and family tradition were combined into one variable, family tradition, considering the importance of the family unit in Latin American agriculture. Additional paired variables, condensed into a single factor, were distance-transport, and drainage-watertable height. Agricultural training, free time, skilled labor supply, water supply (irrigation), buildings and machinery were expected to have little bearing on choice of enterprise within an agricultural system which is evolving from spontaneous occupation of inaccessible tropical steeplands by marginalized peasants; as a result, these factors were replaced by five variables shown to be relevant in Third World nations--desire for long-term security, influence of intermediaries, production costs, land use under previous occupant and promotion of specific crops by mass media (Barlett, 1980; Jochim, 1981; Ruddle and Rondinelli, 1983).

Thirty-nine of the 80 farmers surveyed in 1986 declared coffee to be their principal agricultural use. Other principal enterprises identified were beans (27 farmers), grazing (10 farmers), pigeon peas (2 farmers), garlic (1 farmer) and rice (1 farmer). After each interviewee indicated the main use, he was asked why he had chosen that particular activity. Las Cuevas residents are extroverts and their response to this open-ended question was invariably spontaneous. Visibly relieved that the interview was not a standard interrogation of sensitive issues such as farm size, ownership status or yields, farmers were pleased to express opinions on land use strategy and criteria for site evaluation. Decision-making factors in Table 11 which were not identified independently by the farmer were mentioned subsequently to him one by one and he was asked if they also had influenced his choice of enterprise in any way; this procedure is justified because farmer decision-making includes unconscious pre-attentive information processing that is outside of the decision-maker's ordinary attention and awareness (Gladwin, 1980; Gladwin and Murtaugh, 1980).

Las Cuevas farmers were requested to evaluate relevant factors in one of only two alternative categories, "important" and "somewhat important", with corresponding numerical scores of 2 and 1. Factors considered irrelevant received a score of zero.

CHAPTER V
SITE SUITABILITY ANALYSIS IN LAS CUEVAS WATERSHED

Introduction

In this chapter, ranked land characteristic suitability classes for Las Cuevas agricultural uses--coffee, beans, pigeon peas, garlic, rice grazing--are defined on the basis of literature reviewed in Chapter III. The ranked classes are used to derive site suitability ratings at 350 sites with data collected in 1982 by SEA (Antonini et al., 1985).

Information on altitudinal preferences of crops is scarce; as a result, elevation suitability is classified as very good or severe. Values of other site characteristics are classified as very good, good, mediocre, bad or severe. A site characteristic classified as bad for a specific land use has a negative impact on yields but it cannot by itself make a site bad; it may lead to a bad site suitability rating only when it acts collectively with other site characteristics with bad rankings. On the other hand, a limiting site characteristic classified as severe is, by itself, capable of making a site bad for a specific use.

Site suitability ratings--very good, good, mediocre, bad--are derived from the ranked land characteristics using the method described in Chapter IV. The ratings are discussed using (1) tables which show frequencies of sites by suitability rating and (2) maps which illustrate the spatial distribution of sites in each category. The role of limiting site characteristics is interpreted for each land use.

Coffee

Site characteristic suitability classes. While many environmental factors must influence coffee productivity, the literature review in Chapter III clearly identifies eleven factors which should be considered in evaluating the suitability of a site for coffee--temperature, rainfall, slope, soil depth, stoniness, drainage, texture, pH, organic matter, cation exchange capacity and nutrient status (phosphate and potassium). Information on slope and all soil properties cited above except potassium status was collected in the 1982 Las Cuevas soil survey for 350 sites (Antonini et al., 1985). There is no information on climatic variation in the watershed apart from data collected at the meteorological station in Padre Las Casas and a few scattered rainfall gauges.

Site elevation data are available and this can be used as a surrogate variable for mean annual temperature although relevant literature is quite confusing. Blume (1974) suggests a lapse rate of 0.6 degrees Centigrade per 100 m for the Dominican Republic. Assuming this rate is correct and given a recorded mean annual temperature of 26 degrees Centigrade at Padre Las Casas (altitude 500 m), the optimal temperature range for coffee--16 to 24 degrees Centigrade--would be expected to cover areas with elevations between 830 and 2150 m. Recent work on coffee suggests, however, that coffee grows well only up to 2000 m in equatorial areas and that this upper altitudinal limit decreases polewards because of frost damage (Willson, 1985a). This is in agreement with an earlier study by Ochse et al. (1961) who argue that the best coffee in Colombia, Central America and Mexico is grown below 1700 m. It would appear, therefore, that the estimated 2150 m upper limit for optimum coffee cultivation in Las Cuevas is too high.

ISA (1971) claims that optimal conditions for arabica coffee in the Dominican Republic are found between 600 and 1200 m. While 600 m corresponds to the generally accepted thermal threshold between robusta and arabica (Opeke, 1982; Willson, 1985a), the upper value of 1200 m seems to be too low and certainly not limiting for coffee growth. For the purposes of this study, it is assumed that arabica can be cultivated within an altitudinal range of 600-1700 m; elevations below or above this critical range are assumed to be severe and inappropriate for arabica because temperature is a limiting variable with the power to make a site bad for coffee no matter how favorable other environmental factors may be.

Coffee and other tree crops can be grown on relatively steep slopes which are inappropriate for short-cycle crops but gentle slopes offer greater accessibility and lower costs of conservation; as a result, gentle slopes are worthy of better suitability ratings. The gradient at each survey site can be assigned to one of five ranked suitability classes (Sheng, 1972): very good (0-27 percent), good (28-36 percent), mediocre (37-42 percent), bad (43-65 percent), and severe (> 65 percent). Slope, like elevation, is a limiting variable. No matter how favorable other land characteristics are, slopes > 65 percent should remain uncropped and covered by natural vegetation to avoid soil erosion.

The physical soil properties of depth, stoniness and drainage also, by themselves, can make a site bad for coffee cultivation. ILACO (1981) ranks tropical soils with profiles > 90 cm as deep or very good, 60-90 cm as fairly deep or good, 30-59 cm as shallow or mediocre and < 30 cm as very shallow or bad. It is unlikely that acceptable yields of any crop will be obtained on extremely thin soils. Such soils, unsuitable for agriculture, should be protected under natural vegetation. As a result, the author further subdivides the last depth class into 15-29 cm (very shallow or bad) and < 15 cm (extremely shallow or severe).

No guidelines exist for critical levels of stoniness. The Las Cuevas environmental survey classifies soil stoniness in five categories: > 90 percent, 15-90 percent, 3-14 percent, 0.1-2.9 percent and < 0.1 percent of the soil surface covered with stones. The first category is unequivocally unsuited for any kind of agriculture and must be considered a severe constraint. The second category is very broad and undoubtedly includes both soils unsuitable for agriculture by their stoniness and limited capacity to retain moisture, as well as soils which traditional farmers may be prepared to improve. The author has observed examples of stone clearance within the 15-90 percent range for horticulture in parts of Ecuador. Category 15-90 percent, therefore, must be ranked as bad rather than severe. Other rankings are mediocre (3-14 percent), good (0.1-2.9 percent) and very good (< 0.1 percent).

Very poor drainage is a severe constraint for coffee cultivation. Poorly drained soils warrant a bad suitability ranking for coffee while rankings of good and very good suitability can be assigned to moderately well-drained and well-drained conditions respectively. Other standard drainage categories merit a mediocre classification; imperfect drainage affects availability of oxygen in the soil, while somewhat excessive and excessive drainage may reduce infiltration of precipitation, increase runoff and promote soil erosion.

Soil with very heavy texture (clay, silty clay or sandy clay) may be assigned a mediocre ranking by virtue of negative impact of texture on drainage. Even less suitable, however, are light-textured soils (sand, loamy sand or sandy loam) which are bad because they retain insufficient moisture during dry periods. Moderately heavy textures (clay loam, silty clay loam), as discussed in Chapter III, are good for coffee. Medium textures (sandy clay loam, loam, silt loam and silt), associated with optimum availability of water and oxygen, are given a very good suitability ranking.

Coffee has never been reported on soils with pH > 8.0 and it can be assumed that this degree of alkalinity is bad. Extremely acid conditions with pH < 4.2 are equally bad. Less extreme levels of acidity, however, are acceptable; pH values within the 4.2-4.9 and 6.6-7.0 ranges may be considered good, while pH between 5.0 and 6.5 is very good. Mildly alkaline soil (pH 7.1-8.0) is mediocre.

Soils with organic matter < 2 percent are vulnerable to soil erosion (Morgan, 1979). Moreover, coffee thrives on the natural fertility of humic soils; ILACO (1981) classifies organic matter as very good when > 6.0 percent, good between 4.3 and 6.0 percent, mediocre between 2.0 and 4.2 percent and bad when < 2.0 percent.

ILACO (1981) also provides guidelines for available nutrients and cation exchange capacity which can be classified as bad when below 12 meq/100 gm, mediocre between 12 and 25 meq/100 gm, good between 26 and 40 meq/100 gm and very good at levels higher than 40 meq/100 gm. Available phosphate, similarly, may be classified as bad when < 10 ppm, mediocre between 10 and 30 ppm, good between 31 and 60 ppm and very good when > 60 ppm.

Table 12 and Figure 13 summarize the suitability rankings of site characteristics for coffee.

Site suitability ratings. Suitability ratings for coffee were derived for the 350 Las Cuevas survey sites. Table 13 shows that none of the sites has a very good suitability rating; forty-six sites (13 percent) are good, 101 (29 percent) mediocre, and 203 (58 percent) bad. Nineteen of the bad sites are affected by the cumulative impact of site characteristics with bad or mediocre scores but the majority--184 (53 percent of the total)--are bad because of at least one limiting variable. Table 13 shows there are 117 sites (34 percent) located above or below the recommended altitudinal range of 600-1700 m, and 80 sites (23 percent) have extremely shallow soils (< 15 cm). Twenty-two sites (6 percent) have slopes > 65 percent. Stoniness limits coffee cultivation at 15 sites (4 percent) while only one site has severe drainage conditions.

Figure 14 shows the distribution of sites in each suitability category. Bad sites prevail in the east and west, due largely, but not exclusively to elevation. Much of the eastern watershed area is above 1700 m and conditions are too cool for coffee (Figure 15). Western low-lying areas, on the other hand, have temperatures which are too high for arabica. Most sites with a good suitability rating

TABLE 12

Ranked Site Characteristics for Coffee

Characteristic	Rank	Characteristic	Rank
Elevation (m)		Texture *	
>1700	Severe	Very Heavy	Mediocre
600-1700	Very good	Heavy	Good
<600	Severe	Medium	Very good
		Light	Bad
Slope (%)		pH *	
>65	Severe	<4.2	Bad
43-65	Bad	4.2-4.9	Good
37-42	Mediocre	5.0-6.5	Very good
28-36	Good	6.6-7.0	Good
0-27	Very good	7.1-8.0	Mediocre
		>8.0	Bad
Soil depth (cm)		Organic matter (%) *	
>90	Very good	>6.0	Very good
60-90	Good	4.3-6.0	Good
30-59	Mediocre	2.0-4.2	Mediocre
15-29	Bad	<2.0	Bad
<15	Severe		
Stoniness (%)		CEC (meq/100 gm) *	
<0.1	Very good	>40	Very good
0.1-2.9	Good	26-40	Good
3.0-14.9	Mediocre	12-25	Mediocre
15.0-90.0	Bad	<12	Bad
>90.0	Severe		
Drainage		Phosphate (ppm) *	
Excessive	Mediocre	>60	Very good
Somewhat exc.	Mediocre	31-60	Good
Well-drained	Very good	10-30	Mediocre
Mod. well	Good	<10	Bad
Imperfect	Mediocre		
Poor	Bad		
Very poor	Severe		

* A horizon

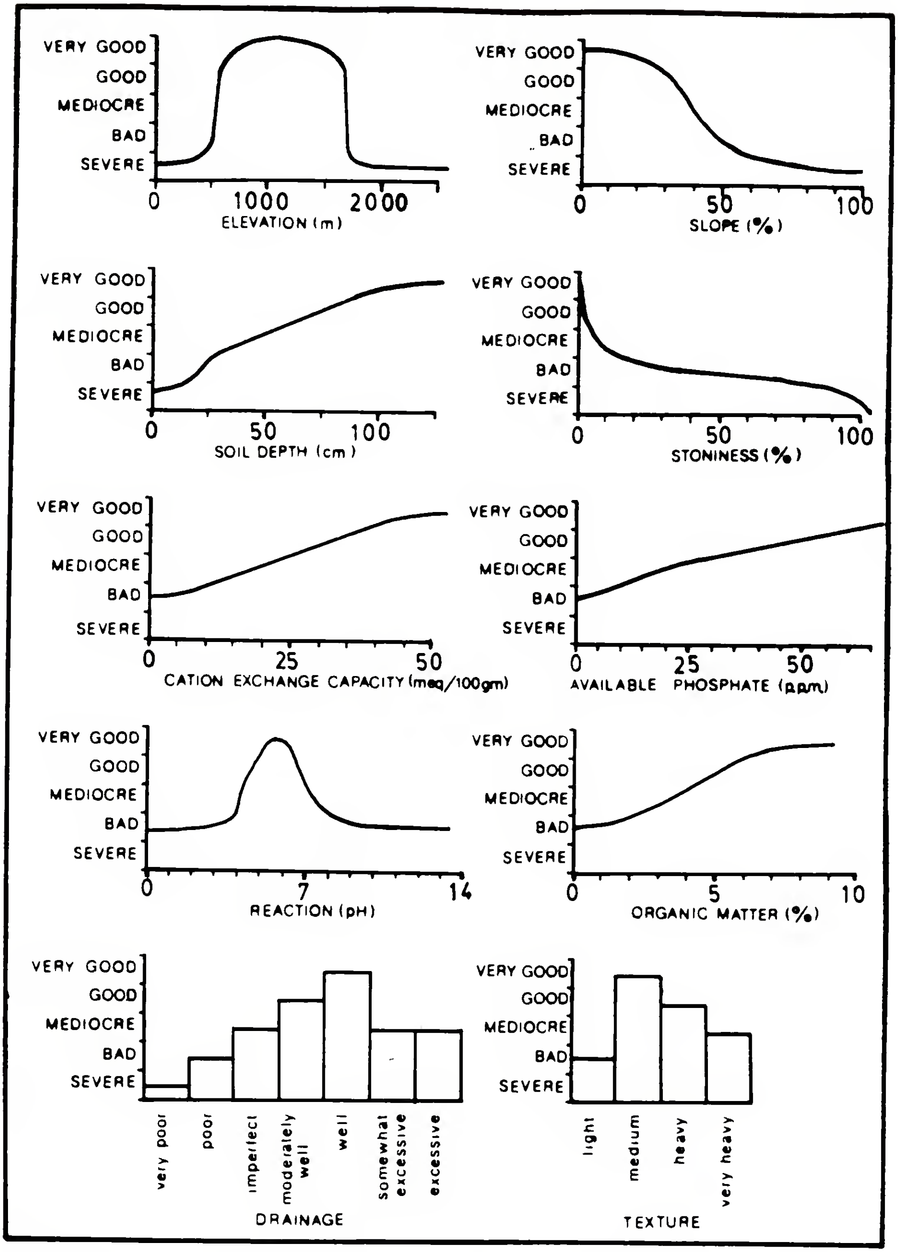

Figure 13. Suitability of Site Characteristics for Coffee

TABLE 13

Site Suitability for Coffee

(a) Frequency Distribution of Sites by Suitability Class

Class:	Very Good	Good	Mediocre	Bad	Total
No. of Sites	-	46	101	203	350
Percentage	-	13	29	58	100

(b) Impact of Limiting Variables on Site Suitability

Limiting Variable	Severe Class	No. Sites	Percent
Elevation (m)	<600	20	6
Elevation (m)	>1700	97	28
Soil depth (cm)	<15	80	23
Slope (percent)	>65	22	6
Stoniness (percent)	>90	15	4
Drainage	Very poor	1	0.3

Note: Limiting variables were classified as severe at 184 (53 percent) of the soil survey sites; of those, 144 were rendered bad for coffee by one limiting variable, 29 by two variables and 11 by three variables.

Data source: Antonini et al. (1985).

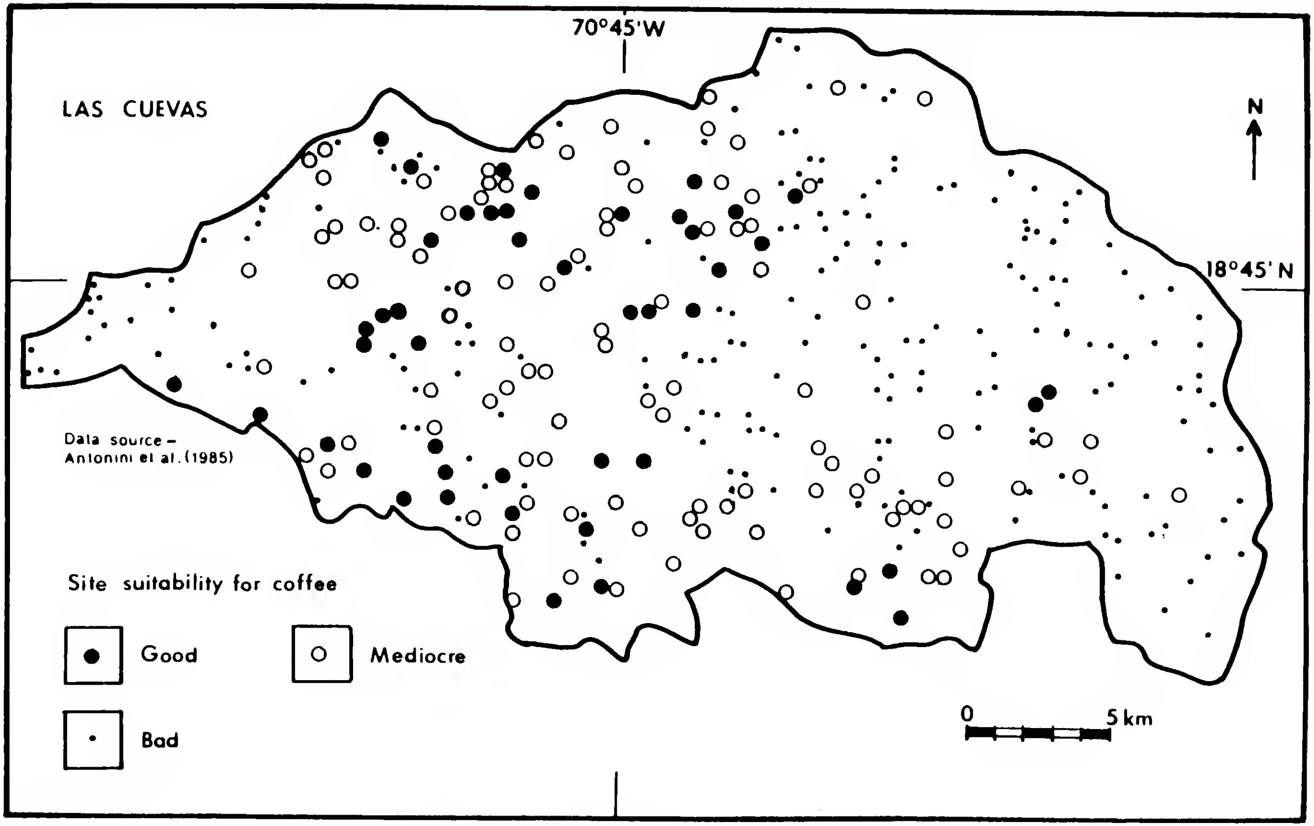

Figure 14. Site Suitability for Coffee in Las Cuevas Watershed

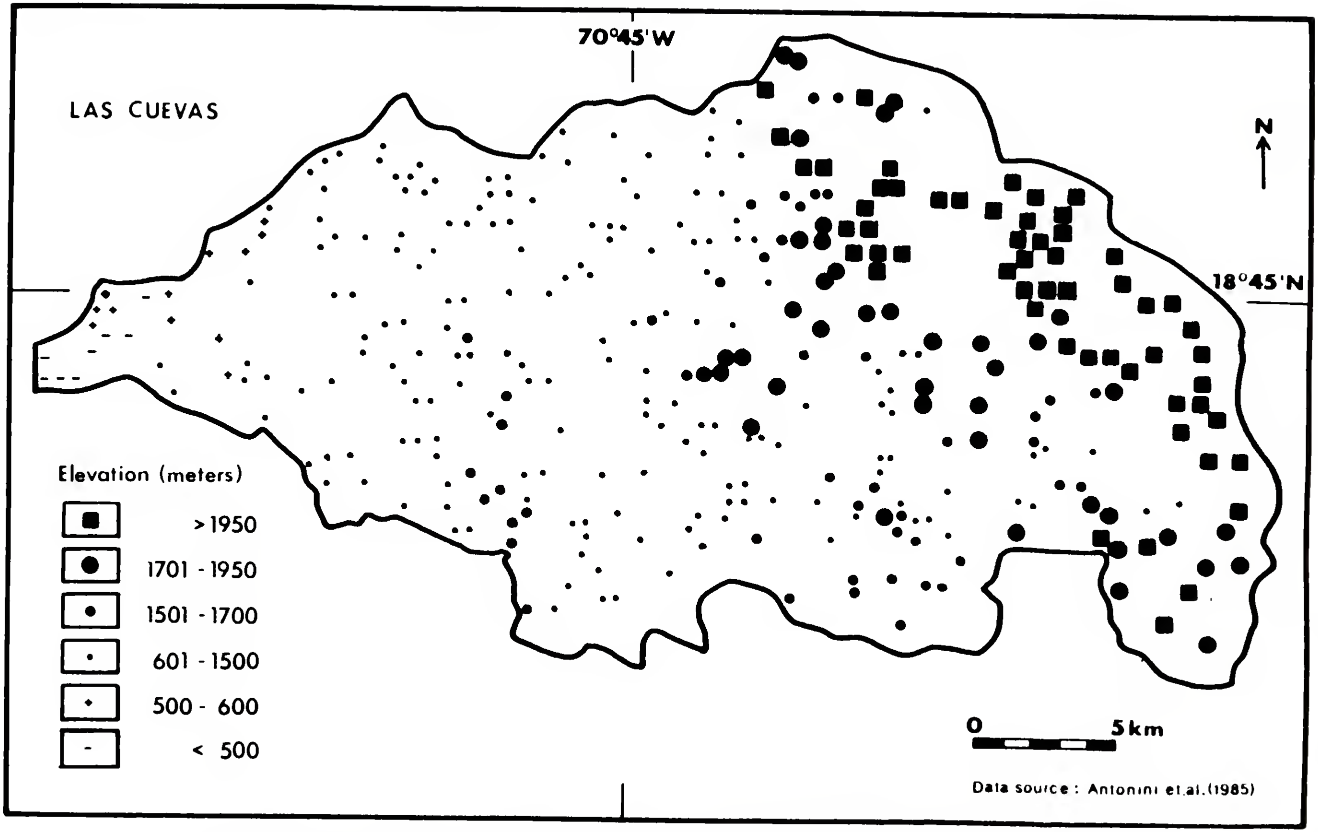

Figure 15. Elevation of Soil Survey Sites in Las Cuevas Watershed

are located in the central watershed, in the vicinity of Monte Bonito, Las Lagunas, La Siembra, Guayabal, La Tina, Arroyo La Savila, Naranjal and Sabana de San Juan.

Beans

Site characteristic suitability classes. Altitudes > 1950 m are considered severe for tropical bean cultivars (Tindall, 1983). Gradient suitability classes are: very good (0-12 percent), good (13-27 percent), mediocre (28-36 percent), bad (37-42 percent) and severe (> 42 percent). This classification follows Sheng's (1972) recommendations for short-cycle crops in tropical steeplands.

Model soils for beans and coffee are very similar. Site suitability for both crops improves with increasing soil depth, organic matter content, cation exchange capacity and phosphate, and diminishes with increasing stoniness. Coffee and beans also share preferences for free drainage and loamy textures. The same soil site requirements, therefore, have been adopted for beans with the exception of pH. There have been no reports of beans grown on soils with pH < 4.2 or > 8.7; such extreme conditions, therefore, are assumed to be bad. A mediocre ranking must be assigned to the range 4.2-5.1 because of toxicity of manganese and inefficient fixation of atmospheric nitrogen. Moderately alkaline soil (7.4-8.7) is also mediocre. Values of pH within the ranges 5.2-5.4 and 7.1-7.3 may be considered good while those between 5.5 and 7.0 are very good (see Table 14 and Figure 16).

Site suitability ratings. Table 15 shows the frequency distribution of sites by classes of site suitability for beans. Only one site was assigned a very good suitability rating. Thirty-five sites (10 percent) were rated good while 104 (29.7 percent) were mediocre and 210 (60 percent) were bad. Thirty sites rated bad score low due to the collective effect of variables with low scores, but limiting variables are responsible for most of the bad ratings, especially slope and soil depth. The spatial distribution of sites with severe values of slope and soil depth are observed in Figures 17 and 18, respectively.

As optimal conditions for coffee and beans are alike, the frequency distributions of sites by suitability class in Tables 13 and 15 are similar. Furthermore, many sites with good suitability for coffee are included in the same category on the map of land suitability for beans (Figure 19). There are, however, fewer sites with good suitability ratings for beans because slope requirements are more demanding for short-cycle crops. As beans are associated with a wider range of mean annual temperature and elevation, several sites are upgraded to mediocre status in the west. Bad suitability ratings continue to prevail in the eastern watershed because of very high altitudes, steep slopes and shallow soils.

TABLE 14

Ranked Site Characteristics for Beans

Characteristic	Rank	Characteristic	Rank
Elevation (m)		Texture *	
>1950	Severe	Very Heavy	Mediocre
<1950	Very good	Heavy	Good
		Medium	Very good
		Light	Bad
Slope (%)		pH *	
>42	Severe	<4.2	Bad
37-42	Bad	4.2-5.1	Mediocre
28-36	Mediocre	5.2-5.4	Good
13-27	Good	5.5-7.0	Very good
0-12	Very good	7.1-7.3	Good
		7.4-8.7	Mediocre
		>8.7	Bad
Soil depth (cm)		Organic matter (%) *	
>90	Very good	>6.0	Very good
60-90	Good	4.3-6.0	Good
30-59	Mediocre	2.0-4.2	Mediocre
15-29	Bad	<2.0	Bad
<15	Severe		
Stoniness (%)		CEC (meq/100 gm) *	
<0.1	Very good	>40	Very good
0.1-2.9	Good	26-40	Good
3.0-14.9	Mediocre	12-25	Mediocre
15.0-90.0	Bad	<12	Bad
>90.0	Severe		
Drainage		Phosphate (ppm) *	
Excessive	Mediocre	>60	Very good
Somewhat exc.	Mediocre	31-60	Good
Well-drained	Very good	10-30	Mediocre
Mod. well	Good	<10	Bad
Imperfect	Mediocre		
Poor	Bad		
Very poor	Severe		

* A horizon

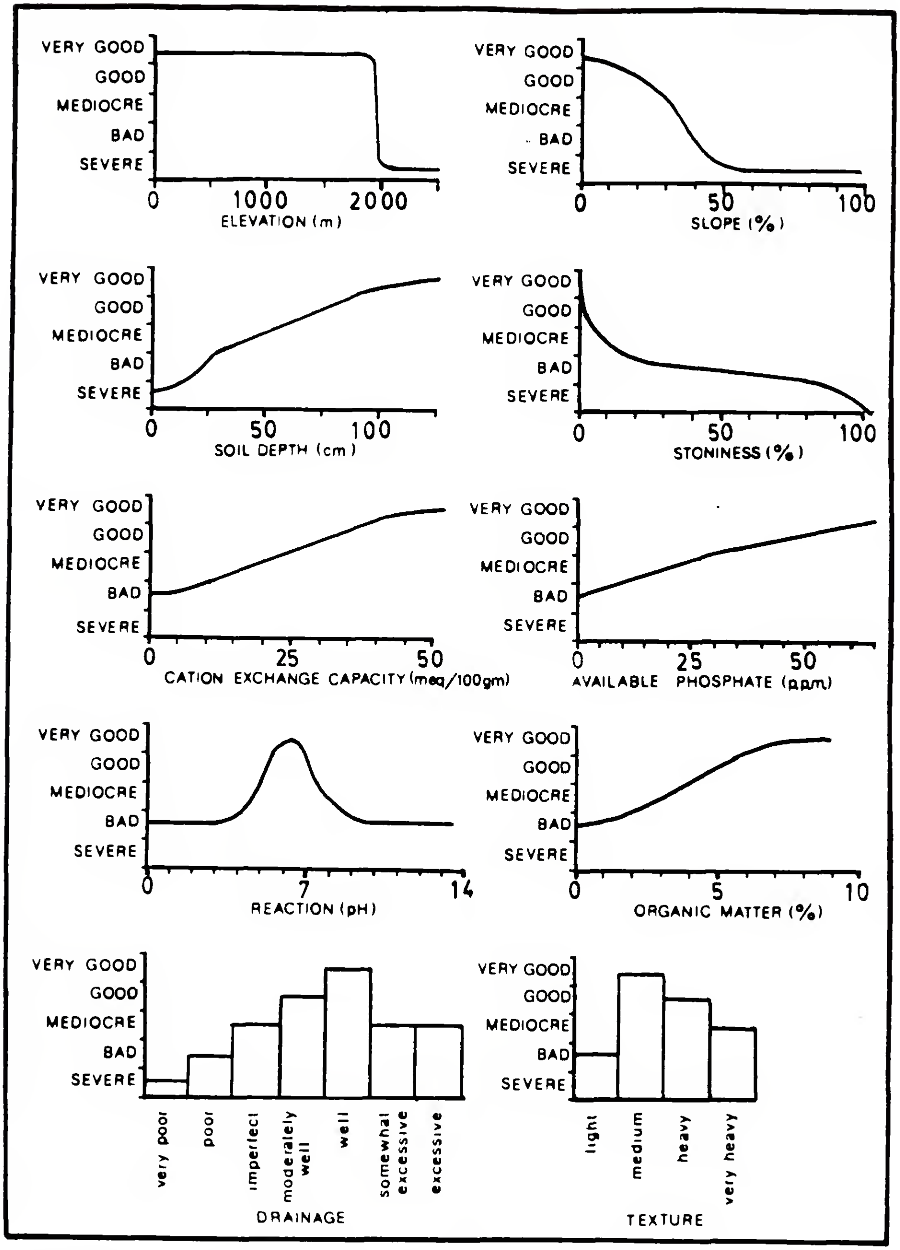

Figure 16. Suitability of Site Characteristics for Beans

TABLE 15

Site Suitability for Beans

(a) Frequency Distribution of Sites by Suitability Class

Class:	Very Good	Good	Mediocre	Bad	Total
No. of Sites	1	35	104	210	350
Percentage	0.3	10	29.7	60	100

(b) Impact of Limiting Variables on Site Suitability

Limiting Variable	Severe Class	No. Sites	Percent
Elevation (m)	>1950	58	17
Soil depth (cm)	<15	80	23
Slope (percent)	>42	97	28
Stoniness (percent)	>90	15	4
Drainage	Very poor	1	0.3

Note: Limiting variables were classified as severe at 180 (51 percent) of the soil survey sites; of those, 121 were rendered bad for beans by one limiting variable, 47 by two variables and 12 by three variables.

Data source: Antonini et al. (1985)

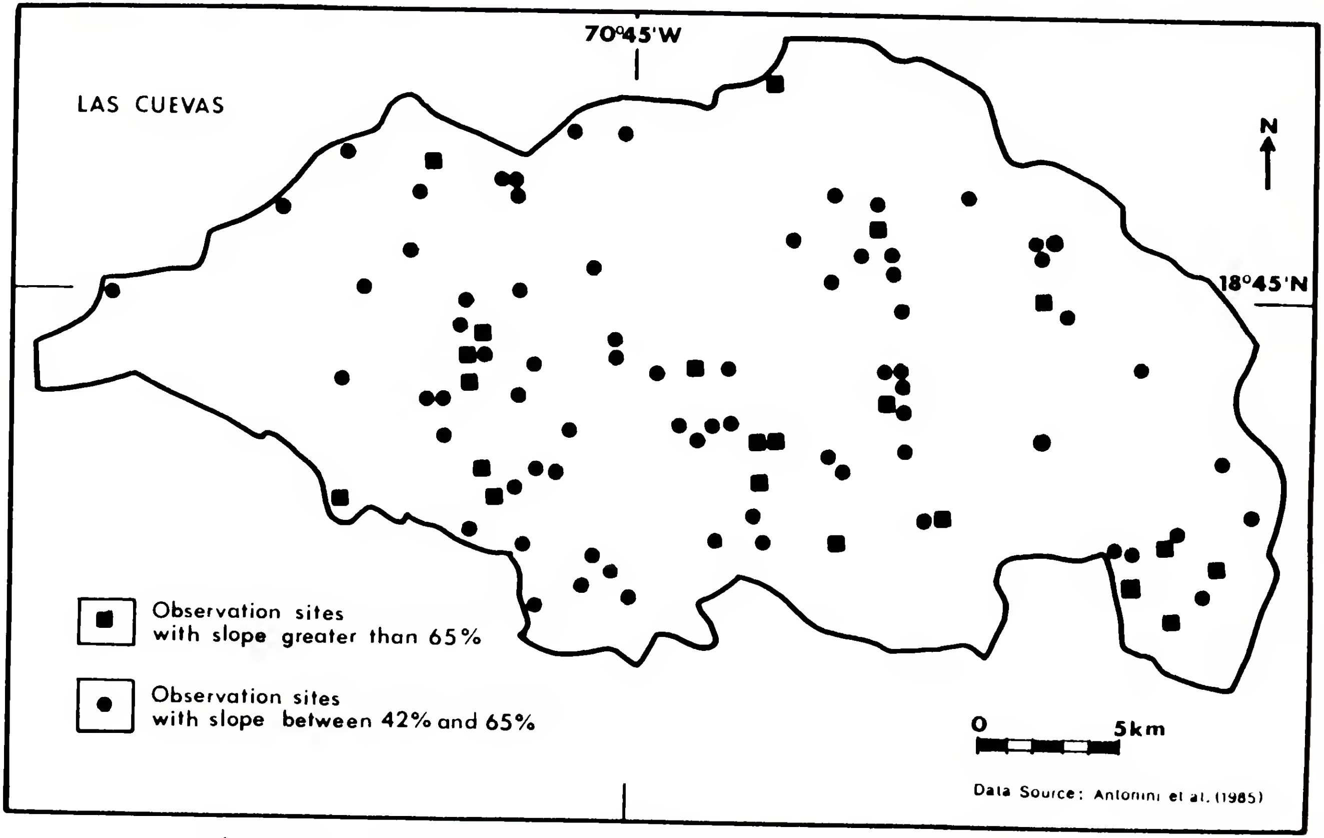

Figure 17. Soil Survey Sites with Severe Values of Slope

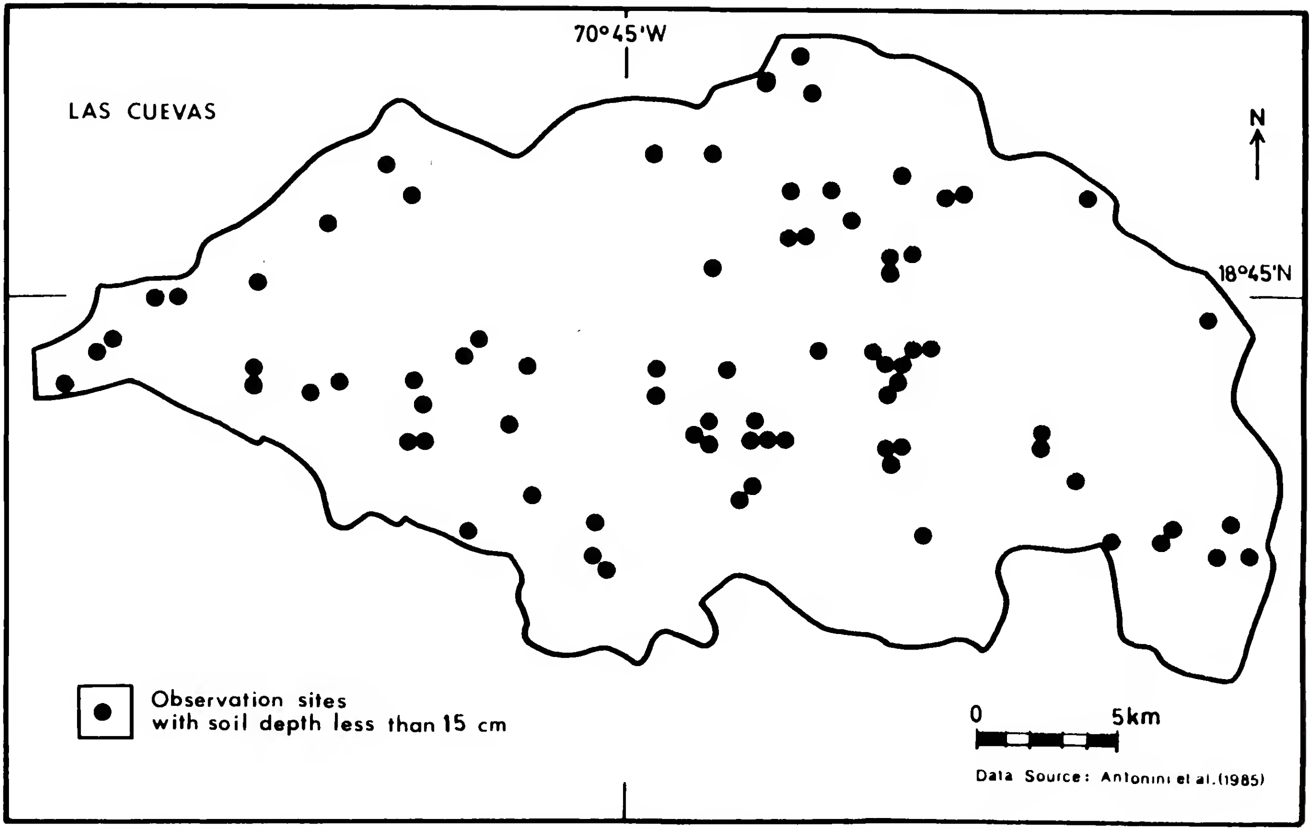

Figure 18. Soil Survey Sites with Severe Values of Soil Depth

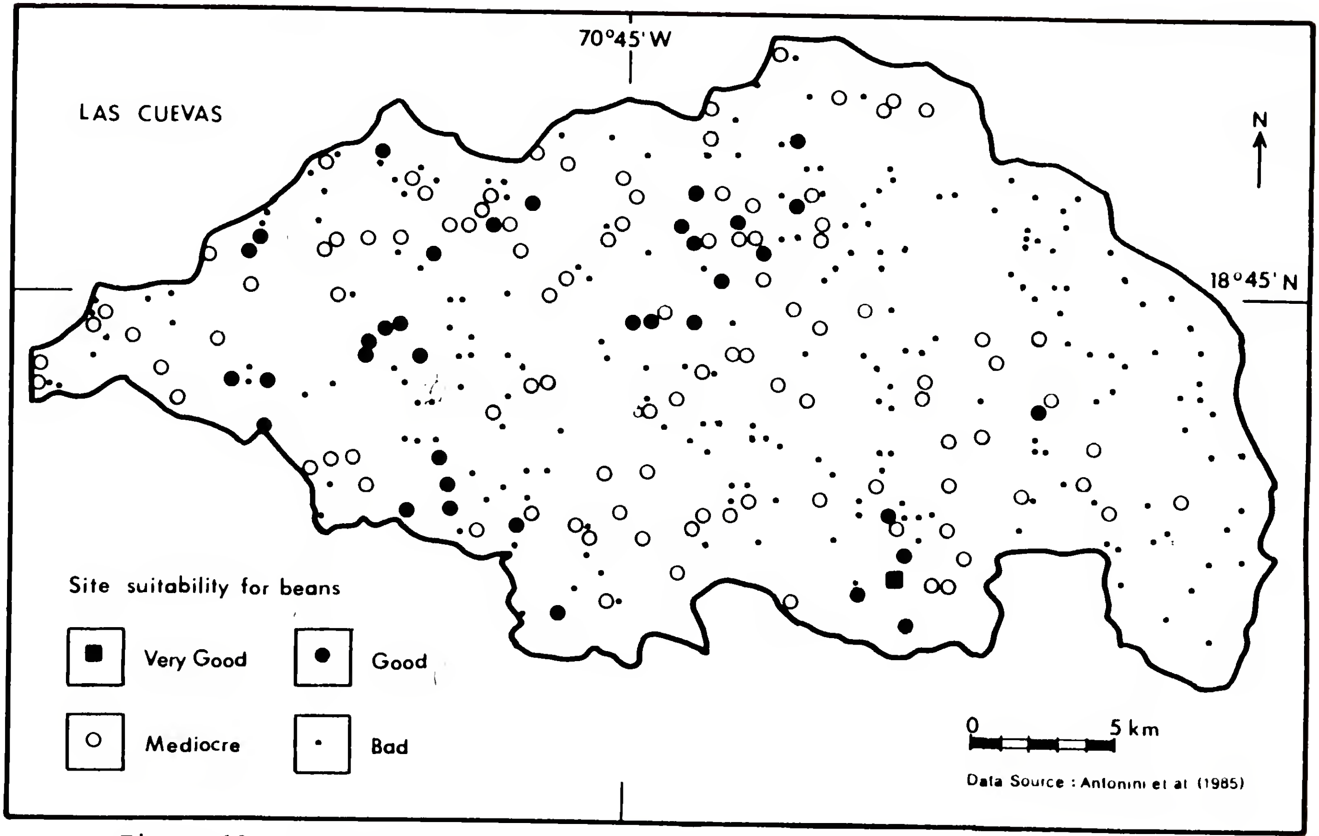

Figure 19. Site Suitability for Beans in Las Cuevas Watershed

Pigeon Peas

Site characteristic suitability classes. Altitudes > 1500 m are considered severe for pigeon peas (Tindall, 1983). They prefer gentle gradients, good drainage, deep soils and few stones as do beans and other legumes. Therefore, pigeon peas and beans are given the same site suitability rankings for those variables.

Pigeon peas, like beans, prefer loamy soils and medium textures. Heavy textures are good but very heavy textures are given a bad suitability rating for pigeon peas because they impede drainage and hinder root development (SEA, 1976a). Light soil textures, on the other hand, are upgraded from bad to mediocre since they are more tolerant than beans of soils with low moisture retention (see Table 16 and Figure 20).

Values of pH between 5.6 and 6.5 are very good while conditions close to neutrality (6.6-7.3) may be considered good. Strongly acid (4.3-5.5) and moderately alkaline (7.4-8.4) reactions are mediocre; values of pH < 4.3 or > 8.4 are assumed to be bad since no reports have been found of pigeon pea production on extremely acid or extremely alkaline soils.

Pigeon peas prosper on relatively infertile soils so that productivity appears to be independent of cation exchange capacity and availability of nutrients such as phosphates. These variables probably need not be considered

TABLE 16

Ranked Site Characteristics for Pigeon Peas

Characteristic	Rank	Characteristic	Rank
Elevation (m)		Texture *	
>1500	Severe	Very Heavy	Bad
<1500	Very good	Heavy	Good
		Medium	Very good
		Light	Mediocre
Slope (%)		pH *	
>42	Severe	<4.3	Bad
37-42	Bad	4.3-5.5	Mediocre
28-36	Mediocre	5.6-6.5	Very good
13-27	Good	6.6-7.3	Good
0-12	Very good	7.4-8.4	Mediocre
		>8.4	Bad
Soil depth (cm)		Organic matter (%) *	
>90	Very good	>6.0	Mediocre
60-90	Good	4.3-6.0	Good
30-59	Mediocre	2.0-4.2	Very good
15-29	Bad	<2.0	Bad
<15	Severe		
Stoniness (%)		Drainage	
<0.1	Very good	Excessive	Mediocre
0.1-2.9	Good	Somewhat exc.	Mediocre
3.0-14.9	Mediocre	Well drained	Very good
15.0-90.0	Bad	Mod. well	Good
>90.0	Severe	Imperfect	Mediocre
		Poor	Bad
		Very poor	Severe

* A horizon

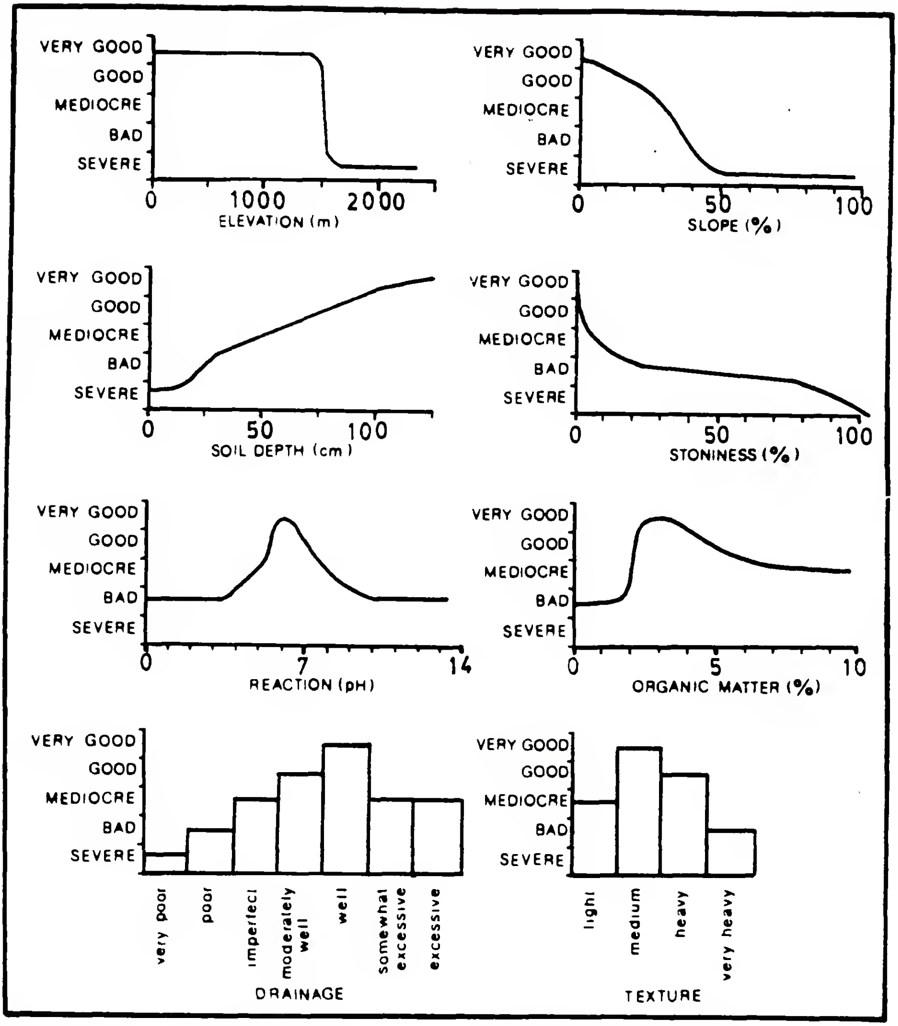

Figure 20. Suitability of Land Characteristics for Pigeon Peas

in evaluation of sites for pigeon pea production. Pigeon peas appear to prefer soils which are not rich in organic matter (ISA, 1971). The presence of some organic matter must be favorable, however, as it plays an important role in development of soil structure which in turn favors natural flow of air and water and makes soil more resistant to erosion. Morgan's (1979) recommended level for all field crops of at least 2 percent of organic matter content appears appropriate for pigeon peas. Thus, a bad suitability rating can be assigned when organic matter falls below 2 percent. A moderate organic matter content of 2.1-4.2 percent is probably optimal. Levels between 4.3 and 6.0 percent may still deserve a good rating but, given the aversion of pigeon peas to high organic matter content, a mediocre suitability rating must be assigned for values > 6 percent.

<u>Site suitability ratings</u>. Pigeon peas are unaffected by low levels of cation exchange capacity or soil nutrients and a comparison of Tables 15 and 17 shows that more sites are classified as good or very good for pigeon peas than for beans. On the other hand, there are more sites with a bad rating for pigeon peas because elevation has greater limiting power; 146 sites (42 percent) have altitudes > 1500 m. A consequence of so many sites being classified as good or bad is that only 55 sites (16 percent) are mediocre (there are almost twice as many sites rated mediocre for coffee and beans).

TABLE 17

Site Suitability for Pigeon Peas

(a) Frequency Distribution of Sites by Suitability Class

Class:	Very Good	Good	Mediocre	Bad	Total
No. of Sites	3	49	55	243	350
Percentage	1	14	16	69	100

(b) Impact of Limiting Variables on Site Suitability

Limiting Variable	Severe Class	No. Sites	Percent
Elevation (m)	>1500	146	42
Soil depth (cm)	<15	80	23
Slope (percent)	>42	97	28
Stoniness (percent)	>90	15	4
Drainage	Very poor	1	0.3

Note: Limiting variables were classified as severe at 234 (67 percent) of the soil survey sites; of those, 150 were rendered bad for pigeon peas by one limiting variable, 63 by two variables and 21 by three variables.

Data source: Antonini et al. (1985)

The greater limiting power of elevation for pigeon peas is evident in Figure 21; there is a predominance of bad suitability ratings in the higher eastern half of the watershed. Elsewhere, because of relaxed requirements of organic matter, cation exchange capacity and available phosphate, 19 sites rated mediocre for beans are good for pigeon peas. Most good sites are located near Padre Las Casas, Arroyo La Savila, Monte Bonito, La Tina and between Las Lagunas and Guayabal.

Garlic

Site characteristic suitability classes. Tindall (1983) indicates that altitudes < 500 m are severe for garlic. It is difficult to specify an upper altitudinal limit as in the cases of coffee, beans and pigeon peas, since no such limit is clearly defined in the literature.

Garlic is most productive on gentle slopes with deep, well-drained, fertile, humic soils which have few stones, abundant nutrients and high cation exchange capacity. These site conditions also are preferred by beans and suitability rankings of slope, drainage, organic matter, stoniness, available phosphate and cation exchange capacity are the same (see Table 18 and Figure 22).

Garlic demonstrates less tolerance than beans for shallow soils. Deep soil profiles (> 90 cm) may be considered very good and moderately deep ones (60-90 cm)

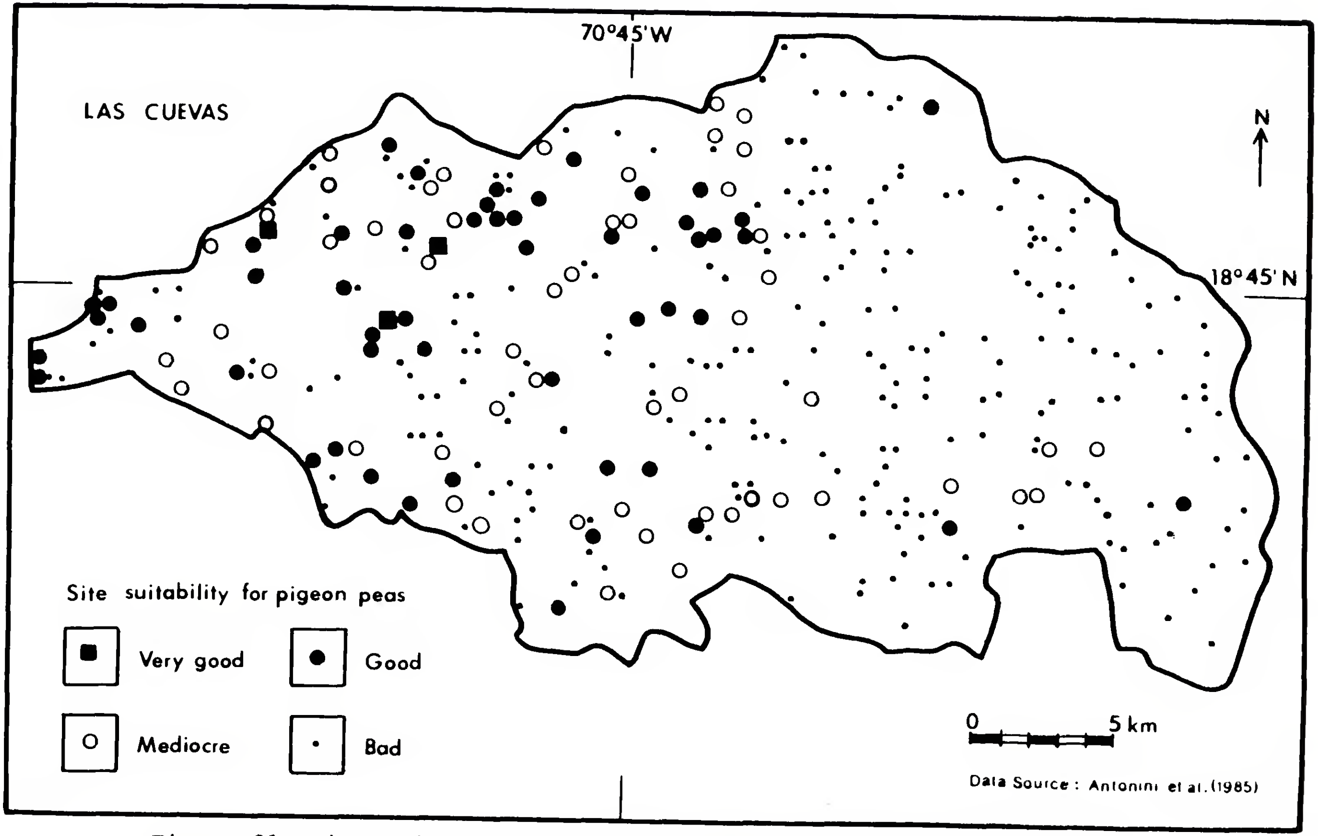

Figure 21. Site Suitability for Pigeon Peas in Las Cuevas Watershed

TABLE 18

Ranked Site Characteristics for Garlic

Characteristic	Rank	Characteristic	Rank
Elevation (m)		Texture *	
>500	Very good	Very Heavy	Bad
<500	Severe	Heavy	Mediocre
		Medium	Very good
		Light	Good
Slope (%)		pH *	
>42	Severe	<4.5	Bad
37-42	Bad	4.5-5.5	Mediocre
28-36	Mediocre	5.6-6.0	Good
13-27	Good	6.1-6.8	Very good
0-12	Very good	6.9-7.3	Good
		7.4-8.3	Mediocre
		>8.3	Bad
Soil depth (cm)		Organic matter (%) *	
>90	Very good	>6.0	Very good
60-90	Good	4.3-6.0	Good
45-59	Mediocre	2.0-4.2	Mediocre
15-44	Bad	<2.0	Bad
<15	Severe		
Stoniness (%)		CEC (meq/100 gm) *	
<0.1	Very good	>40	Very good
0.1-2.9	Good	26-40	Good
3.0-14.9	Mediocre	12-25	Mediocre
15.0-90.0	Bad	<12	Bad
>90.0	Severe		
Drainage		Phosphate (ppm) *	
Excessive	Mediocre	>60	Very good
Somewhat exc.	Mediocre	31-60	Good
Well-drained	Very good	10-30	Mediocre
Mod. well	Good	<10	Bad
Imperfect	Mediocre		
Poor	Bad		
Very poor	Severe		

* A horizon

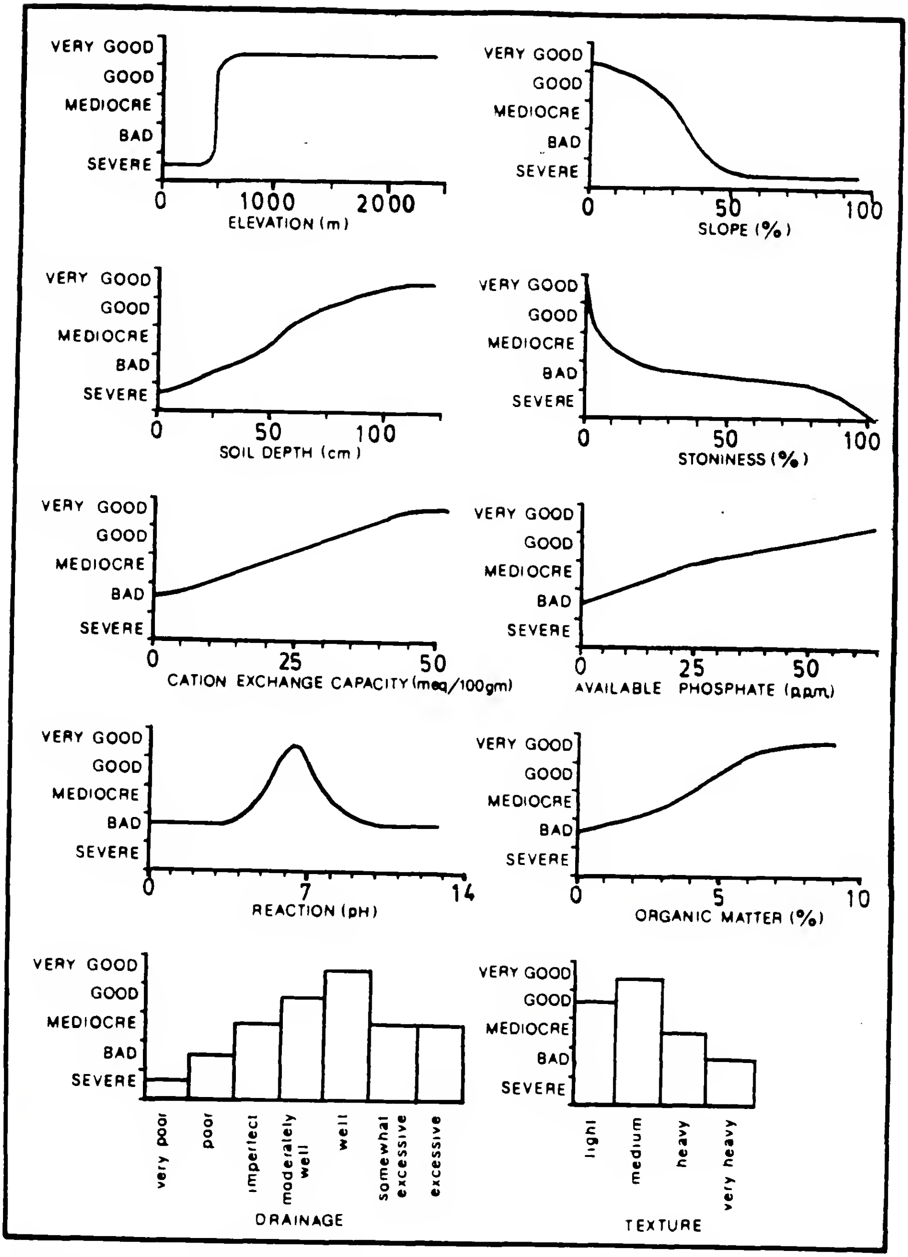

Figure 22. Suitability of Land Characteristics for Garlic

have a good suitability rating. Minimum depth for satisfactory garlic production, however, is 45-60 cm (Yamaguchi, 1983). Shallow soils, therefore, are re-classified as follows: mediocre (45-59 cm), bad (15-44 cm) and severe (< 15 cm).

Garlic, like beans, prefers medium soil texture. It is more tolerant, however, of light-textured soil and less tolerant of heavy textures which impede drainage and deform bulbs. General textural classes are: very good (medium), good (light), mediocre (heavy) and bad (very heavy).

Optimum conditions of pH between 6.1 and 6.8 have a very good rating; pH values of 5.6-6.0 and 6.9-7.3 are good; alkaline (7.4-8.3) and strongly acid (4.5-5.5) reactions are mediocre; and pH values < 4.5 or > 8.3 are bad.

Site suitability ratings. Frequencies of sites by suitability class for garlic are quite similar to corresponding frequencies for coffee and beans, crops which share garlic's preference for fertile soils. Table 19 shows that 40 sites (12 percent) were rated good while 123 (35 percent) were mediocre and 187 (53 percent) were bad.

The impact of elevation on the garlic site index is relatively unimportant because no upper altitudinal limit has been specified. Indeed, only 8 sites (2 percent) in Las Cuevas watershed are located below the critical lower limit of 500m. In contrast, elevation was considered a severe constraint at 58 sites for beans (17 percent), 117 sites for

TABLE 19

Site Suitability for Garlic

(a) Frequency Distribution of Sites by Suitability Class

Class:	Very Good	Good	Mediocre	Bad	Total
No. of Sites	-	40	123	187	350
Percentage	-	12	35	53	100

(b) Impact of Limiting Variables on Site Suitability

Limiting Variable	Severe Class	No. Sites	Percent
Elevation (m)	<500	8	2
Soil depth (cm)	<15	80	23
Slope (percent)	>42	97	28
Stoniness (percent)	>90	15	4
Drainage	Very poor	1	0.3

Note: Limiting variables were classified as severe at 153 (44 percent) of the soil survey sites; of those, 108 were rendered bad for garlic by one limiting variable, 39 by two variables and 6 by three variables.

Data source: Antonini et al. (1985)

coffee (34 percent) and 146 sites for pigeon peas (42 percent). Relative freedom from altitudinal constraints, however, has led to a relatively small decrease in the number of sites with bad ratings. Comparison of Figures 15, 17 and 18 shows that more than one-third of the sites in areas of high elevation (> 1500 m) are worthy of a bad suitability rating because of limiting levels of soil depth or slope; others suffer from the collective effect of site characteristics with low scores and are rated bad or mediocre. Figure 23 shows that only 6 sites in the eastern mountains have site characteristics with scores favorable enough to merit a good suitability rating for garlic.

Rice

Site characteristic suitability classes. In steepland Latin American regions wetland rice is restricted to low-lying areas. Las Cuevas rice crops are planted in rotation with peanuts and beans. These crops are associated with a similar range of mean annual temperatures (Duke, 1978); thus, the 1950 m maximum elevation limit for beans is assumed appropriate for rice.

Wetland rice, by virtue of its dependence on irrigation, requires special suitability scales for slope, drainage and texture. Although rice can be cultivated on steep slopes using sophisticated systems of terraces, as in Asia, paddies are restricted generally to slopes of 0-8

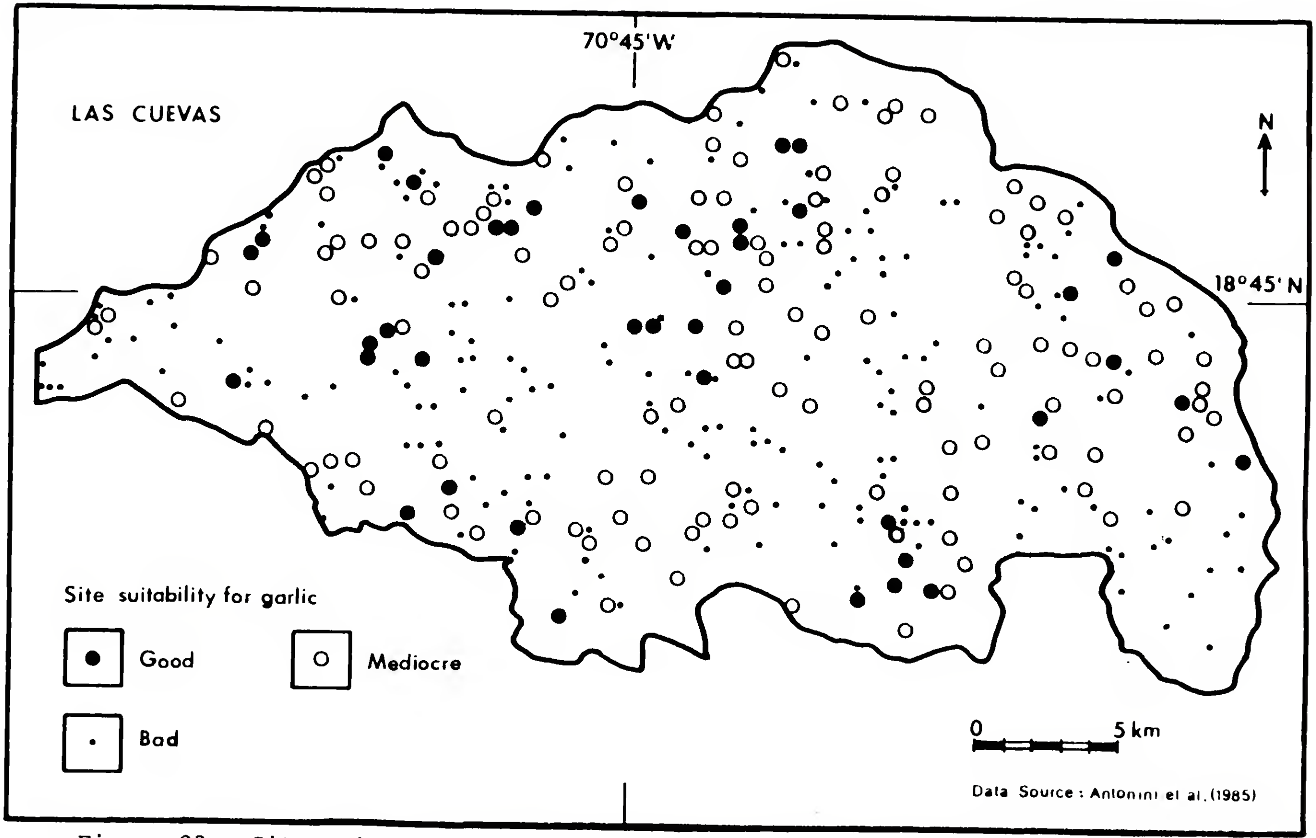

Figure 23. Site Suitability for Garlic in Las Cuevas Watershed

percent. Gradients < 2 percent merit a very good suitability rating for wetland rice and, assuming that the cost of paddy construction increases with increasing slope, other gradients may be classified as good (2-4 percent), mediocre (5-6 percent), bad (7-8 percent) and severe (> 8 percent).

Rice, like garlic, is relatively intolerant of shallow soils. Sites with more than 90 cm of soil are assigned a very good suitability rating and soils with a 60-90 cm profile are good. Shallow soils, however, are re-classified as mediocre (40-59 cm), bad (15-39 cm) and severe (< 15 cm). Stone-free soils are as advantageous for rice as they are for most short-cycle crops.

Very good suitability ratings are assigned to poor and imperfect drainage. Stagnant water should be avoided and very poor drainage merits a mediocre rating. Moderately well drained soil is given a good rating but well-drained soil is considered mediocre; somewhat excessive and excessive drainage conditions are bad.

Light sandy textured soils permit excessive water seepage and heavy textured soils are preferred for rice paddies. General textural classes may be ranked as very good (very heavy texture), good (heavy), mediocre (medium) and bad (light) for wetland rice. Soil pH between 5.0 and 6.5 is ideal and is given a very good rating. Soil reactions close to neutrality (6.6-7.3) are good, but strongly acid

(3.5-5.9) and moderately alkaline (7.4-8.3) conditions are mediocre. Soil pH < 3.5 or > 8.3 is bad. Suitability rankings assigned to beans and garlic for organic matter content, cation exchange capacity and available phosphate are appropriate also for rice (see Table 20 and Figure 24).

Site suitability ratings. The frequency distribution of sites by rice suitability class (Table 21) differs completely from that of other crops. No less than 94 percent of the sites are bad, principally because flat land is required for paddy construction. Steep slopes are the norm in the watershed and only 33 sites have gradients between 0 and 8 percent; 13 sites which satisfy slope requirements are still bad for rice because of shallow soils, high elevation or the cumulative effect of site characteristics with low scores. Half of the 20 good or mediocre sites are associated with floodplains and terraces of Las Cuevas River (Figure 25).

Grazing

Site characteristic suitability classes. Natural grassland, like permanent crops, is a less intensive land use than short-cycle cropping. Natural grasses grow on infertile soils and soil chemical properties need not be considered in site suitability evaluation. Texture and drainage also are relatively unimportant. Suitability

TABLE 20

Ranked Site Characteristics for Rice

Characteristic	Rank	Characteristic	Rank
Elevation (m)		Texture *	
>1950	Severe	Very Heavy	Very good
<1950	Very good	Heavy	Good
		Medium	Mediocre
		Light	Bad
Slope (%)		pH *	
>8	Severe	<3.5	Bad
7-8	Bad	3.5-4.9	Mediocre
5-6	Mediocre	5.0-6.5	Very good
2-4	Good	6.6-7.3	Good
<2	Very good	7.4-8.3	Mediocre
		>8.3	Bad
Soil depth (cm)		Organic matter (%) *	
>90	Very good	>6.0	Very good
60-90	Good	4.3-6.0	Good
40-59	Mediocre	2.0-4.2	Mediocre
15-39	Bad	<2.0	Bad
<15	Severe		
Stoniness (%)		CEC (meq/100 gm) *	
<0.1	Very good	>40	Very good
0.1-2.9	Good	26-40	Good
3.0-14.9	Mediocre	12-25	Mediocre
15.0-90.0	Bad	<12	Bad
>90.0	Severe		
Drainage		Phosphate (ppm) *	
Excessive	Bad	>60	Very good
Somewhat exc.	Bad	31-60	Good
Well-drained	Mediocre	10-30	Mediocre
Mod. well	Good	<10	Bad
Imperfect	Very good		
Poor	Very good		
Very poor	Mediocre		

* A horizon

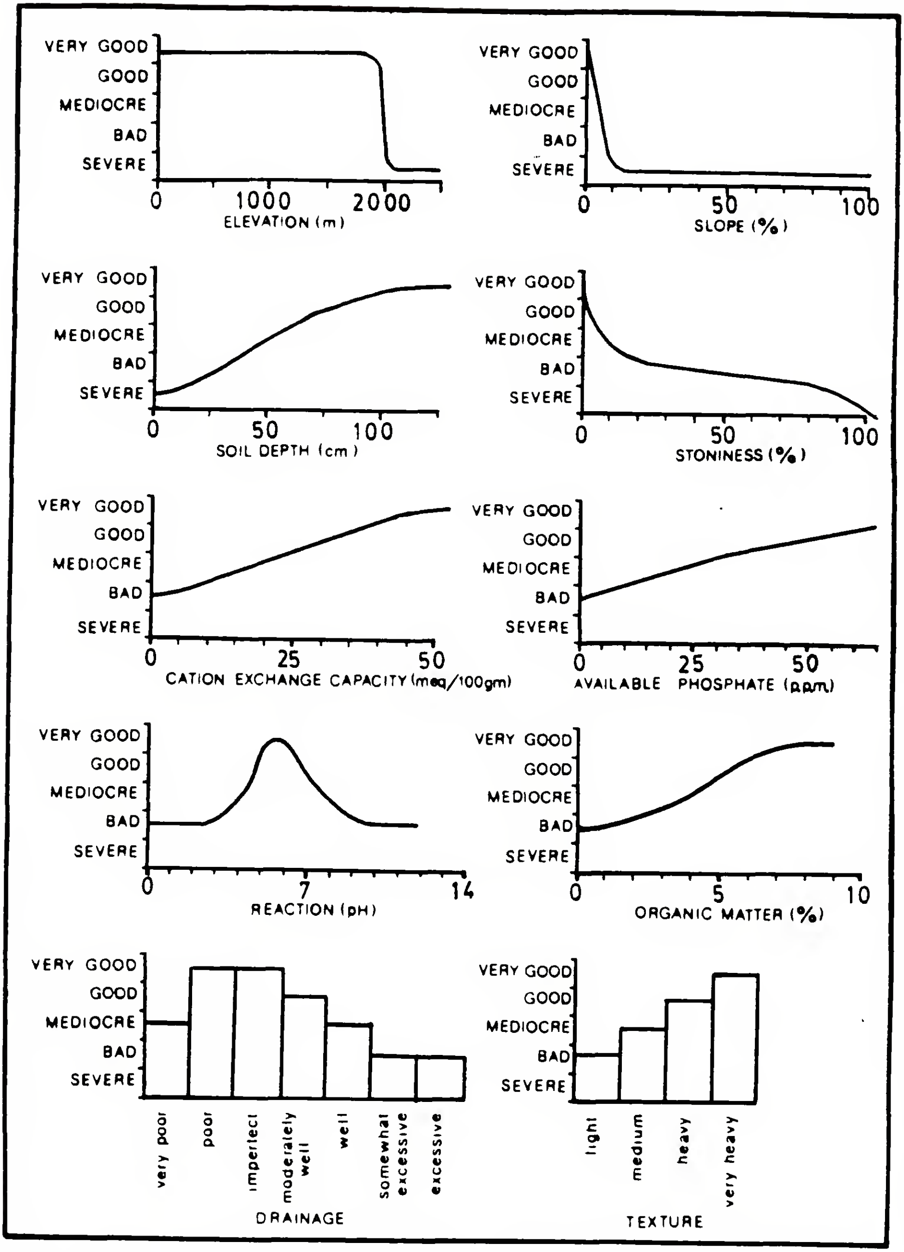

Figure 24. Suitability of Land Characteristics for Rice

TABLE 21

Site Suitability for Rice

(a) Frequency Distribution of Sites by Suitability Class

Class:	Very Good	Good	Mediocre	Bad	Total
No. of Sites	-	4	16	330	350
Percentage	-	1	5	94	100

(b) Impact of Limiting Variables on Site Suitability

Limiting Variable	Severe Class	No. Sites	Percent
Elevation (m)	>1950	58	17
Soil depth (cm)	<15	80	23
Slope (percent)	>8	317	91
Stoniness (percent)	>90	15	4

Note: Limiting variables were classified as severe at 328 (94 percent) of the soil survey sites; of those, 207 were rendered bad for rice by one limiting variable, 100 by two variables and 21 by three variables.

Data source: Antonini et al. (1985)

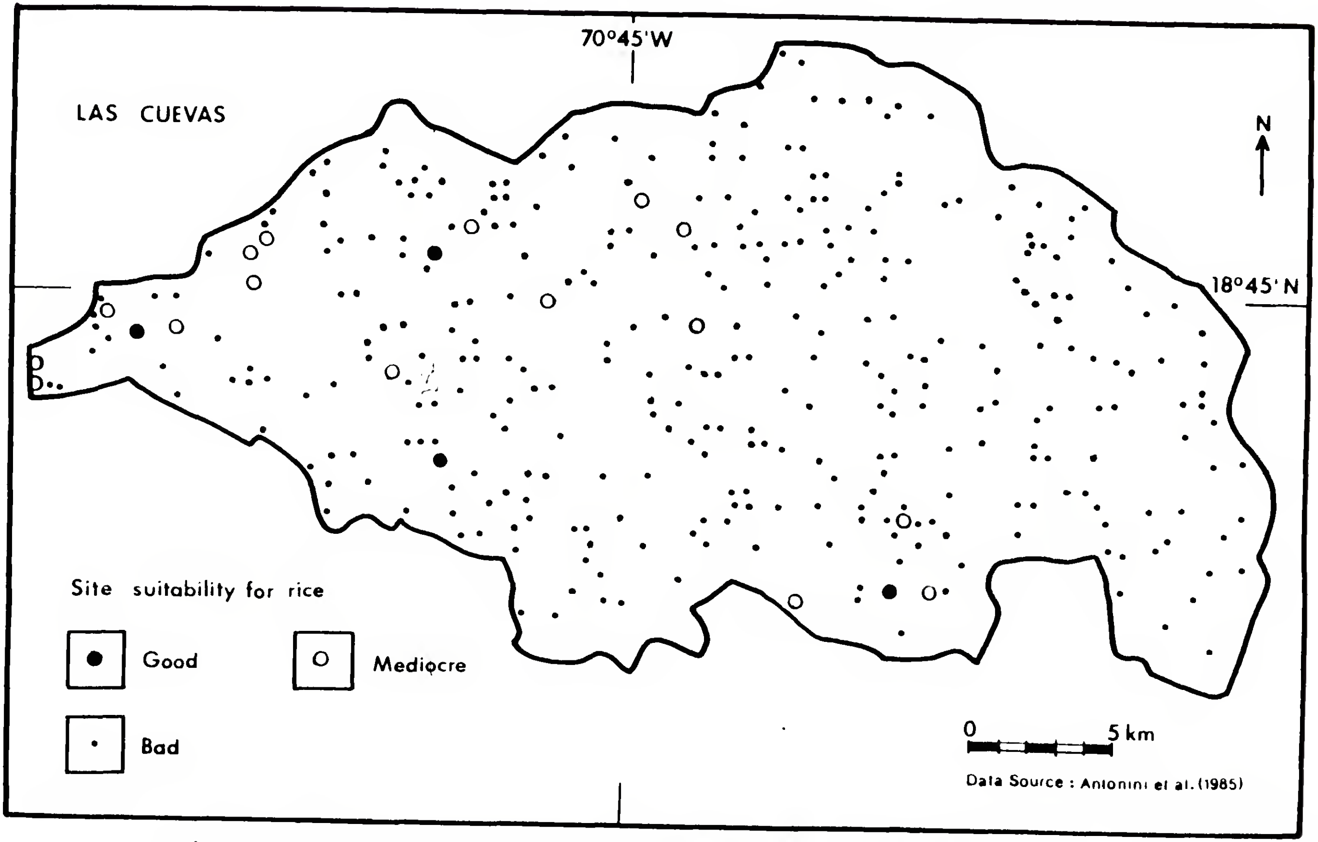

Figure 25. Site Suitability for Rice in Las Cuevas Watershed

scales of slope, soil depth and stoniness established for coffee are adopted for grazing (see Table 22 and Figure 26).

Site suitability ratings. The discussion of suitable garlic sites in Las Cuevas showed that freedom from the limiting power of elevation led to an improvement in the suitability of a modest number of sites in the high eastern area. When most soil properties are ignored, as in the site suitability index for grazing, 25 eastern sites are upgraded further to good or very good. Figure 27 shows that a large number of sites are upgraded also in other parts of the watershed, near Padre Las Casas, Arroyo La Savila, El Recodo and La Siembra. Almost one-third of the sites are good or very good for grazing but, as shown in Table 23, there are 167 sites (48 percent) classified as bad; soil depth is the principal limiting factor but 69 sites (20 percent) owe their bad rating to the cumulative effect of bad scores.

TABLE 22

Suitability Rankings of Site Characteristics for Grazing

Site Characteristic	Category	Rank
Slope (percent)	>65	Severe
	43-65	Bad
	37-42	Mediocre
	28-36	Good
	0-27	Very good
Soil depth (cm)	>90	Very good
	60-90	Good
	30-59	Mediocre
	15-29	Bad
	<15	Severe
Stoniness (percent)	<0.1	Very good
	0.1-2.9	Good
	3.0-14.9	Mediocre
	15.0-90.0	Bad
	>90.0	Severe

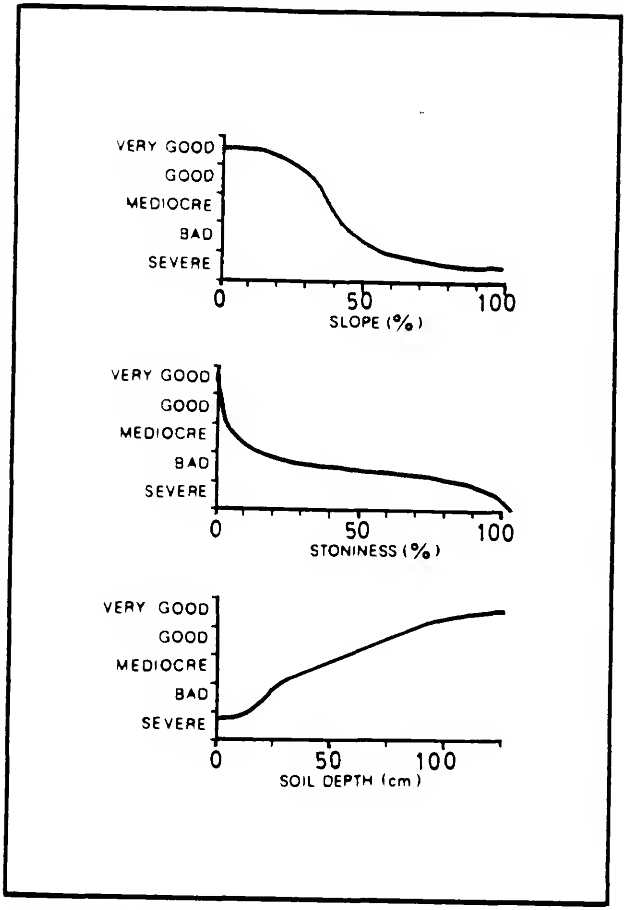

Figure 26. Suitability of Land Characteristics for Grazing

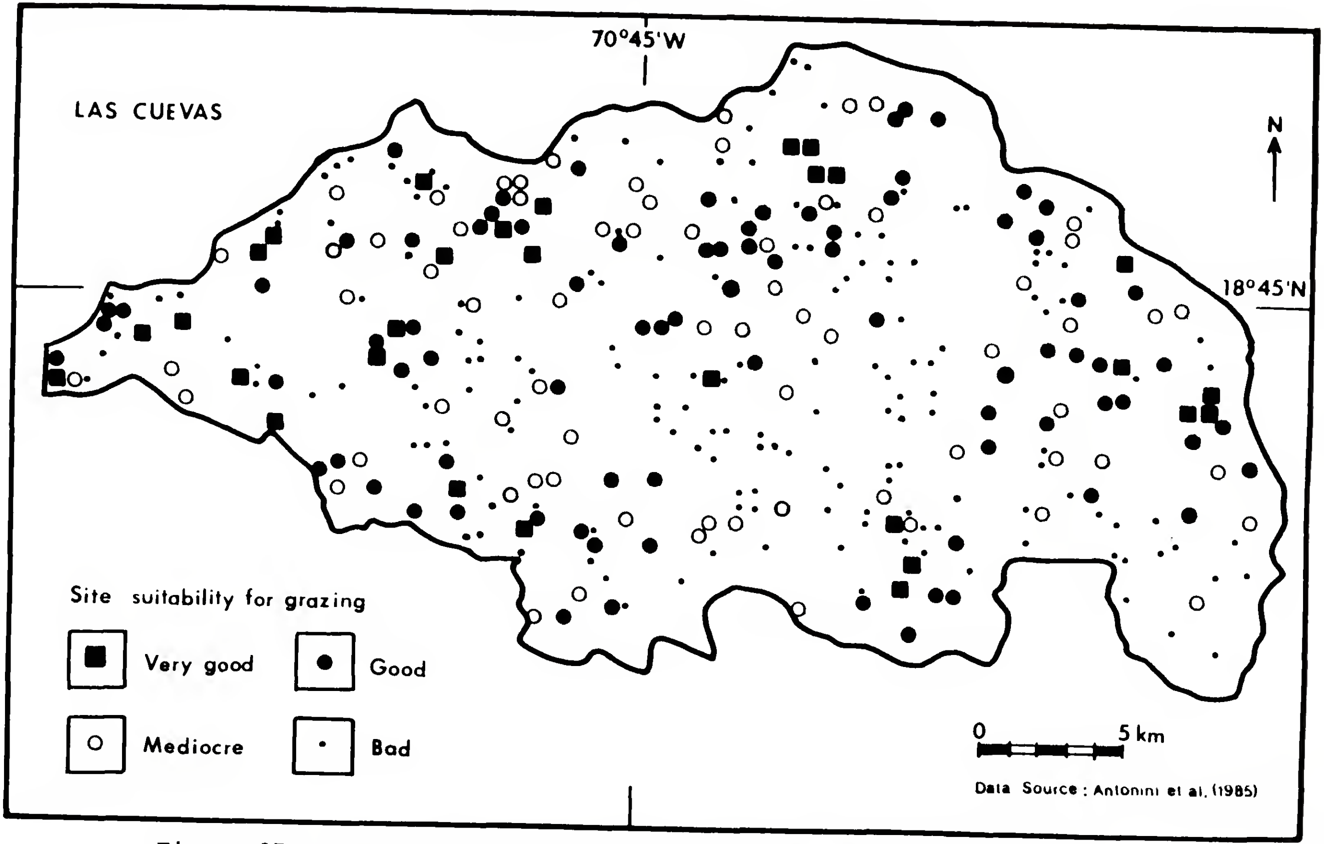

Figure 27. Site Suitability for Grazing in Las Cuevas Watershed

TABLE 23

Land Suitability for Grazing

(a) Frequency Distribution of Sites by Suitability Class

Class:	Very Good	Good	Mediocre	Bad	Total
No. of Sites	29	82	72	167	350
Percentage	8	23	21	48	100

(b) Impact of Limiting Variables on Site Suitability

Limiting Variable	Unsuitable Class	No. Sites	Percent
Soil depth (cm)	<15	80	23
Slope (percent)	>65	22	6
Stoniness (percent)	>90	15	4

Note: Limiting variables were classified as unsuitable at 98 (28 percent) of the soil survey sites; of those, 83 were rendered unsuitable for grazing by one limiting variable, 9 by two variables and 6 by three variables.

Data source: Antonini et al. (1985)

CHAPTER VI
FARMING SKILLS ANALYSIS IN LAS CUEVAS WATERSHED

Introduction

The prime objective of this study is to compare the author's suitability ratings for Las Cuevas land uses to local farmers' opinions of site suitability. It is necessary, therefore, to gain an appreciation of farming skills in the watershed. As a result, this chapter examines information on Las Cuevas farmers collected by Montanez (1985) in 1984 and the author in 1986; an analysis is made of the degree of modernization of Las Cuevas farming technology, awareness of soil erosion, local soil taxonomy and farmers' opinions of specific criteria for agricultural site evaluation--rainfall, temperature, soil depth, color, drainage, texture, stoniness and slope.

Agricultural Technology

A re-examination of data collected in 1984 for a sample of 211 farmers (Montanez, 1985) and a comparison with data from the author's 1986 survey of 80 farmers provide a basis for evaluating farming technology in the watershed. The corresponding data files include observations of presence or absence of six major inputs associated with neotechnic agriculture--fertilizer, insecticide, herbicide, irrigation, power (animal or tractor) and soil conservation practices. Table 24 shows absolute frequency and percentage of farmers using each input in the 1984 and 1986 surveys. Both samples confirm limited adoption of neotechnic agricultural methods. Fertilizer is used by less than one-third of the farmers and insecticide is applied on only 19 percent of the farms. Few farms have irrigation systems or tractors. More than one-half of the farmers do not even make use of oxen.

The percentage of farmers using irrigation and mechanization differs between sample surveys. They are slightly lower in the 1986 sample which was derived from a map of randomly distributed soil survey sites (Antonini et al., 1985) and favored middle- and large-holdings. The 1984 sample (Montanez, 1985) was drawn from a land-holder list containing a greater proportion of small farms with intensive agriculture, particularly short-cycle farms on the alluvial plain at Padre Las Casas. Fifteen of the 17 mechanized farms sampled in 1984 adjoin Padre Las Casas and 13 have an area of less than 100 tareas; 8 farms specialize in rice production and all but one are irrigated.

Aquino Gonzalez (1978), Dore y Cabral (1982) and Vicens (1982) may be correct in relating neotechnic production to large land-holdings on the coastal plain and interior lowland of Dominican Republic, but owners of large farms in mountainous Las Cuevas display little interest in modern

TABLE 24

Modern Technological Inputs in Las Cuevas Farms

Input	Survey of 1984 * (sample of 211 farms)		Survey of 1986 ** (sample of 80 farms)	
	No. farmers	Percent	No. farmers	Percent
Fertilizer	59	28	18	23
Insecticide	40	19	15	19
Herbicide	1	0.5	2	3
Irrigation	31	15	6	7
Animal power	68	32	36	45
Tractor	17	8	2	3
Conservation	11	5	13	16

Data sources: * Montanez (1985)
** the author's 1986 farmer survey

inputs. Sloping land discourages investment in irrigation and tractors. Furthermore, short-cycle crop production on large farms of the watershed is merely a supplement to coffee growing and/or extensive grazing.

A simple additive index of modern technology can be derived using available information on inputs (Table 25). Where present, each input contributes one point to the index which can have, as a result, a maximum summed score of six. In the case of energy, one-half point is added to the index if the power source is animal and one full point is assigned if tractors and fossil fuels are used.

In contrast to abundant scientific literature on land evaluation, there is a dearth of information on agricultural technology evaluation. No recommendations are available on the comparative merit of additive and multiplicative indices for this purpose. If the objective of the index were to predict crop yields, it could be argued that the multiplicative approach is appropriate. None of the inputs is truly limiting because paleotechnic farmers have shown that sustained production is possible without any of the inputs. On the other hand, without the secure supply of water provided by irrigation, benefits of other inputs are greatly reduced. Even addition of both water and fertilizer to the field may be unsuccessful if the increased yield is consumed by pests. It is also true that soil which is not protected by conservation practices will not be spared from erosion by herbicides.

TABLE 25

Scores Used to Compute the Technological Index for Las Cuevas Farms

Input	Status	Score
Fertilizer	Absent	0
	Present	1
Insecticide	Absent	0
	Present	1
Herbicide	Absent	0
	Present	1
Irrigation	Absent	0
	Present	1
Energy	Human	0
	Animal	0.5
	Tractor	1
Conservation	Absent	0
	Present	1

Note: The technological index is the sum of scores assigned to inputs. Its value may vary from 0 to 6.

The function of the index in this study, however, is to measure the degree of modernization of the farmer and the straightforward additive approach is sufficient to demonstrate how many components of the neotechnic "package" have been adopted. For the sake of simplicity, equal weight is assigned to all inputs.

In the 1984 sample of 211 farmers, the value of the technological index varies from 0 to 4.5 and the arithmetic mean (0.917) is very low. The 80 farms investigated in 1986 have the same minimum and maximum values and the mean (0.913) is almost identical. Table 26 indicates the frequency distribution of farmers according to three levels of technology which are defined using the technological index. The lowest level is composed of farms which use no modern inputs or are limited to use of oxen to till the land. In both samples, more than one-half of the farmers are assigned this low technological rating. In contrast, the highest level of technology is represented principally by mechanized and irrigated farms; the frequency is higher in the 1984 survey because that sample included a cluster of small mechanized and irrigated land-holdings near Padre Las Casas. Only three farmers surveyed in 1986 are classified at the highest technological level and two of these farmers also cultivate on the irrigated floodplain at Padre Las Casas.

TABLE 26

Classification of Las Cuevas Farmers by Technological Level

Level of Technology	Index	Sample of 1984* (211 farmers)		Sample of 1986** (80 farmers)	
		Number	Percent	Number	Percent
Low	<1	139	66	43	54
Moderate	1-3	43	20	34	42
High	>3	29	14	3	4

Data sources: * Montanez (1985)
** the author's 1986 farmer survey

Pearson correlation coefficients in Table 27 show that the technological index, in general, is not related to farm size. While farms which adopt neotechnic methods are mostly small and located on the alluvial floodplain, there are many other small farms located on slopes which use no modern cultivation techniques. Table 28 shows that almost two-thirds (63 percent) of farms observed with < 100 tareas in 1984 merit a technology index < 1 and belong to the lowest level of technology.

Correlation of technology to age and education also is weak; Table 27 gives low values of the respective coefficients which are not statistically significant in both farmer surveys. Limited influence of education and age on technological adoption is consistent with the Montanez (1985) thesis that farmer perception of soil erosion is unrelated to education or age. It appears that farmers who have attended school were given little instruction relevant to agriculture and young farmers simply follow the example of their elders.

Although the technological index was not designed to predict crop yields, it is clearly related to yields of beans (Table 27). The relatively high correlation coefficient (0.706) is remarkable considering that yields are conditioned also by land suitability. The association between technological index and bean yield is confirmed at the 99 percent level of confidence by the corresponding t-

TABLE 27

Correlation of the Technological Index with Other Variables

Variable	Sample of 1984 (211 farmers)	Sample of 1986 (80 farmers)
Age	- 0.109	- 0.273 *
Education	0.230 **	0.102
Farm Size	- 0.015	- 0.034
Bean Yield (170 observations)	0.706 **	-

* correlation is significant at 95 percent level of confidence (a = 0.05)
** correlation is significant at 99 percent level of confidence (a = 0.01)

Data sources: Sample of 1984 (Montanez, 1985)
Sample of 1986 (the author)

TABLE 28

Frequency Distribution of Farms by Size and Level of Technology, 1984

Technology	Farm Size (tareas)									
	<100		100-250		251-750		751-5000		>5000	
Low	47	(63)	33	(65)	20	(56)	24	(92)	15	(65)
Moderate	12	(16)	12	(23)	11	(30)	2	(8)	6	(26)
High	16	(21)	6	(12)	5	(14)	0	(0)	2	(9)
TOTAL	75	(100)	51	(100)	36	(100)	26	(100)	23	(100)

Note: Values in parenthesis are percentages of farms in each farm size category.

Data source: Montanez (1985)

test and the relationship is expressed visually in Figure 28 as a scattergram.

Low values of the technological index demonstrate that Las Cuevas farmers, in general, cannot be considered neotechnic agriculturalists. On the other hand, their farming methods are not truly traditional because key elements of the paleotechnic model are missing.

Like traditional agriculturalists, most farmers in Las Cuevas rely on local natural and human resources, cultivate a mixture of crops on irregularly shaped fields and use fallow periods to regenerate soil fertility. Beans are inter-planted with corn in cool high altitude areas and mixed with pigeon peas, corn and cassava at lower altitudes. Coffee is inter-planted with bananas until other trees, such as guama and avocado, grow tall enough to provide shade. Their polyculture, however, does not seem to be sophisticated enough to protect crops from pests; 65 percent of farmers interviewed in 1986 declared pests and disease to be serious problems. In addition, some farms have rejected the custom of polyculture and adopted temporal rotation of crops. In particular, irrigated farms on the alluvial floodplain cultivate beans in rotation with peanuts and/or rice.

Traditional farms are distinguished by skilful use of multiple varieties of crops which are carefully bred and finely tuned to local environmental variations. In Las

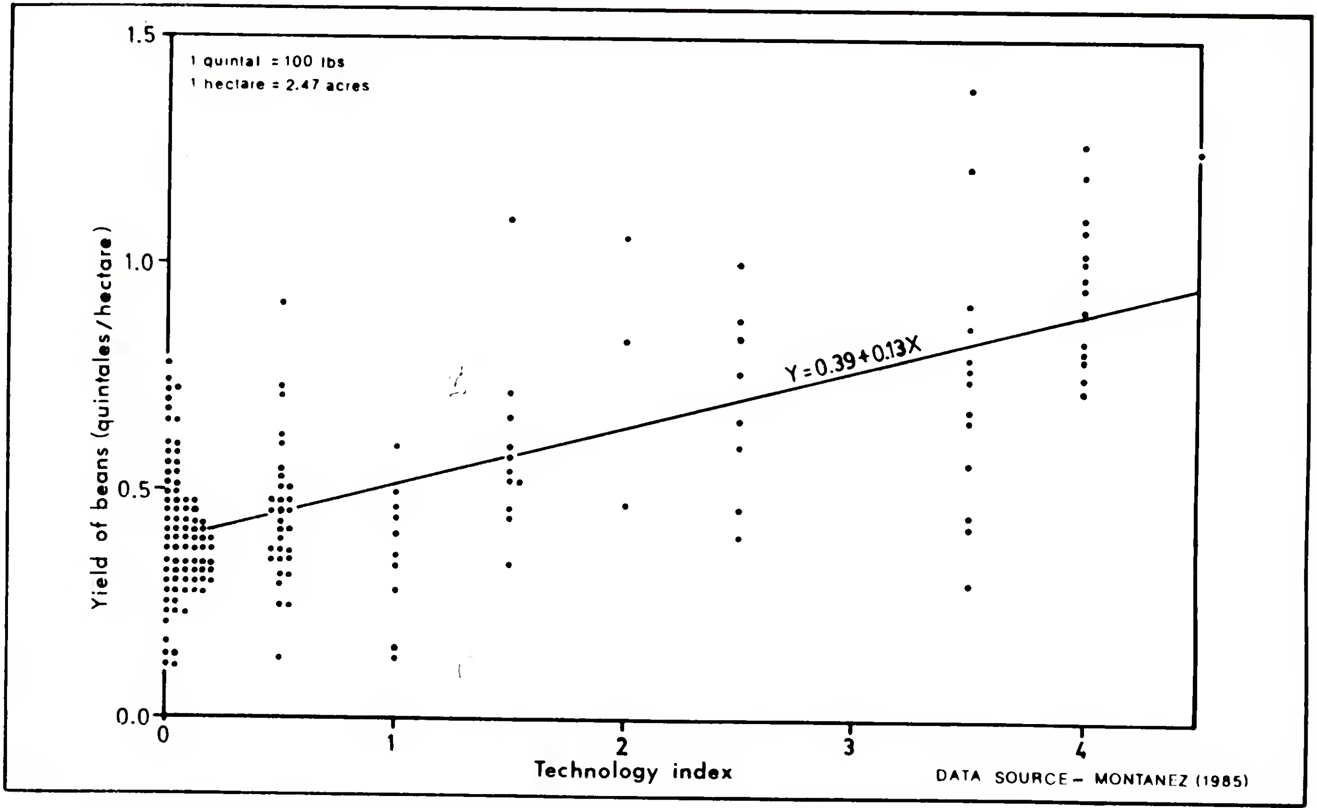

Figure 28. Modern Agricultural Technology and Bean Yields in Las Cuevas

Cuevas, however, there are external forces which encourage adoption of a reduced number of cultivars. Government agronomists are promoting replacement of local strains of typica and bourbon coffee with the new dwarf caturra cultivar. Peanut farmers obtain their seeds from the local manufacturing plant. Farmers who produce beans are dependent increasingly on seeds supplied by a small number of powerful intermediaries and moneylenders; the variety Checa is now sown by 56 percent of bean farmers in the Dominican Republic (INESPRE, 1983). There may be a large variety of cultivars of crops more closely associated with subsistence; Box (1987) reports the existence of more than 70 varieties of cassava elsewhere in the Dominican Republic.

True paleotechnic agriculture is associated with shifting cultivation and long-term forest fallows, or sophisticated systems based on earthworks and water management. As mentioned above, however, production of short-cycle crops in Las Cuevas is more akin to a fallow system. Plots are irregular and unfenced but there is private ownership and a clearly defined distribution of land among users; fallows are short and forest cover is sparse. Farmers in Las Cuevas still follow advice from their elders but soil degradation and falling productivity have made them lose self-esteem for their own farming skills. They increasingly yearn for technical assistance and the inputs of neotechnic agriculture, especially fertilizer.

Awareness of Soil Erosion in Las Cuevas

Farmer awareness of soil erosion is widespread in the watershed. No less than 62 of the 80 farmers (78 percent) interviewed in 1986 were aware of the process. Thirty-eight farmers (48 percent) attributed knowledge of soil erosion to contact with extension agents and, in particular, with representatives of the SEA project which was established to promote soil conservation in the watershed. The other 24 farmers (30 percent) declared that they learned about soil erosion from their parents or from personal observation. The term "erosion" is rarely used by farmers but they describe the process well in their own words. Although farmers seem to be aware of soil erosion, Table 24 shows that there is still little interest in soil conservation and only 13 of the 80 farmers (16 percent) have adopted soil conservation practices. Two farmers have constructed ditches to divert runoff while the other 11 have built barriers of stones or crop residues across the slope to reduce the rate of downhill movement of soil and water. Limited adoption of soil conservation practices appears to support the views of Pearson and Pryor (1978) and Blaut (1984) who believe that farmer awareness by itself will not solve the problem of soil erosion in tropical steeplands. The marginalized peasant will continue to mine the soil unless he is provided with secure access to good agricultural land and supported by effective financial and technical assistance. On the other hand, there are owners of middle- and large-holdings in the watershed who have sufficient resources to apply conservation measures but continue to till land or graze livestock without protecting the soil. Twenty-seven of the farmers surveyed in 1986 have access to more than 750 tareas of land but only six of these land-owners use conservation methods. Like farming technology, soil conservation does not become more significant on large farms in Las Cuevas.

Farmer Soil Taxonomy in Las Cuevas

Las Cuevas farmers interviewed in 1986 were asked to describe soils observed on their farms. None of the farmers named more than six soils and only 25 percent distinguished more than three soils. Table 29 lists soils perceived by farmers and the frequency with which they were identified.

Las Cuevas farmers, like Middle American counterparts, distinguish soils by color and texture. Black is the most frequently cited soil color. White soil, sometimes called caliche, is identified by one-third of the farmers; gray and grayish-brown soils may be variants of this soil class. Other soil colors identified are yellow and red.

The most important soil texture is clayey soil which is mentioned by 33 farmers (38 percent). Clayey soils simultaneously are described as red in color by 6 farmers; thus, red soil and clayey soil taxa may overlap. There may be an additional overlap of yellow soil and clayey soil

TABLE 29

Soil Taxonomy of Las Cuevas Farmers Surveyed in 1986

Soil classes identified by the farmers	Number of farmers referring to the soil class	Percent
Black soil (tierra negra)	74	88
Yellow soil (tierra amarilla)	18	23
Red soil (tierra colorada)	9	11
Grayish-brown soil (tierra parda)	4	5
Gray soil (tierra gris)	1	1
White soil (tierra blanca/caliche)	27	34
Clayey soil (tierra barrosa)	33	38
Sandy soil (tierra arenosa)	15	19
Gravelly soil (tierra de cascajo)	6	8
Stony soil (tierra de laja)	1	1

Data source: the author's 1986 farmer survey.

because 4 farmers declared clayey soil to be yellow. Sandy soils were identified by 15 farmers (19 percent). Stone content rarely was used to classify soil; 6 farmers indicated the existence of gravelly soil while only 1 interviewee referred specifically to stony soil.

Ashby (1985), in a study of Colombian mountain farmers, found that they applied three names--black soil (tierra negra), mixed soil (tierra mezclada) and red soil (tierra colorada)--to the same soil at different stages of soil erosion. She implied that Colombian farmers are aware of the erosive process which gives origin to these three soils. In contrast, informal conversations with 80 farmers in Las Cuevas revealed to the author that only 4 farmers perceived such a relationship between soils of different color. A coffee farmer, also General Secretary of the National Confederation of Peasants, indicated the existence of five kinds of soil--black, black over yellow, black over red, red, red over white. None of the other farmers gave such an explicit description of soil color horizons. Another farmer, who makes regular visits to agronomists in Padre Las Casas and Constanza, explained how black soil is washed away leaving behind underlying yellow soil. In an innovative experiment, he is planting apple trees in small pits excavated into yellow subsoil and filled in with remains of an eroded black topsoil. A third farmer, who attended a course in conservation, complained that his coffee was giving poor yields but could not be replaced by alternative crops because the best soil had been lost and only white soil was left. The fourth farmer, perceptive of soil horizons, was a woman who had no formal training but explained that soils vary according to the quantity of material that has been stripped off the land by falling rain; she pointed out the contrast between black soil under woodland and eroded yellow soil on gully slopes.

All 61 farmers who pointed out existence of black soil considered it to be the most fertile soil of all. Forty-one farmers, however, were unable to explain the origin of its black color. All but one who referred to caliche emphasized its very low agricultural potential. Yellow, red, clayey and sandy soils, generally, were considered inferior to black soil but preferable to caliche.

Farmer and Scientific Criteria for Agricultural Site Evaluation

It is difficult to compare criteria used by scientists and farmers for evaluation of site suitability. Scientific concepts such as pH, cation exchange capacity and phosphate status are meaningless to the peasant. Even opinions on crop requirements of temperature, rainfall and slope are difficult to compare because most tropical steepland farmers do not recognize scientific scales of measurement such as degrees Centigrade, millimeters of rainfall and percent slope. Similarly, scientists know little of farmers' site evaluation criteria.

An attempt was made during the 1986 farmer survey to compare scientific and farmer evaluation criteria. The eight land characteristics chosen for this purpose were rainfall, temperature, soil depth, soil color, drainage, texture, stoniness and slope. Considered relevant to crop growth by scientists, these variables also are obvious environmental characteristics that can be defined by the interviewer in a straightforward manner. Furthermore, folk soil taxonomy literature suggests they are used by many peasants to classify soils.

The farmer was asked to assign one of three ranked categories--not important, somewhat important, or very important--to each site characteristic according to its significance for his principal agricultural use. For each variable considered somewhat or very important, the farmer subsequently selected one of three appropriate ordinal values. In the case of slope, for example, the author described flat land, gentle slopes and steep slopes and asked the farmer to specify which of these three conditions is optimal for his main activity.

Rainfall. The principal agricultural uses of Las Cuevas farmers in 1986 were coffee, beans, pigeon peas, garlic, rice and pasture. Scientific studies of crop requirements reviewed in Chapter III show that coffee is grown in a variety of rainfall regimes although moderate rainfall is preferred. Vulnerability to drought and sensitivity to diseases associated with intense humidity make moderate rainfall even more strongly recommended for beans. Heavy rainfall is detrimental to vegetative growth and bulb formation of garlic which usually is produced in dry areas, with irrigation water applied periodically during initial stages of growth. Pigeon peas grow well under all conditions of moisture, irrigated rice cultivation is largely independent of rainfall, and livestock can be grazed under a broad range of moisture regimes.

Rainfall was considered very important by 79 of the 80 surveyed farmers including the 6 land-holders with irrigation facilities. As one farmer explained, bean cultivation is a risky venture even in irrigated areas because water supply can be unreliable during dry periods and irrigation does not solve problems associated with excessive rainfall. Table 30 shows that farmers' opinions of rainfall requirements correspond in general to those of the scientific literature. Moderate rainfall was recommended by three-quarters of the coffee farmers, both land-holders who cultivate pigeon peas and all but one of the bean farmers. The rice farmer's recommendation of abundant rainfall probably reflects unreliable supply of irrigation water. Two coffee farmers and one rancher considered conditions of low rainfall to be ideal; both coffee plantations are located at high altitudes (approximately 1500 m) and, as one of the owners pointed out, coffee in such cool areas requires less rainfall.

TABLE 30

Farmer Recommendations of Rainfall

Ratings of the Significance of Rainfall:

	Not Important	Somewhat Important	Very Important
Coffee farmers	-	1	38
Bean farmers	-	-	27
Ranchers	-	-	10
Others	-	-	4
TOTAL	-	1	79

Farmer Recommendations of Rainfall Requirements:

	Quantity of Rainfall		
	Low	Moderate	Abundant
Coffee farmers	2	29	8
Bean farmers	-	26	1
Ranchers	1	4	5
Others	-	3 **	1 *
TOTAL	3	62	15

* rice
** pigeon peas and garlic

Data source: the author's 1986 farmer survey.

Temperature. Scientific literature reviewed in Chapter III suggests that arabica cultivation is most successful in temperate to warm conditions with mean annual temperature between 16 and 24 degrees Centigrade; growth is inhibited by very high temperatures while nocturnal frost can cause harm in cool climates. Beans are associated with a wide range of thermal regimes and tropical cultivars grow well at altitudes of up to 1950 m. Cool climates are not suitable for pigeon peas which are most productive at altitudes < 1500 m. In contrast, garlic suffers in intense heat and prefers temperate or cool conditions. Rice cultivation is most successful when the growing season is temperate or warm with mean monthly temperatures of over 20 degrees Centigrade while mobility of livestock lends flexibility to temperature requirements of ranching.

Farmer evaluations are not as straightforward for temperature as they are for rainfall. Table 31 shows that 13 land-holders declared temperature to be of no importance whatsoever for their main land use. In addition, 5 persons offered ambiguous evaluations. One ambiguous coffee farmer stated that coffee can be grown in both hot and temperate climates while another said that both cool and temperate conditions are suitable. The other 3 farmers provided enlightening justifications for their ambiguity. A rancher, who said that both hot and temperate conditions are suitable for livestock, explained that he moves his animals to hot

TABLE 31

Farmer Recommendations of Temperature

Ratings of the Significance of Temperature:

	Not Important	Somewhat Important	Very Important
Coffee farmers	6	2	31
Bean farmers	6	4	17
Ranchers	1	2	7
Others	-	-	4
TOTAL	13	8	59

Farmer Recommendations of Temperature Requirements:

	Temperature Conditions		
	Hot	Temperate	Cool
Coffee farmers	3	21	7
Bean farmers	3	12	4
Ranchers	4	3	1
Others	2 *	2 **	-
TOTAL	12	38	12

* rice and pigeon peas
** garlic and pigeon peas

Data source: the author's 1986 farmer survey.

low-altitude pastures (tierra caliente) in the cool season and to temperate high-altitude plots (tierra templada) in the warm season. Similar seasonal altitudinal migrations were reported in subsequent interviews by two additional ranchers. The two ambiguous bean farmers described a parallel altitudinal strategy for cultivation of short-cycle crops; they produce beans on hot low-altitude plots in the cool season and obtain a supplementary harvest in the warm season on temperate high-altitude fields. The use of complementary ecological niches by ranchers and bean farmers represents a seasonal flight from thermal extremes and a search for temperate conditions. In subsequent interviews, three other bean farmers said that they also make alternate use of high- and low-altitude plots. Those who only have access to high-altitude land are restricted to planting beans in the warm season.

The remaining 62 farmers made an unambiguous selection of one of the three ordinal classes of temperature. Their opinions corresponded, in general, to those expressed in scientific literature. The majority of coffee-growers and bean farmers considered temperate conditions to be most appropriate. Cool conditions were not recommended by the producers of rice and pigeon peas. The garlic farmer preferred temperate climates and did not recommend hot conditions.

<u>Soil depth</u>. Scientific literature emphasizes the importance of deep soil for all of the principal agricultural uses surveyed in Las Cuevas. The author had great difficulty, however, in explaining the concept of soil depth to many Las Cuevas farmers, who, in keeping with Middle American Hispanic and indigenous counterparts, classify soil according to spatial variation in surface soil; this differs from the scientist's perception of soil as three-dimensional and definable by diagnostic horizons (Williams and Ortiz-Solorio, 1981). Las Cuevas farmers do not consider soil a living body of finite dimension underlain by inert parent material. Comments above on awareness of soil erosion confirm that extension agents have convinced many local peasants there is a process of soil degradation; the author's interviews with local farmers suggest, however, that the concept of a diminishing soil profile has not been grasped by the majority. Table 32 shows that no less than 50 of the 80 farmers did not understand the property of soil depth and rated it unimportant for their main agricultural uses. Paradoxically, ten of the thirteen farmers who have adopted soil conservation practices are included in this group. All of the remaining 30 farmers who appreciated soil depth knew about soil erosion but only three apply soil conservation.

<u>Soil color</u>. When asked if soil color is important, farmers who gave an affirmative response immediately

TABLE 32

Farmer Recommendations of Soil Depth

Ratings of the Significance of Soil Depth:

	Not Important	Somewhat Important	Very Important
Coffee farmers	23	2	14
Bean farmers	18	-	9
Ranchers	7	-	3
Others	2 **	-	2 *
TOTAL	50	2	28

* pigeon peas and garlic
** pigeon peas and rice

Farmer Recommendations of Soil Depth Requirements:

	Soil Depth		
	Deep	Average	Shallow
Coffee farmers	14	2	-
Bean farmers	9	-	-
Ranchers	3	-	-
Others	2 *	-	-
TOTAL	28	2	-

* pigeon peas and garlic

Data source: the author's 1986 farmer survey.

mentioned black soil and extolled its virtues although, as pointed out above, the majority are unaware of its origin. Some dark soils with expanding clays or volcanic scoria do not have a high humus content. In general, however, soils become darker with increasing amounts of organic matter and dark topsoil commonly is associated with potential fertility. Scientific literature stresses benefits of soil organic matter for cultivation of coffee, beans, garlic and rice. High levels of organic matter may not be suitable for pigeon peas but a moderate amount still is recommended because it promotes development of soil structure and improves resistance to erosion. Improved pasture benefits from humic soils but natural pasture grows without difficulty on infertile soil.

In agreement with the literature, almost all bean farmers and 77 percent of coffee farmers expressed a preference for dark soil (Table 33). The farmers with rice and garlic shared that opinion. Good yields of pigeon peas are obtained even on infertile soil and it is not surprising that one of the two farmers specializing in that crop should consider soil color unimportant. Grazing in Las Cuevas is based on hardy unimproved yaragua grass (Melinis minutiflora) which easily invades any soil. As a result, only 2 of the 10 ranchers considered dark soil necessary.

Drainage. The literature indicates good drainage is necessary for coffee, beans, garlic and pigeon peas. Areas

TABLE 33

Farmer Recommendations of Color

Ratings of the Significance of Color:

	Not Important	Somewhat Important	Very Important
Coffee farmers	8	1	30
Bean farmers	2	-	25
Ranchers	8	-	2
Others	1 **	-	3 *
TOTAL	19	1	60

* pigeon peas
** pigeon peas, garlic and rice

Farmer Recommendations of Color Requirements:

	Color		
	Very Dark	Somewhat Dark	Light
Coffee farmers	30	1	-
Bean farmers	25	-	-
Ranchers	2	-	-
Others	3 *	-	-
TOTAL	60	1	-

* pigeon peas, garlic and rice

Data source: the author's 1986 farmer survey.

with poor drainage are appropriate for wetland rice while cattle can be grazed in all conditions of drainage. Like soil depth, the term "drainage" is meaningless to Las Cuevas peasants. Once drainage was described, however, as dealing with rates of water flow over the soil surface, they were prepared to relate the concept to their empirical experience. Only eleven of the 80 land-holders considered drainage to be unimportant (Table 34). In agreement with scientific opinion, the majority pointed out negative consequences of both rapid and slow drainage. One coffee farmer, seven bean farmers, and a land-holder specialized in pigeon pea production, departed from conventional scientific wisdom and recommended slow drainage. All of the anomalous farmers cultivate hot low-altitude plots in the vicinity of Las Lagunas, La Siembra and Guayabal; rainfall is scarce, droughts are frequent and hollows which trap runoff can be considered advantageous.

Texture. The scientific literature recommends loamy textures for coffee and beans because clays impede drainage and sandy soils are droughty. Pigeon peas and garlic also prefer loamy soils but they are relatively tolerant of light-textured soil. In contrast, wetland rice requires poor drainage and heavy soils are preferred. There are no specific textural requirements for grazing.

The term "texture" conveys no meaning to Las Cuevas farmers but they are aware of differences in soil particle

TABLE 34

Farmer Recommendations of Drainage

Ratings of the Significance of Drainage:

	Not Important	Somewhat Important	Very Important
Coffee farmers	4	4	31
Bean farmers	3	-	24
Ranchers	4	-	6
Others	0	-	4
TOTAL	11	4	65

Farmer Recommendations of Drainage Requirements:

	Drainage		
	Slow	Average	Rapid
Coffee farmers	1	34	-
Bean farmers	7	16	-
Ranchers	-	6	-
Others	2 *	1 **	-
TOTAL	10	57	-

* rice and pigeon peas
** garlic

Data source: the author's 1986 farmer survey.

size and use the terms "clay" and "sand" to classify soils. Farmers do not recognize the words "loam" or "silt". To facilitate communication, loams were described as being soils with a mixture of particle sizes in which neither sand nor clay predominates.

Soil texture was considered unimportant by only 12 farmers of whom 4 were ranchers (Table 35). Five farmers offered ambiguous responses. A rancher considered both clays and loams to be suitable for pasture and four farmers suggested that coffee prefers loams but will grow on certain sands and clays. In agreement with scientific opinion, almost all of the remaining coffee farmers and the majority of the bean farmers declared an unconditional preference for loams. Five bean farmers and one land-holder with pigeon peas contradicted scientific reasoning and recommended clayey soil; they all belong to the group of farmers who preferred poorly drained soil because it retains scarce moisture in a drought-prone environment. Contrary to conventional scientific knowledge and despite the fact that he cultivates a loam, the rice farmer recommended sandy soil.

Stoniness. Scientists take a dim view of soils with stones which interfere with tillage and are believed to impair the soil's capacity to retain moisture. Stones also are considered inconvenient for grazing as they promote discontinuity in grass cover. Contrary to scientific opinion, thirty-one Las Cuevas farmers attached no

TABLE 35

Farmer Recommendations of Texture

Ratings of the Significance of Texture:

	Not Important	Somewhat Important	Very Important
Coffee farmers	5	3	31
Bean farmers	3	-	24
Ranchers	4	-	6
Others	0	-	4
TOTAL	12	3	65

Farmer Recommendations of Texture Requirements:

	Texture		
	Clayey	Mixed	Sandy
Coffee farmers	1	27	2
Bean farmers	5	17	2
Ranchers	-	3	2
Others	1 *	1 **	2 ***
TOTAL	7	48	8

* pigeon peas
** garlic
*** pigeon peas and rice

Data source: the author's 1986 farmer survey.

importance whatsoever to stone content. In addition, only four of those who rated stoniness somewhat or very important declared that it was preferable to cultivate soils without stones. Thirty-four farmers recommended soil with a few stones and seven land-holders even preferred stones in abundance (Table 36).

Four farmers had ambiguous opinions. One coffee farmer and two bean farmers declared that stony soil is suitable whether stones are few or abundant. The fourth ambiguous land-holder was a rancher who believes that stones should be few or absent. In disagreement with conventional scientific wisdom, the farmers who recommend stoniness argue that the presence of a few stones improves moisture retention. One farmer in La Coja turned over stones in his field to show the author that underlying soil was moist.

Slope. Scientific literature recommends avoidance of steep slopes which facilitate soil erosion and make agricultural operations more difficult. Sheng's (1972) slope classification cannot be compared to Las Cuevas farmers' opinions because they do not measure gradients in degrees or as a percentage ratio. Scientists believe that coffee may occupy steeper slopes than beans, garlic or pigeon peas because it is a permanent crop, requires less tillage and has an extensive leaf canopy which protects soil from the erosive impact of falling raindrops. Relatively steep slopes also may be used for pasture as long as density of livestock

TABLE 36

Farmer Recommendations of Stoniness

Ratings of the Significance of Stoniness:

	Not Important	Somewhat Important	Very Important
Coffee farmers	17	3	19
Bean farmers	7	3	17
Ranchers	5	1	4
Others	2 **	-	2*
TOTAL	31	7	42

* pigeon peas
** rice and garlic

Farmer Recommendations of Stoniness Requirements:

	Many Stones	Some Stones	No Stones
Coffee farmers	2	17	1
Bean farmers	4	13	2
Ranchers	1	2	1
Others	-	2 *	-
TOTAL	7	34	4

* pigeon peas

Data source: the author's 1986 farmer survey.

is low. Wetland rice demands flat land which can be irrigated.

More than three-quarters of the farmers considered slope to be an important factor and, in agreement with scientific literature, recommended flat or gently sloping land (Table 37). Coffee farmers were less demanding than other farmers. Twelve of the thirty-nine coffee growers considered slope unimportant and less than one-half stated a preference for flat land. Ranchers prefer flat land because their animals can lose balance and fall on steep slopes.

Conclusions

Las Cuevas farmers use a fallow system that has neither the ecological advantages of paleotechnic techniques nor the productive capacity of the neotechnic approach; this farming system permits survival in a harsh physical and economic environment but it favors environmental degradation. Many of the farmers are aware of soil erosion because they have been targeted by government programs to promote public awareness of the problem. Conservation practices, however, have been adopted by very few. Like Middle American counterparts, Las Cuevas peasants classify soil according to surface color or texture. Although they may have difficulty in perceiving soil as a three-dimensional body, most farmers have a clear understanding of crop requirements. Their recommendations with respect to rainfall, temperature,

TABLE 37

Farmer Recommendations of Slope

Ratings of the Significance of Slope:

	Not Important	Somewhat Important	Very Important
Coffee farmers	12	2	25
Bean farmers	3	2	22
Ranchers	2	-	8
Others	1 *	-	3 **
TOTAL	18	4	58

* pigeon peas
** pigeon peas, rice and garlic

Farmer Recommendations of Slope Requirements:

	Steep	Gentle	Flat
Coffee farmers	-	9	17
Bean farmers	-	1	20
Ranchers	-	-	8
Others	-	1 *	2 **
TOTAL	-	11	47

* pigeon peas
** rice and garlic

Data source: the author's 1986 farmer survey.

color, drainage, texture and slope correspond, in general, to scientific opinion. Once examined in detail, even ambiguous and apparently anomalous recommendations are found to be logical adaptations to local environmental conditions and reflect interactions of site characteristics. Low rainfall may be preferable in cool high-altitude settings; heavy-textured soils and poor drainage may compensate for low rainfall in hot low-altitude areas; and beans can be cultivated at both low and relatively high elevations in the appropriate season.

CHAPTER VII
SUITABILITY RATINGS, FARMER OPINION AND LAND USE IN LAS CUEVAS WATERSHED

Introduction

The understanding which Las Cuevas farmers have of environmental crop requirements, their awareness of soil erosion, their ability to survive severe physical and economic constraints and the intimate empirical experience they have of their own land all suggest that their opinions should be used by scientists concerned with land evaluation for agriculture. The first section of this chapter compares site suitability ratings derived by the author in Chapter V using 1982 soil survey data (Antonini et al., 1985) to farmers' opinions of site suitability obtained during the author's field survey of 1986. The second section examines the relationship between the author's site suitability ratings and existing land cover at all 350 soil survey sites.

Site Suitability Ratings and Farmer Opinion

Each of the 80 farmers interviewed by the author in 1986 was asked to evaluate an 1982 soil survey site (Antonini et al., 1985) located on his land. The farmers expressed suitability for observed agricultural use as one of four ordinal ratings--very good, good, mediocre and bad. Table 38 shows the site uses and corresponding suitability ratings assigned by farmers. Las Cuevas farmers consider their farms of little value for agriculture; two-thirds (52 of 80) consider their land mediocre or bad for present use (Table 38). Those who grow short-cycle crops are particularly critical; only 6 of the 33 farmers with beans, rice, garlic or pigeon peas assigned a good or very good suitability rating.

Tables 39, 40, 41 and 42 permit comparison of the author's suitability ratings with farmers' evaluations. Forty-one of the 80 sites (51 percent) were placed in exactly the same site suitability class. A similar degree of compatibility was reported by Fisher et al. (1986) when they compared land capability ratings established by the Soil Survey of England and Wales to those formulated by 100 farmers in the Welsh Marches (58 percent of the fields evaluated in that study were assigned the same rating by farmer and soil surveyor).

Three-quarters of the farmers whose evaluations differed from the author's suitability ratings (29 of 39) gave a more favorable appraisal of their site. Considering that the land-holders cultivate steeplands with low agricultural potential and that they have evaluated the land for its present agricultural use, this finding is consistent

TABLE 38

Farmer Evaluations of Site Suitability in Las Cuevas

Farmer Evaluation of Site Suitability	Number of Survey Sites with coffee	with beans	with pasture	other uses	Total
Very good	2	2	-	-	4
Good	13	4	7	-	24
Mediocre	11	18	6	2 *	37
Bad	8	5	-	2 **	15
TOTAL	34	29	13	4	80

* pigeon peas and rice
** pigeon peas and garlic

Data source: the author's 1986 farmer survey.

TABLE 39

Comparison of Farmer Site Evaluations to the Author's Site Suitability Rating for Coffee

Farmer Evaluation*	Site Suitability Rating**				
	Bad	Mediocre	Good	Very Good	TOTAL
Bad	7	1	-	-	8
Mediocre	2	6	3	-	11
Good	3	5	5	-	13
Very Good	1	-	1	-	2
TOTAL	13	12	9	-	34

Data sources: * the author's 1986 farmer survey.
** Antonini et al. (1985).

TABLE 40

Comparison of Farmer Site Evaluations to the Author's Site Suitability Ratings for Short-Cycle Crops (Beans, Pigeon Peas, Garlic and Rice)

Farmer Evaluation*	Site Suitability Rating**				
	Bad	Mediocre	Good	Very Good	TOTAL
Bad	6	-	1	-	7
Mediocre	4	12	4	-	20
Good	1	1	2	-	4
Very Good	-	1	-	1	2
TOTAL	11	14	7	1	33

Data sources: * the author's 1986 farmer survey
** Antonini et al. (1985)

TABLE 41

Comparison of Farmer Site Evaluations to the Author's Site Suitability Rating for Grazing

Farmer Evaluation*	Site Suitability Rating**				
	Bad	Mediocre	Good	Very Good	TOTAL
Bad	-	-	-	-	-
Mediocre	4	1	1	-	6
Good	3	3	1	-	7
Very Good	-	-	-	-	-
TOTAL	7	4	2	-	13

Data sources: * the author's 1986 farmer survey
** Antonini et al. (1985).

TABLE 42

Comparison of Farmer Site Evaluations to the Author's Site Suitability Ratings for All Land Uses

Farmer Evaluation*	Site Suitability Rating**				
	Bad	Mediocre	Good	Very Good	TOTAL
Bad	13	1	1	-	15
Mediocre	10	19	8	-	37
Good	7	9	8	-	24
Very Good	1	1	1	1	4
TOTAL	31	30	18	1	80

Data sources: * the author's 1986 farmer survey.
** Antonini et al. (1985)

with studies of British farmers. Davidson (1976) found that Scottish farmers with poor land tend to have an over-optimistic view of its capability while Fisher et al. (1986) discovered that Welsh farmers tend to over-estimate suitability of land for familiar uses and to downgrade its value for less familiar activities.

The remaining 10 Las Cuevas farmers offered a more pessimistic evaluation of their land than that of the author. For example, eight of the ten sites belonging to these farmers were assigned a good suitability rating by the author but were considered mediocre by the owners. An inspection of corresponding values of the author's site suitability index reveals, however, that his over-estimation is relatively slight. Seven sites with values of the suitability index varying from 0.71 to 0.76 avoid classification in the mediocre suitability class (0.50-0.70) by a relatively small margin.

The relationship between farmer site evaluations and scientific site suitability ratings can be examined for the complete sample of 80 farmers using the chi-square test of statistical association. The reliability of the chi-square test, however, is adversely affected by low expected frequencies. As a rule of thumb, for 3 x 3 tables, the expected frequency should be at least 5 in 75 percent of the cells in the contingency table and at least 1 in all other cells (Agresti and Agresti, 1979). This condition is satisfied if the categories of good and very good suitability in Table 42 are collapsed. Expressed in this form (see Table 43), statistical association is confirmed by a chi-square test statistic of 20.37 at the 99.9 percent level of confidence.

The farmer's evaluation and the scientific site suitability rating are both ordinal variables. As a result, their statistical relationship also can be examined using Kendall's tau-b (Agresti and Agresti, 1979). Like the linear correlation coefficient used to measure statistical association between variables expressed on an interval scale, tau-b has a value ranging from -1 to +1. Applied to the information in Table 43, tau-b is found to be 0.321 which indicates a positive association between farmer evaluations and the author's site suitability ratings. The relevant test statistic (Agresti and Agresti, 1979: pp. 254-5) also was computed and it shows that the value of 0.321 is significant at the 99 percent level of confidence.

Relationship of the Site Suitability Index to Present Agricultural Use

Assuming agricultural use in the watershed is ecologically rational and farmers tend to locate crops according to environmental requirements, plots dedicated to a specific use would be expected to be associated with higher values of the relevant suitability index. The first column of Table 44 shows how the arithmetic mean of the

TABLE 43

Comparison of Farmer Site Evaluations to Site Suitability Ratings for All Land Uses (Collapsed Version)

Farmer Evaluation*	Site Suitability Rating**			
	Bad	Mediocre	Good or Very Good	Total
Bad	13	1	1	15
Mediocre	10	19	8	37
Good/Very Good	8	10	10	28
Total	31	30	19	80

Data sources: * the author's 1986 farmer survey.
** Antonini et al. (1985).

Null hypothesis: no statistical association.
Alternative hypothesis: statistical association.
a = 0.001, df = 4
Critical value of chi-square statistic = 18.47
Computed value of chi-square statistic = 20.37 > 18.37
Reject the null hypothesis.

null hypothesis: tau-b = 0
alternative hypothesis: tau-b = 0
a = 0.01
Computed Kendall's tau-b = 0.321
Critical value of test statistic z = 2.58
Computed value of test statistic z = 3.195 > 2.58
Reject the null hypothesis.

coffee suitability index varies for soil survey sites under coffee, short-cycle crops, pasture, scrub and forest. As would be expected, the arithmetic mean of the coffee suitability index computed for coffee sites (0.52) is larger than the corresponding means for sites with other land uses. Similarly, the second column of Table 44 shows that the mean of the beans suitability index is highest for sites observed under short-cycle crops. In both columns, sites which have the lowest mean suitability are those under forest.

Land with good environmental characteristics tends to be dedicated to cropping so that pasture frequently is relegated to land which does not satisfy optimal requirements for grazing. Consequently, it can be observed in the third column of Table 44 that arithmetic means of the grazing suitability index for sites under coffee and forest are as high as the mean of the same index for sites under pasture. Furthermore, the mean of that suitability index for sites under pasture is lower than the corresponding value for sites under short-cycle crops.

Values of site suitability indices are not normally distributed. As a result, analysis of variance cannot be used to compare the means in Table 44 and test whether differences between them are statistically significant. Frequency distributions of soil survey sites by site suitability class, however, can be compared using nonparametric Wilcoxon, chi-square and Kolmogorov-Smirnov

TABLE 44

Arithmetic Means of Suitability Indices for Coffee, Beans and Grazing Computed for Sites Under Five Major Land Uses

Land Use at Survey Site	Arithmetic Means of Site Suitability Indices		
	for Coffee	for Beans	for Grazing
Coffee (39 sites)	0.52	0.40	0.52
Short-cycle crops (34 sites)	0.44	0.47	0.65
Pasture (64 sites)	0.39	0.40	0.51
Scrub (81 sites)	0.39	0.31	0.43
Forest (132 sites)	0.26	0.30	0.51

Data source: Antonini et al. (1985)

tests (Agresti and Agresti, 1979). Table 45 shows the frequency distribution of survey sites under coffee according to site suitability together with the corresponding distribution of sites with other uses. It can be observed that only 31 percent of sites used for coffee have a bad suitability rating. In contrast, 61 percent of sites with other uses are rated bad for coffee. Similarly, 31 percent of coffee sites are worthy of a good suitability rating while only 11 percent of the other sites fall within this category. When the Wilcoxon test is applied to this information, the test statistic, a z-score, is found to have a value of -4.03; the negative sign reflects the relatively small proportion of coffee sites in the bad suitability class while its high absolute value permits rejection of the null hypothesis of identical population distributions with a level of confidence of more than 99 percent (a = 0.01). If the null hypothesis were true, the probability of obtaining a z-score above 4.03 or below -4.03 is 0.00006. Relatively high values of the chi-square statistic (17.45) and the Kolmogorov-Smirnov D statistic (0.30) confirm rejection of the null hypothesis at the 99 percent level of confidence.

The same tests can be used to examine ordinal categorical distributions of survey sites classified according to suitability for beans. Table 46 shows the frequency distribution of sites under short-cycle crops together with the corresponding distribution of sites with

TABLE 45

Frequency Distribution of Soil Survey Sites by Land Use and Site Suitability Class for Coffee

Land Use	Site Suitability for Coffee							
	Good		Mediocre		Bad		Total	
	No. of sites	%	No. of sites	%	No. of sites	%	No. of sites	%
Coffee	12	31	15	38	12	31	39	100
Other Uses	34	11	86	28	191	61	311	100
Total	46	13	101	29	203	58	350	100

Data source: Antonini et al. (1985).

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.
a = 0.01

Critical value of Wilcoxon test statistic z = -2.58
Computed value of Wilcoxon test statistic z = -4.03
Reject the null hypothesis.

Critical value of chi-square statistic = 9.21 (df = 2)
Computed value of chi-square statistic = 17.45 > 9.21
Reject the null hypothesis.

Critical value of Kolmogorov-Smirnov D = 0.28
Computed value of Kolmogorov-Smirnov D = 0.30 > 0.28
Reject null hypothesis.

other uses. Forty-seven percent of sites used for short-cycle crops have a bad suitability rating for beans but this value is still < 61 percent which is the proportion of sites with other uses which are rated bad for beans. In addition, the proportion of sites with short-cycle crops which have a good or very good suitability rating is 24 percent while only 9 percent of the other sites are assigned one of these ratings. The Wilcoxon test statistic of -2.06 and the chi-square statistic of 7.47 permit rejection of the null hypothesis of identical population distributions with a level of confidence of 95 percent (a = 0.05). Those results, however, are not supported by the Kolmogorov-Smirnov D statistic of 0.15 which is too low to allow rejection of the null hypothesis at an acceptable level of confidence.

It was shown above that observation sites with pasture are not associated with high values of the suitability index for grazing. Areas of better suitability for grazing tend to be dedicated to crops. Grazing is less dependent upon environmental conditions and still can be profitable on land of low suitability. Table 47 shows that the frequency distributions of sites with and without pasture are very similar. The corresponding values of the chi-square, Kolmogorov-Smirnov and Wilcoxon test statistics are very low and indicate that the null hypothesis of identical population distributions cannot be rejected.

TABLE 46

Frequency Distribution of Soil Survey Sites by Land Use and Site Suitability Class for Beans

Land Use	Site Suitability for Beans							
	Good/V.Good		Mediocre		Bad		Total	
	No. of sites	%	No. of sites	%	No. of sites	%	No. of sites	%
Short-cycle crops	8	24	10	29	16	47	34	100
Other Uses	28	9	94	30	194	61	316	100
Total	36	10	104	30	210	60	350	100

Data source: Antonini et al. (1985).

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.

---

a = 0.05
Critical value of Wilcoxon test statistic z = -1.96
Computed value of Wilcoxon test statistic z = -2.06
Reject the null hypothesis.

---

a = 0.05, df = 2
Critical value of chi-square statistic = 5.99
Computed value of chi-square statistic = 7.47 > 5.99
Reject the null hypothesis.

---

a = 0.10
Critical value of Kolmogorov-Smirnov D = 0.22
Computed value of Kolmogorov-Smirnov D = 0.15 < 0.22
Cannot reject null hypothesis.

TABLE 47

Frequency Distribution of Soil Survey Sites by Land Use and Site Suitability Class for Grazing

Land Use	Site Suitability for Grazing							
	Very Good		Good		Mediocre		Bad	
	No. of sites	%	No. of sites	%	No. of sites	%	No. of sites	%
Pasture	4	6	17	27	14	22	29	45
Other Uses	25	9	65	23	58	20	138	48
Total	29	8	82	23	72	21	167	48

Data source: Antonini et al. (1985).

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.
a = 0.10

Critical value of Wilcoxon test statistic z = -1.645
Computed value of Wilcoxon test statistic z = -0.24
Cannot reject the null hypothesis.

Critical value of chi-square statistic = 6.25 (df = 3)
Computed value of chi-square statistic = 0.87 < 6.25
Cannot reject the null hypothesis.

Critical value of Kolmogorov-Smirnov D = 0.17
Computed value of Kolmogorov-Smirnov D = 0.03 < 0.17
Cannot reject the null hypothesis.

CHAPTER VIII
LAND USE DECISION-MAKING IN LAS CUEVAS

Statistics in Chapter VII show that coffee, short-cycle crops and pasture can all be observed on poor quality land in Las Cuevas. For example, bad suitability ratings were assigned by the author to 31 percent of survey sites under coffee and 47 percent of those with short-cycle crops. It is worthwhile, therefore, to apply point score analysis, examine the decision-making process of the watershed's farmers and determine the role played by environmental factors in the farmer's selection of particular agricultural uses.

Thirty-nine of the 80 farmers surveyed in 1986 declared coffee to be their principal agricultural use. Other principal enterprises identified were beans (27 farmers), grazing (10 farmers), pigeon peas (2 farmers), garlic (1 farmer) and rice (1 farmer). After each interviewee indicated the main use, he was asked why he had chosen that particular activity. Decision-making factors which were not identified independently by the farmer were mentioned subsequently to him one by one and he was asked if they also had influenced his choice of enterprise in some way.

Farmers were requested to evaluate relevant factors in one of two alternative categories, "important' and "somewhat important", with corresponding numerical scores of 2 and 1. Factors considered irrelevant received a score of 0. Table 48 shows the relative importance of 18 decision-making factors as perceived by the total sample of 80 farmers. A factor considered very important by all would be assigned two points by each farmer and would obtain the maximum summed score of 160. Family tradition is the highest ranked factor; the associated summed score of 130 is equivalent to 81 percent of the maximum value. Another socio-personal variable--area tradition--ranks third; it is clear that influence of family and peers is very important in choice of enterprise in the watershed. The other three factors worthy of more than 50 percent of the maximum score are economic variables. The commercial nature of agriculture in the region is confirmed by the second place ranking of demand which obtained 76 percent of the maximum score. Low risk and low production cost are ranked in fourth and fifth positions and have percentage scores of 61 and 59 respectively.

The remaining thirteen decision-making factors have much less importance for the total sample although two environmental variables (climate and soil) and two additional socio-personal attributes (personal preference and land use under the previous occupant) each obtained one-third of the maximum score. Variables which appear to have

TABLE 48

Relative Importance of Decision-Making Factors for All Farmers Surveyed in Las Cuevas in 1986

Decision-Making Factor	Score*	Percentage of Maximum Score (score/160)	Rank
Family tradition	130	0.81	1
Demand	122	0.76	2
Area tradition	109	0.68	3
Low risk	98	0.61	4
Production cost	95	0.59	5
Personal preference	63	0.39	6
Climate	57	0.36	7
Previous occupant	56	0.35	8
Soil	50	0.31	9
Available credit	36	0.23	10
Intermediary	34	0.21	11
Regular income	30	0.19	12
Security	28	0.18	13
Government policy	15	0.09	14
Slope	4	0.03	15
Drainage	0	0.00	16
Distance to market	0	0.00	16
Mass media	0	0.00	16

* the maximum score is 160.

Data source: the author's 1986 farmer survey.

almost no impact on choice of enterprise are government policy, mass media, slope, drainage and distance to market.

Additional insight into choice of principal agricultural activity is gained from a comparison of Tables 49, 50 and 51 which show how decision-making factors are ranked by coffee growers, bean farmers and ranchers. As shown above for English farmers, relative importance of decision-making factors varies according to type of farming practiced. The factor rated most highly by both coffee farmers and ranchers is low risk. Even in dry years, some yield is obtained from coffee plantations and cattle can be moved to water or sold. In contrast, low risk is an essentially irrelevant variable in bean cultivation which is severely dependent upon the quantity and fortuitous timing of rainfall over the short growth cycle of three months.

In a similar fashion, some significance is attributed to personal preference by coffee growers and ranchers while it has almost no bearing on the decision to grow beans. Coffee brings prestige and, after the preliminary cost and effort of establishing the plantation, production of this permanent crop requires relatively little work from the farmer. The prospect of less work in old age is appealing and the coffee farmer derives satisfaction from the knowledge that he will be able to offer a tangible inheritance for his children. Ranchers need to make a particularly large initial investment in land acquisition,

TABLE 49

Relative Importance of Decision-Making Factors for 39 Coffee Farmers Surveyed in Las Cuevas in 1986

Decision-Making Factor	Score*	Percentage of Maximum Score (score/78)	Rank
Low risk	68	0.87	1
Family tradition	63	0.81	2
Demand	52	0.67	3
Area tradition	49	0.63	4
Climate	49	0.63	4
Soil	42	0.54	6
Personal preference	42	0.54	6
Production cost	35	0.45	8
Previous occupant	34	0.44	9
Security	24	0.31	10
Government policy	12	0.15	11
Available credit	5	0.06	12
Intermediary	1	0.01	13
Regular income	0	0.00	14
Slope	0	0.00	14
Drainage	0	0.00	14
Distance to market	0	0.00	14
Mass media	0	0.00	14

* maximum score is 78

Data source: the author's 1986 farmer survey.

TABLE 50

Relative Importance of Decision-Making Factors for 27 Bean Farmers Surveyed in Las Cuevas in 1986

Decision-Making Factor	Score*	Percentage of Maximum Score (score/54)	Rank
Demand	52	0.96	1
Family tradition	49	0.91	2
Area tradition	45	0.83	3
Production cost	42	0.78	4
Regular income	30	0.56	5
Intermediary	29	0.54	6
Available credit	27	0.50	7
Previous occupant	16	0.30	8
Personal preference	10	0.19	9
Soil	6	0.11	10
Climate	4	0.07	11
Low risk	4	0.07	11
Government policy	1	0.02	13
Security	0	0.00	14
Distance to market	0	0.00	14
Mass media	0	0.00	14
Drainage	0	0.00	14
Slope	0	0.00	14

* maximum score = 54

Data source: the author's 1986 farmer survey.

TABLE 51

Relative Importance of Decision-Making Factors for 10 Ranchers Surveyed in Las Cuevas in 1986

Decision-Making Factor	Score*	Percentage of Maximum Score (score/20)	Rank
Low risk	20	1.00	1
Demand	19	0.95	2
Production cost	16	0.80	3
Family tradition	12	0.60	4
Personal preference	11	0.55	5
Area tradition	9	0.45	6
Security	4	0.20	7
Previous occupant	4	0.20	7
Government policy	2	0.10	9
Available credit	0	0.00	10
Regular income	0	0.00	10
Intermediary	0	0.00	10
Mass media	0	0.00	10
Distance to market	0	0.00	10
Soil	0	0.00	10
Drainage	0	0.00	10
Climate	0	0.00	10
Slope	0	0.00	10

* maximum score = 20

Data source: the author's 1986 farmer survey.

land clearance, fence-building and livestock purchase but large herds bestow even greater prestige than coffee plantations and subsequent operations require little outlay of capital or labor. On the other hand, personal preference is given a low rating by bean farmers who cannot be expected to derive satisfaction from hard physical labor required to plant, weed and harvest each new crop; they do not have the pleasure of seeing wealth accumulate in an expanding plantation or a growing herd of cattle. Motivations of bean farmers are revealed in Table 50 by relatively high ratings given to regular income, intermediaries and available credit; lack of capital makes them dependent on the quick return which comes from growing short-cycle crops and production is only possible by means of credit available from local intermediaries who lend money or seed at high interest rates. One advantage of growing beans is that they can be consumed by the farmer and his family; poor farmers often reserve beans for sale, however, and consume other products such as cassava, pigeon peas and bananas which have lower prices in the market.

Tables 50 and 51 show that environmental factors are virtually irrelevant for farmers who choose to make bean cultivation or grazing their principal activity. This finding of the decision-making analysis would appear to contradict comments in Chapter VI which showed that Las Cuevas farmers recognize soil taxa with different levels of fertility and attach importance to appropriate conditions of rainfall, temperature, slope, drainage, texture and soil color. In general, however, Las Cuevas farmers are not motivated to adopt a particular land use by environmental resource endowment because the degraded steeplands of the watershed make most of the land unattractive for agriculture. As shown in Chapter VII, two-thirds of Las Cuevas farmers surveyed in 1986 consider their land mediocre or bad for its present use. Those who grow mainly short-cycle crops are especially unappreciative; only 6 of the 33 farmers with beans, rice, garlic or pigeon peas assigned a good or very good suitability rating to their land. Coffee farmers do attribute some importance to climate and soil in their decision to specialize in that crop; both variables are assigned more than half of the maximum score in the point score analysis (see Table 49).

CHAPTER IX
CONCLUSIONS

Summary

Land Suitability

The SEA (1987a) study of land capability suggests that 57 percent of Las Cuevas is unsuitable for agriculture and should be forested; pasture with permanent crops is considered acceptable on 41 percent of the watershed but only 2 percent is appropriate for other crops. This pessimistic view of agricultural potential in Las Cuevas is generally supported by the author's site suitability analysis but ratings indicate that a larger proportion of the basin is classified as good or very good for short-cycle crops (pigeon peas, 15 percent; garlic, 12 percent; beans, 10 percent). The SEA estimate of land reserved for woodland (57 percent) is lower than the author's 69 percent figure.

Carrying Capacity

Arithmetic means of coffee and beans suitability indices computed for sites under forest and scrub are significantly lower than corresponding means for sites currently used for agriculture (crops, fallow and pasture). Some areas of woodland may owe their tree cover to government protection but most probably survive only because their agricultural potential is low and local peasants consider them unsuitable for agriculture. Much land with scrub was undoubtedly cultivated in the past but subsequently abandoned because of inherent low agricultural potential or environmental deterioration.

It can be assumed, therefore, that most land suitable for agriculture is already being used. Population density in Las Cuevas may be less than one-half the national average but a significant increase in the carrying capacity of the watershed will not be achieved through expansion of the cultivated or grazed areas. Efforts to increase agricultural production in Las Cuevas must be concerned principally with land already in use. Fields and pastures vulnerable to soil erosion should be taken out of production and dedicated to woodland to provide fuel while agroforestry techniques could be promoted on farmland with good or very good suitability ratings.

Farming Skills

The analysis reveals limited application of neotechnic farming methods in Las Cuevas. Several farmers complained to the author about the prohibitive cost of technological inputs, especially fertilizer and insecticide, but inputs generally are rare even on large farms with sufficient resources for modernization. While Las Cuevas peasants are not neotechnic agriculturalists, they are no more representative of paleotechnic farmers; fallows are too short to conserve soil fertility and local polyculture is not sophisticated enough to provide protection against pests. Government promotion of agroforestry techniques is needed to help Las Cuevas farmers combine better aspects of modern agriculture--fertilizer, manures, irrigation, soil conservation--with the polyculture, species diversity and minimum tillage associated with traditional agriculture.

Local peasants, like Middle American counterparts, refer to soil types by surface color and texture. The farmers clearly understand crop requirements and share scientific opinions of appropriate rainfall, temperature, slope, drainage, soil color and texture conditions. The vast majority also profess to be aware of the negative impact of soil erosion. This awareness may be incomplete because more than one-half of the farmers do not grasp the concept of soil depth. On the other hand, continued widespread application of erosive practices--deforestation, plowing on steep slopes, burning of crop residues--is not necessarily a consequence of farmer ignorance or inability to recognize which land is unsuitable for agriculture. Las Cuevas peasants have realistic perceptions of the low agricultural value of their land. Two-thirds of those interviewed in 1986 consider their land mediocre or bad for present use. Thus, many Las Cuevas farmers knowingly cultivate or graze land which is environmentally inappropriate. They do not have the privilege of choosing between suitable and unsuitable sites for their crops and pasture.

Site Suitability and Farmer Opinion

The author's site suitability ratings were derived for six agricultural uses--coffee, beans, pigeon peas, garlic, rice and grazing. Chi-square and Kendall's tau-b statistics showed a clear correlation between the ratings and farmers' evaluations, confirming the hypothesis that suitability analysis based on numerical (parametric) indices is meaningful. The majority of farmers whose assessments differed from the author's ratings gave a more favorable appraisal of their land. This finding is consistent with studies of British farmers who overestimate the value of poor land and present an over-optimistic evaluation of land for familiar uses.

Choice of Enterprise

Point score analysis of the complete sample of 80 farmers interviewed in 1986 demonstrates that Las Cuevas peasants consider family and peers highly influential in their choice of principal enterprise. Three economic variables--high demand, low risk and low production costs--also are perceived to be extremely important.

The decision-making analysis confirms the author's hypothesis that environmental variables are comparatively insignificant in choice of enterprise. This finding would appear to contradict the farming skills analysis which showed that Las Cuevas peasants recognize soil taxa with different levels of fertility and attach importance to appropriate conditions of rainfall, temperature, slope, drainage, soil color and soil texture. It also appears to disagree with suitability index values which suggest that Las Cuevas farmers reject remaining forest and scrub areas because they have low environmental potential for agriculture. The adoption of specific land uses, however, is not motivated by environmental resource endowment in Las Cuevas because most of the watershed is unattractive for agriculture. As shown above, two-thirds of the farmers surveyed in 1986 consider their land mediocre or bad for its present use.

Studies of English farmers suggest that perceived importance of decision-making factors varies according to type of farming practiced. Such variation is confirmed by a comparison of coffee growers, bean farmers and ranchers in Las Cuevas. Thus, low risk and personal preference are declared significant by coffee farmers and ranchers but are considered essentially irrelevant by bean farmers. Bean cultivation is severely dependent upon the quantity and fortuitous timing of rainfall over the short growth cycle of three months. Little pleasure is derived from the hard labor needed to plant, weed and harvest each new crop. Unable to make the required large initial investment, bean farmers are denied the satisfaction of seeing wealth accumulate in an expanding plantation or a growing herd of cattle. Many bean farmers would prefer to grow coffee or raise cattle--activities which happen to promote less soil erosion--but scarce resources of land and capital place these enterprises out of reach.

While environmental factors are virtually irrelevant for both bean farmers and ranchers, climate and soil were considered somewhat significant by coffee farmers in their decision to grow that crop. It would appear that coffee is less tolerant of sub-optimal conditions than beans or grazing and physical factors cannot be completely over-ridden by socio-personal and economic considerations.

Distance to market has been given a great deal of attention by geographers in applications of the von Thunen model of agricultural land use patterns. The literature review in Chapter III, however, shows that distance to market is considered relatively unimportant in choice of enterprise by British hop farmers and horticulturalists. The author's decision-making analysis reveals that this factor also is perceived as insignificant by Las Cuevas farmers. Agricultural produce is sold locally in Guayabal and Padre Las Casas, mainly to powerful intermediaries and moneylenders.

Policy Implications

Uncultivated land in Las Cuevas has low agricultural potential and future resource development policy in the watershed must be concerned with land already in use. Farmland vulnerable to soil erosion should be taken out of production and dedicated to fuelwood production while agroforestry techniques could be promoted on land with good suitability. Farmers who possess only fragile steeplands must be given access to more gentle slopes within the watershed or elsewhere; several farmers told the author they would gladly trade their mountain farms for a few hectares of fertile, irrigated flat land on the Azua plain.

Government promotion of soil conservation has been ineffective and even large farmers have shown no desire to control environmental degradation. Attempts to diffuse awareness of soil erosion must make the process more explicit and clarify the concept of finite soil depth. More important, they must be accompanied by meaningful incentives for investment in conservation practices. Furthermore, if the farmers are assisted in producing more intensively on suitable land, they will have less need to use marginal steepland plots which are susceptible to erosion. Credit programs also would allow farmers to cultivate less rainfed beans and invest in tree crops, cattle or irrigated vegetable crops. In other words, the problem of environmental degradation will not be solved unless forces at large are modified, including unjust land distribution, lack of credit, low food crop prices, inadequate technical assistance and limited research into viable agroforestry alternatives for Dominican steeplands. Considering the vital influences of family and peers on choice of enterprise, it should not be difficult to diffuse effective strategies; farmers will readily adopt procedures shown to be successful on their neighbors' properties.

Future Land Evaluation Research

Farmer opinion in Las Cuevas has confirmed the validity of suitability indices in land evaluation. Index precision may be improved with further research designed to (1) clarify environmental requirements of specific land uses and (2) develop multivariate measures of land qualities which take into account interaction of individual land characteristics. Future research also must explore methods of extrapolating site suitability ratings to surrounding areas using automated cartographic routines.

Much is to be gained from communication with farmers in development projects. Information on farm and farmer characteristics must be complemented with insight into farmer opinions, goals, values and experience; point score analysis is clearly applicable in such studies. Soil surveyors should record farmer evaluations at sites studied in the field. Attempts also should be made to investigate farmers' criteria for land evaluation and enlist their assistance in field soil mapping. Their empirical knowledge is invaluable and can no longer be ignored.

APPENDIX A
QUESTIONNAIRE USED IN FARMER SURVEY OF 1986

Date:- ____________________

Questionnaire number:- ____________

Soil Survey Site No.:- ____________

Location of Soil Survey Site:- ________

BASIC ECONOMIC INFORMATION

Farmer's name:- ____________________

Farmer's residence:- ________________

Age:- __________ Education (years):- ______

Principal enterprise:- ______________

Area of land dedicated to
the principal enterprise :- __________

Experience of principal enterprise (years):- ____

Total farm size:- ___________________

Tenure:- ___________________________

Number of parcels in farm:- __________

Land use of parcels:-

Parcel	Area	Land Use
1		
2		
3		
4		
5		
6		

Technological inputs (underline if present):-
- (a) fertilizer
- (b) insecticide
- (c) herbicide
- (d) irrigation
- (e) animal power
- (f) tractor
- (g) soil conservation (specify:- ____________)

Impact of pests and diseases (underline the appropriate intensity) :-
- (a) not important
- (b) minor problem
- (c) major problem

Off-farm employment ? :- ________________

DECISION-MAKING FACTORS

How important were the following things in your decision to plant and continue producing your principal crop ?

	Very Important	Somewhat Important	Not Important
Physical factors			
Soil type			
Climate			
Slope			
Drainage			
Distance to market			
Economic factors			
Demand			
Production costs			
Low risk			
Intermediaries			
Available credit			
Government policy			
Mass media			
Regular income			
Long-term security			
Socio-personal factors			
Previous occupant			
Family tradition			
Area tradition			
Personal preference			

ENVIRONMENTAL PERCEPTION

In your opinion, how does the land at this site rate for its present use ? (underline appropriate class):-

(a) very good
(b) good
(c) mediocre
(d) bad

Consider the following and indicate their importance for your principal crop:-

	VERY IMPORTANT	SOMEWHAT IMPORTANT	NOT IMPORTANT
Rainfall			
Temperature			
Soil Depth			
Soil Color			
Drainage			
Texture			
Stoniness			
Slope			

For each variable considered somewhat or very important, indicate the optimum condition below (circle the appropriate word):-

Rainfall	Abundant	Moderate	Low
Temperature	Hot	Temperate	Cool
Soil depth	Deep	Average	Shallow
Soil Color	Very dark	Somewhat dark	Light

Drainage	Slow	Average	Rapid
Texture	Clayey	Mixed	Sandy
Stoniness	Many stones	Some stones	No stones
Slope	Steep	Gentle	Flat

Which type of soil is best for your principal land use ? ______________________

What other kinds of soil are there on your land and in your vicinity ? ______________________

____

List the soils you know in descending order of fertility ______________________

____

If black soil is identified, ask the farmer to explain why it is dark in color ______________________

____

Have you heard of soil erosion (erosion, arrastre) ?

(a) Yes
(b) No

(Verify an affirmative answer by asking the farmer to describe the process of soil erosion)

If the answer is affirmative, ask the farmer to identify the source of his awareness of soil erosion:-

(a) personal observation
(b) parents
(c) extension agents
(d) other (specify):- ______________________

APPENDIX B
COMPARISON OF 1984 AND 1986 FARMER SURVEYS

Farmer's Ages in 1984 and 1986

Farmer's Age	1986 Survey** (sample: 80 farms)		1984 Survey* (sample: 211 farms)	
	No. farmers	Percent	No. farmers	Percent
15-34	6	8	24	11
35-49	24	31	77	37
50-64	37	45	83	39
65 or more	13	16	27	13
Total	80	100	211	100

Data sources: * Montanez (1985)
** the author's 1986 survey

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.
a = 0.40, df = 3

Critical value of chi-square statistic = 2.85
Computed value of chi-square statistic = 2.69 < 2.85
Cannot reject the null hypothesis.

Critical value of Kolmogorov-Smirnov D = 0.12
Computed value of Kolmogorov-Smirnov D = 0.09 < 0.12
Cannot reject the null hypothesis.

Farmer Education in 1984 and 1986

Years at School	1986 Survey** (sample: 80 farms)		1984 Survey* (sample: 211 farms)	
	No. farmers	Percent	No. farmers	Percent
0	35	44	97	46
1 - 3	25	31	65	30
4 - 6	12	15	31	15
7 - 12	8	10	18	9
Total	80	100	211	100

Data sources: * Montanez (1985)
** the author's 1986 survey

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.
a = 0.40, df = 3

Critical value of chi-square statistic = 2.85
Computed value of chi-square statistic = 0.23 < 2.85
Cannot reject the null hypothesis.

Critical value of Kolmogorov-Smirnov D = 0.12
Computed value of Kolmogorov-Smirnov D = 0.02 < 0.12
Cannot reject the null hypothesis.

Farm Ownership in 1984 and 1986

Declared Ownership Status	1986 Survey (sample: 80 farms)		1984 Survey (sample: 211 farms)	
	No. farmers	Percent	No. farmers	Percent
Owner	78	97.5	205	97.2
Non-owner	2	2.5	6	2.8
Total	80	100	211	100

Data sources: * Montanez (1985)
** the author's 1986 survey

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.
a = 0.40, df = 3

Critical value of chi-square statistic = 2.85
Computed value of chi-square statistic = 0.03 < 2.85
Cannot reject the null hypothesis.

Farm Fragmentation in 1984 and 1986

Number of Parcels Farmed	1986 Survey** (sample: 80 farms)		1984 Survey* (sample: 211 farms)	
	No. farmers	Percent	No. farmers	Percent
1	20	25	50	24
2	32	40	98	46
3	15	19	41	19
>3	13	16	22	11
Total	80	100	211	100

Data sources: * Montanez (1985)
** the author's 1986 survey

Null hypothesis: no significant difference.
Alternative hypothesis: significant difference.
a = 0.40, df = 3

Critical value of chi-square statistic = 2.85
Computed value of chi-square statistic = 2.24 < 2.85
Cannot reject the null hypothesis.

Critical value of Kolmogorov-Smirnov D = 0.12
Computed value of Kolmogorov-Smirnov D = 0.05 < 0.12
Cannot reject the null hypothesis.

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BIOGRAPHICAL SKETCH

Roy Ryder received initial training in geography at the University of Glasgow where he was awarded the Bachelor of Science (with honours) degree in 1966. Continued study at the same university allowed him to obtain the Diploma in Photogrammetry (1967) and prepare a Master of Science thesis (1968) on the geomorphology of Rhum, an island off the northwest coast of Scotland which is managed by the Nature Conservancy.

Mr. Ryder's interest in Latin America developed later during a prolonged visit to Ecuador where he taught airphoto interpretation at the Military School of Engineers and married a resident of Quito. Between 1973 and 1976, Mr. Ryder was Visiting Professor at the University of Costa Rica in San Jose. His principal achievement was the design and direction of a new Department of Geography. In 1977, he became Academic Director of the Panamerican Center for Geographical Studies (CEPEIGE), an international organization established in Quito by the Panamerican Institute of Geography and History to promote the study of geography in Latin America. For eight years, he was able to work with students and faculty from almost every nation in America and do research on Pre-Columbian agricultural landforms, urban land use and urban ecology. Mr. Ryder enrolled in the doctoral program of the University of Florida in 1984 and developed an interest in land evaluation for agriculture in tropical steeplands of Latin America.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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August 1989

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